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Embracing a One Health Framework to Fight Antimicrobial Resistance

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Foreword

The COVID-19 pandemic demonstrated that infectious diseases could have far-reaching social and economic consequences. Today, a much older and a more silent pandemic is threatening the effectiveness of the many medical advances made in the 20th century. Antimicrobial resistance (AMR) – the ability of microbes to resist antimicrobial agents – is among the most pressing public health challenges facing the global community.

Tackling AMR demands urgent attention and co-ordinated action. It has been eight years since 194 countries endorsed the Global Action Plan on AMR. Since then, OECD, EU/EEA and G20 countries have made important strides in developing and implementing their own action plans on AMR. The One Health framework – a multi-sectoral approach that promotes co-ordinated action across human and animal health, agrifood systems and the environment – has underpinned these efforts. But more needs to be done.

This report follows on from the 2018 OECD report *Stemming the Superbug Tide: Just a Few Dollars More* to produce new evidence covering all the key One Health sectors. National data and evidence gathered from OECD, EU/EEA and G20 countries were fed to the OECD Strategic Public Health Planning for AMR microsimulation model and to machine learning tools to gauge the unacceptably high health and economic cost of inaction.

The report shows that today, one in five bacterial infections are resistant to antibiotic treatment in OECD countries. Resistant infections claim the lives of around 79 000 people every year across OECD and EU/EEA countries. Healthcare acquired resistant infections account for more than 60% of AMR-related deaths. The report also considers the impact of the COVID-19 pandemic. It shows that the COVID-19 pandemic severely disrupted the implementation of policies that aim to optimise antimicrobial use in humans. At the same time, it placed a spotlight on infection prevention and control policies. The report underscores that investments in line with the One Health framework offer a cost-effective means to limit the harmful effects of AMR, with stewardship programmes to optimise the use of antimicrobials in humans and better environmental and hand-hygiene practices in healthcare facilities identified as the most effective actions.

The global response to the COVID-19 pandemic is a silver lining. The pandemic highlighted that the health of humans is closely connected to the health of animals and the environment. The time to strengthen efforts to tackle the AMR pandemic is now.

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Executive summary

Antimicrobial resistance (AMR) – the ability of microbes to resist antimicrobial agents – is one of the greatest public health threats globally, with far-reaching social, economic and health consequences for people, animals and the environment.

This report builds on the 2018 OECD report *Stemming the Superbug Tide: Just a Few Dollars More*. It demonstrates that in the absence of stronger One Health action – targeting people, animals, agri-food systems and the environment – AMR levels will remain unacceptably high for at least the next 25 years. Resistant infections will claim the lives of thousands of people in OECD and EU/EEA countries every year and exert additional pressure on hospital resources that are already strained from the COVID-19 pandemic. The cost to health systems and economies will continue to mount.

The report demonstrates that tackling AMR is an excellent investment by looking at the effectiveness and cost-effectiveness of 11 One Health policy interventions and three policy packages to reduce the deleterious impacts of AMR. The report highlights the following key insights.

Worrisome trends in antibiotic consumption raise the risk of untreatable infections

Consumption of antimicrobials – both in humans and animals – remains at high levels. In human health, despite policy efforts to optimise antibiotic consumption, average sales of all classes of antibiotics have been rising by nearly 2% since 2000, while more than one-third of OECD countries do not meet the target set by the World Health Organization for first line (Access) antibiotics to make up at least 60% of all antibiotic consumption. If historical trends continue, consumption of antibiotics in humans will not decrease significantly until at least 2035.

In animals, the use of antimicrobials across OECD countries has halved from 181 to 91 milligrams of antimicrobial per kilogram of food animal between 2000 and 2019 and projections suggest that it could decrease by an additional 10% by 2035. But the majority of antimicrobial sales for animals takes place outside OECD countries and sale of antimicrobials for animal use in G20 countries is expected to reach nearly double that of the OECD average by 2035.

Fuelled by high levels of inappropriate use of antimicrobials, resistance proportions across 12 antibiotic-bacterium combinations stand at around 20% across the OECD, meaning that one in every five infections is now caused by superbugs. However, there are even more alarming trends:

- If left unchecked, resistance to third-line antimicrobials – the last resort drugs against difficult-to-treat infections – could be 2.1 times higher by 2035 in the OECD compared to 2005. This means that health systems will be closer to running out of options to treat patients suffering from a range of illnesses such as pneumonia and bloodstream infections;
- Today, AMR remains dangerously high in some countries such as Greece, India and Türkiye. In these countries, more than 40% of all infections caused by the 12 antibiotic-superbug combinations that OECD studied are expected to be resistant to antibiotics by 2035;

- For certain antibiotic-bacterium pairs such as fluoroquinolone-resistant and carbapenem-resistant *Acinetobacter baumannii*, the projected resistance proportions can be as high as nearly 90% in the countries with the highest resistance proportions.

Without decisive policy action, too many lives will be lost due to resistant infections

Every year, around 79 000 people lose their lives due to resistant infections across 34 OECD and EU/EEA countries. This corresponds to 2.4 times the number of deaths due to tuberculosis, influenza and HIV/AIDS combined in 2020. The elderly bear the brunt of AMR death toll, with around two out of three deaths due to AMR occurring among people above 65 years of age. Babies are also at risk.

The resistant strains of three bacteria – *Escherichia coli*, *Klebsiella pneumoniae* and *Staphylococcus aureus* – are the main drivers of the AMR burden, causing nearly three in four deaths due to resistant infections and making it more difficult and costly to treat meningitis, bloodstream, surgical site and other infections. Resistant infections acquired in healthcare settings are particularly dangerous. These infections account for about one in three resistant infections but represent more than 60% of AMR-related deaths.

Health systems and economies will continue to bear a heavy financial burden

The cost of inaction to tackle AMR is high. The cost of treating complications due to resistant infections can exceed USD 28.9 billion every year adjusting for purchasing power parity across 34 OECD and EU/EEA countries. For comparison, across 17 countries for which data is available, the total health expenditure incurred each year due to AMR is about 19% of the total health expenditure due to treating COVID-19 patients in 2020. Most of these costs are caused by longer hospitalisations: additional 32.5 million days are spent in hospital per year to treat the consequences of AMR. This is roughly equivalent to using the entire acute bed capacity of Spain for a whole year.

The impact of AMR on workforce participation and productivity is estimated to be equivalent to USD 36.9 billion, corresponding roughly to one fifth of the gross domestic product in Portugal in 2020.

Investments across human and animal health, agrifood systems and the environment deliver the highest returns

The vast majority of OECD, EU/EEA and G20 countries have already developed a national action plan to tackle AMR. In addition to ensuring that the national action plans are funded and implemented, the policy analysis has identified the following policy priorities for action:

- Bolstering nationwide implementation of programmes for infection prevention and control and for optimal use of antimicrobials in line with international standards and best practices across human and animal health, as well as agri-food systems;
- Investing in more robust surveillance systems, particularly in specific areas in human health (e.g. long-term care) and animal health;
- Ensuring greater compliance with regulatory frameworks, especially to promote prudent use of antimicrobials in animals; and
- Increasing investments in research and development for new antibiotics, vaccines and diagnostics.

By addressing many of the existing policy gaps, all 11 policy interventions modelled by the OECD are estimated to generate substantial health and economic gains. In particular, the following interventions yield the highest gains:

- Three human health policies: strengthening antimicrobial stewardship programmes, better environmental and hand hygiene practices in healthcare settings; and
- Two policies outside human health – better food safety practices and improved biosecurity in farms – are also promising.

Scaling up investments in One Health packages of actions against AMR is affordable, with a return on investment significantly greater than implementation costs. Every USD 1 invested in a mixed policy package across the health and food sectors, generates returns equivalent to USD 5 in economic benefits achieved through reductions in health expenditure and increased productivity at work. The health and economic benefits of implementing One Health policies as policy packages far exceed the benefits accrued by implementing these policies in isolation.

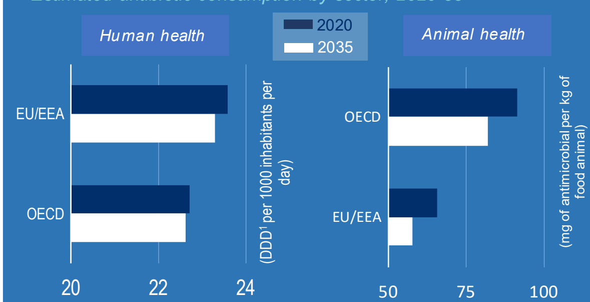
The AMR pandemic is already here. While COVID-19 has led to efforts to prevent and control the spread of infections, there is no room for complacency in the fight against AMR. Results from the OECD analysis demonstrate that policy action that is grounded in a One Health approach is urgently needed to tackle AMR.

Infographic 1. Key facts and figures

Antibiotic consumption is set to broadly remain at current levels

Unless we take action, antibiotic consumption in OECD and EU/EEA will stay mostly flat in humans and decline slightly in animals by 2035.

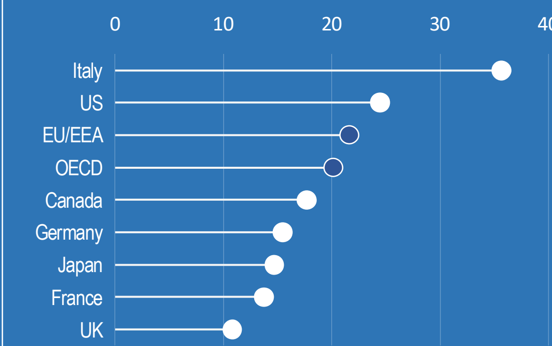
Estimated antibiotic consumption by sector, 2020-35



The AMR pandemic is here

One in five infections in OECD are resistant to antibiotic treatment. This will not improve without policy action.

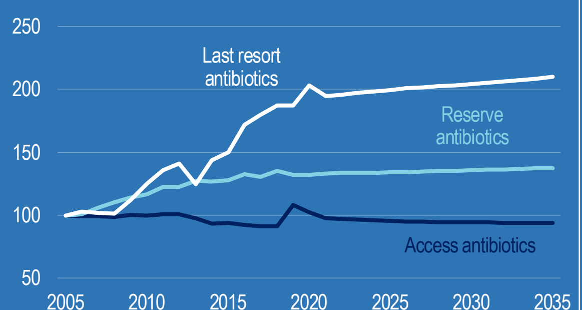
Share of resistant infections as % of total infections in 2019



We are exhausting our antibiotic arsenal

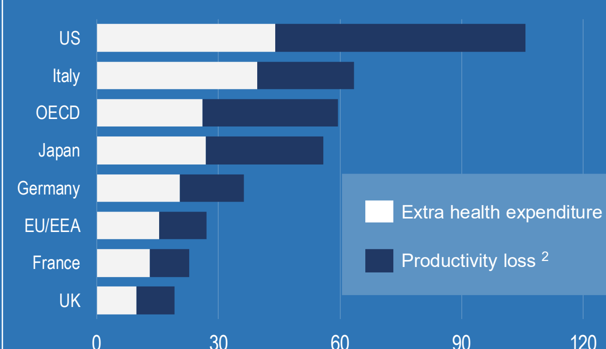
Resistance to last resort drugs in OECD countries could more than double by 2035 compared to 2005.

AMR index (Average AMR in 2005 = 100)



We pay a high price for inaction

Health and labour cost of resistant infections per year up to 2050, Per capita (USD PPP)



Time for One Health[3] action

Priority policies include:

- Strengthen infection prevention and control as well as support optimal use of antimicrobials
- Ensure greater compliance with regulations, especially to promote optimal use of antimicrobials in animals
- Strengthen AMR and antimicrobial use surveillance systems
- Scale up R&D in new antibiotics, vaccines and diagnostics

One Health policies save lives and money

A multi-sectoral mixed policy package[4] can lead to …

- 1.6 million infections avoided
- USD PPP 9.4 billion saved in health expenditure
- 17 000 deaths averted
- USD PPP 13.8 billion gained in workforce productivity

* Every year up to 2050 in 34 OECD and EU/EEA countries

Notes: (1) Defined daily doses. (2) Productivity loss refers to reduction in participation in the labour market and reduced productivity. (3) One Health refers to multidisciplinary and multisectoral actions targeting people, animals, agri-food systems and the environment. (4) The package includes programmes for hand hygiene, antimicrobial stewardship, delayed antimicrobial prescription, mass media campaigns and food handling practices.

1 Addressing antimicrobial resistance

Antimicrobial resistance (AMR) is well recognised as one of the most pressing public health threats globally. This chapter assembles the key messages emerging from the publication and discusses the main policy implications from the OECD analysis on the health and economic burden of AMR. The chapter presents the recent trends and projections for 51 OECD countries, European Union (EU) and European Economic Area (EEA) members and Group of 20 (G20) countries. It identifies the main gaps in multi-sectoral policy action to tackle AMR. Results from a special focus on AMR in long-term care settings are also presented. The chapter concludes by summarising an analysis of the effectiveness and cost-effectiveness of 11 modelled policy interventions and 3 policy packages designed in concordance with the One Health approach. Combined, the analyses presented in the chapter make a powerful economic case for continued policy action to tackle AMR.

Key findings

Total antibiotic consumption increased slightly in humans and declined for animals, but worrisome AMR trends persist, particularly for highest-priority antibiotics and certain antibiotic-bacterium pairs

- Between 2000 and 2019, on average, the sales of all classes of antibiotics in humans increased slightly by 1.9% across all OECD countries. The OECD forecasts suggest that antibiotic consumption is expected to remain relatively flat across OECD countries between 2019 and 2035. In the OECD, the consumption of highest priority and third-line antibiotics in humans has been increasing relatively faster than total consumption. If left unchecked, resistance to third-line antimicrobials can more than double by 2035 in the OECD compared to where it was in 2005.
- Over the last two decades, on average, the sales of all classes of antimicrobials used in meat production are estimated to have halved across OECD countries, after adjusting for key factors. If historical trends continue, antimicrobial consumption in food animals could decrease an estimated 10% in the OECD and 12% in the EU/EEA by 2035 compared to 2020 while stabilising in the G20 at 2020 levels.
- In 2019, resistance proportions across 12 priority antibiotic-bacterium combinations averaged at 20% in OECD countries, 22% in the EU/EEA and 30% in the G20. It is projected that between 2019 and 2035, resistance proportions for these antibiotic-bacterium combinations will remain mostly stable if current trends continue and no new policy actions are taken. A stabilisation of average resistance proportions at 2017 levels is also projected for EU/EEA countries and G20 countries.
- Despite the overall stabilisation of resistance proportions, for certain countries, including Greece, India and Türkiye, resistance is expected to remain above 40% by 2035. For certain antibiotic-bacterium pairs, the projected resistance proportions can be as high as nearly 90%.

AMR continues to pose a large burden on population health and the economy. The OECD Strategic Public Health Planning for AMR (SPHeP-AMR) model used data from national surveillance systems and other intergovernmental organisations from 34 OECD and EU/EEA countries, including all 29 EU/EEA countries, as well as Japan, Switzerland, Türkiye, the United Kingdom and the United States, and shows that on average, every year until 2050:

- Seventy-nine thousand people (22 000 in the EU/EEA) lose their lives due to resistant infections, corresponding to 2.4 times the number of deaths due to tuberculosis (TB), influenza and human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) in 2020. Resistant strains of *Escherichia coli* (*E. coli*), *Klebsiella pneumoniae* (*K. pneumoniae*) and *Staphylococcus aureus* (*S. aureus*) are the top killers, causing nearly three in four deaths.
- Resistant infections acquired in healthcare settings pose a greater risk of mortality compared to those acquired in the community. Healthcare-acquired resistant infections account for more than 60% of AMR-related deaths, even though they only represent 31% of total resistant infections.
- Deaths due to AMR are concentrated among the elderly populations, with around 2 in 3 AMR-related deaths occurring among people above 65 years of age. Among the younger population under 20 years of age, nearly 10% of all resistant infections are estimated to occur among newborns and children below 5 years of age.
- The annual cost of treating complications caused by AMR is estimated to average more than USD 28.9 billion adjusting for purchasing power parity (PPP) (USD PPP 7.5 billion in the EU/EEA) if all resistant infections were eliminated and USD PPP 5.9 billion (USD PPP 1.6 billion in the EU/EEA) if all resistant infections were replaced by susceptible infections.

- AMR is expected to cause a decline in the labour market output of about 734 000 full-time equivalents (FTEs) in the working population every year. Around 84% of the decline in labour market output is due to a reduction in workforce participation. These economic losses cost in total USD PPP 36.9 billion each year (USD PPP 5.8 billion in the EU/EEA).

Despite recent progress, considerable gaps remain in the policy action to tackle AMR

- Around 92% (47/51) of OECD, EU/EEA and G20 countries combined already developed their national action plans to tackle AMR by 2020-21. However, only around 20% (10/51) reached the final stage of implementation, where financial provisions for the implementation of the national action plans to tackle AMR are incorporated in the national action plans and budgets. In 2020, Group of 7 (G7) and OECD countries were the leading sources of development funding allocated to AMR but the current level of development funding is unlikely to fill the existing gaps in domestic funding in low- and middle-income countries.
- Since the launch of the World Health Organization (WHO) Global Action Plan on AMR (AMR-GAP) in 2015, nearly all OECD, EU/EEA and G20 countries rolled out multi-sectoral policies consistent with their national policy priorities and recommendations of the AMR-GAP. However, notable gaps remain in the implementation of interventions, including optimising antibiotic use in human and animal health, monitoring antibiotic use and AMR surveillance, scaling up infection prevention and control programmes, scaling up nationwide activities to raise AMR awareness, incorporating AMR in the training and education of healthcare professionals and implementing good management and hygiene practices in farms and food establishments.
- Only 17 out of 32 OECD and EU/EEA countries that reported data in a recent OECD survey indicated having national action plans that reference long-term care facilities (LTCFs). Antimicrobial stewardship and AMR surveillance remain limited, with only nine countries having in place antibiotic guidelines or restrictive lists for antimicrobials in LTCFs and only six countries conducting surveillance of antibiotic consumption and AMR in LTCFs.

Policies to tackle AMR offer an excellent investment

- The modelled policies can substantially improve population health. Hospital-based interventions usually offer the highest protective effects, including antimicrobial stewardship programmes (ASPs) and enhancing environmental hygiene and improving hand hygiene. Community-based interventions and One Health interventions, such as delayed antimicrobial prescription, scaling up the use of point-of-care rapid diagnostic tests and enhanced food handling, also offer significant protective effects, albeit of smaller magnitude.
- By investing in the modelled interventions, countries can realise substantial savings in healthcare expenditure and productivity gains. Enhancing environmental hygiene and improving hand hygiene are estimated to yield the highest annual savings in health expenditures by eliminating both resistant and susceptible infections, amounting to USD PPP 7.2 billion and USD PPP 6 billion respectively.
- Combining single interventions into policy packages addressing many of the policy gaps identified by the OECD analysis can yield considerable health and economic benefits. For instance, investing in a mixed package – improving hand hygiene, scaling up ASPs, delaying antimicrobial prescription, increasing mass media campaigns and enhancing food safety – could generate a gain of 466 000 life years (LYs) per year across all 34 countries included in the analysis and saves about USD PPP 9.4 billion annually in health expenditure.
- Benefits of implementing policy packages more than make up for their implementation costs. The annual average cost of implementing the mixed package is around five times lower than the reduction in health expenditure and productivity gains combined. This benefit-to-cost ratio is around 4.7 for a package focusing on hospital-based actions and 2.5 for a package comprising community-based actions.

AMR is a top public health threat that can be prevented by effective policy action at little cost

In 2018, the *OECD Stemming the Superbug Tide: Just A Few Dollars More* report highlighted the huge benefits of early and comprehensive action to tackle AMR. The report found that under a business-as-usual scenario, in which no policy changes were made, resistance proportions, averaged across 8 priority antibiotic-bacterium combinations, could increase by 1 percentage point between 2015 and 2030 (OECD, 2018[1]). The report also highlighted that the challenge was multifaceted, spanning numerous antibiotic-bacterium combinations, with levels and trends of antimicrobial use and resistance widely disparate across countries and antibiotic-bacterium combinations. At the time of the release of the report, countries were upscaling their action to stem the rise of superbugs fearing the threat of a post-antibiotic world. The report was a loud call to action by producing evidence on the effectiveness and the cost-effectiveness of policies to optimise the use of antimicrobials and prevent the spread of infections in humans.

Building on that seminal work, the OECD has continued working on this top public health threat to extend the scope of its analysis and to provide a more comprehensive assessment of priority actions for the next phase of the fight against AMR. A first major lesson learnt since 2018 is that any credible action should endorse a One Health approach, going beyond human health to include animal and plant health and the environment and by recognising that all of these sectors are closely linked to one another (FAO/WHO, 2021[2]; WHO, 2022[3]). For this reason, actions in one sector alone may not produce any tangible impact if they do not go hand-in-hand with actions in other sectors. Further, the new OECD report draws on newly released data and evidence regarding the effectiveness of policy actions and best practices, which are selected on policy priorities defined by countries in their national action plans and based on an analysis of the still significant gaps in the implementation of policies on the ground. The report also considers the impact of another pandemic, COVID-19, and how the “new normal” following the most acute phase of COVID-19 may have affected the AMR pandemic.

An overarching message from this report is that there are some signs that efforts to tackle AMR, rolled out since the release of *Stemming the Superbug Tide*, went in the right direction and reviewed countries are possibly curbing the growth in AMR, although these efforts do not seem to be yet sufficient to fully reverse trends. Actions to optimise the use of antibiotics may be reaping some initial benefits, particularly in the livestock sector where there has been a significant decline in the sale of antimicrobials. Despite some recent reductions in sales of antibiotics for use in humans – reductions that continued during the initial phase of the COVID-19 pandemic, at least in many EU/EEA countries – today, antibiotic consumption across the OECD remains higher than 20 years ago, after adjusting for population size and defined daily dose (DDD).[1] Projecting these trends, AMR is expected to continue growing but at a slower pace than in the past. The OECD analysis suggests that AMR may stabilise or even slightly decrease by 2035, particularly in the case of some bacteria-drug combinations. However, this should not give any reason for complacency as some worrying trends are forecast for backup antibiotics in some countries such as large non-OECD economies part of the G20 and Mediterranean countries part of the OECD and the EU/EEA. The new input data used to feed the model show a small increase in the health and economic burden caused by AMR, compared to the analyses produced in 2018. At that time, it was calculated that about 2.4 million persons would die as a consequence of AMR in Europe, North America and Australia between 2015 and 2050 and that AMR-related complications could cost up to USD PPP 3.5 billion per year to the health system of the 33 OECD and EU/EEA countries included in the analysist at the time (OECD, 2018[1]).

The AMR national policy landscape has significantly improved since 2018 but gaps in the implementation of the policies on the ground remain. The COVID-19 pandemic has posed new challenges. For example, many OECD countries reported that programmes aiming to promote the prudent use of antibiotics were severely disrupted in the early phases of the pandemic. At the same time, COVID-19 has also opened new opportunities placing a spotlight on infection prevention and control (IPC) policies and inducing significant improvements. Based on countries’ responses to the 2021-22 Tripartite AMR Country Self-assessment

Survey (WHO/FAO/OIE, 2021[4]), nearly all OECD countries developed a national action plan for AMR, which was not the case at the time of releasing the previous publication. However, only 20% of OECD countries report the most advanced stage of implementation, which entails integrating the financial provisions for nation plans to tackle AMR in the national budgets and action plans. In addition, the analysis of the level of implementation of policies identifies some key priority areas for action. First, policies promoting prudent use of antibiotics and preventing the spread of infections in humans are too often implemented haphazardly without nationwide coverage and their designs do not reflect best practices. Second, surveillance systems to monitor antibiotic use and AMR are not yet of sufficiently high standards, particularly in the case of monitoring AMR levels, hindering the implementation of other policies, particularly in long-term care settings. Finally, only a minority of countries enforce controls to ensure compliance with regulatory frameworks to promote prudent use of antimicrobials in animals.

To further upscale their action to tackle AMR, countries can count on a comprehensive set of evidence-based options. The new OECD analysis identifies 29 One Health policy options, ranging from those promoting prudent use of antimicrobials in the human and agriculture sectors (e.g. stewardship programmes, financial incentives, and education and training of healthcare professionals) to those preventing or reducing the incidence of infections, mainly through improved hygiene and to improve vaccination coverage. Environmental interventions also show the potential to reduce the concentration of antibiotics in the environment and AMR levels, particularly in the case of regulatory policies. For a subset of interventions for which evidence is more consolidated and by using the OECD model for Strategic Public Health Planning (SPHeP), the report also calculates the health and economic impact of scaling up interventions and their return on investment.

If the 2018 report argued that just a few dollars more would be sufficient to stem the superbug tide, this report shows that countries, in some cases more than others, have responded to this call and have mobilised investments to tackle AMR, also reaping some initial, albeit small benefits. Extra effort is needed to consolidate the path towards a more positive outlook. While additional investments supporting the development and access to the market of new antimicrobials, vaccines and devices are sorely needed and will require time to produce results, countries should continue investing in public health policies to promote prudent use of antimicrobials and prevent the spread of infections across humans, agriculture and the environment. One Health policies already in place should be fine-tuned to meet the highest standards and match best practices. Equally important is for countries to make sure that these policies are consistently implemented nationwide. In some cases, innovative policies, with a focus on One Health policies, should be also implemented to ensure a more comprehensive and effective action to cover sectors that, so far, have not been considered of the highest priority such as long-term care and the environment. Countries with higher AMR rates – large G20 non-OECD economies and Mediterranean OECD and EU/EEA countries for example – should make even greater efforts to catch up with countries at the forefront of the fight against AMR.

This chapter summarises the findings and policy recommendations from the report. It starts by discussing the trends and patterns of antimicrobial consumption and AMR across countries. Next, the chapter presents results from the analysis of the health and economic burden of AMR across 34 OECD and EU/EEA countries. It then shifts its focus to an assessment of the AMR policy landscape discussing countries' priorities based on an analysis of the 2021-22 Tripartite AMR Country Self-Assessment Survey (WHO/FAO/OIE, 2021[4]) and national action plans using natural language processing techniques. Complementing this analysis, results from a comprehensive review of the latest evidence on the effectiveness of AMR policies in line with the One Health approach are presented. Results from these analyses shed light on the current gaps in policy implementation and put forward a menu of evidence-based interventions to close such gaps. Next, the chapter places the spotlight on tackling AMR in long-term care settings, an emerging area of interest that saw substantially less policy action compared to other settings (e.g. hospital care) despite being recognised as a significant reservoir of AMR. Finally, the chapter reports results from the cost-effectiveness analysis for 11 One Health interventions making the economic case for investment.

AMR is forecasted to grow at a slower pace than in historical trends, suggesting that recent efforts to optimise antibiotic use may be yielding promising results, particularly in the livestock sector

While many OECD and EU/EEA countries show modest declines in sales of antibiotics for use in humans, possibly due to the promotion of prudent use of antimicrobials, long-term trends still show that sales have increased in the majority of countries. In contrast, sales in the livestock sector have decreased substantially, particularly over the last decade. However, this sector still accounts for a large majority of antibiotic sales and, while data are haphazard and incomplete, some worrying trends regarding antibiotics dispersed in the environment were identified.

Currently, the OECD analysis suggests that one in five bacterial infections are resistant to antibiotic treatment in the OECD but the growth rate has been relatively small over the last decade. Assuming that trends continue into the future, calculations from the OECD model suggest that the overall resistance proportions in OECD would remain mostly flat by 2035 but significant differences across countries will persist. For example, 18 countries are projected to experience growth in AMR rates across antibiotic-bacterium combinations. Importantly, in many OECD and EU/EEA countries, resistance to second- and third-line antibiotics, our backup option for difficult-to-treat infections, will grow much more than for first-line antibiotics. While data for 2020, the first year of the COVID-19 pandemic, are still considered tentative, they suggest that the policy response to contain SARS-CoV-2 may have produced a secondary impact on AMR, at least in EU/EEA countries (Box 1.1). It is still too early to say whether this impact will persist in the "new normal" or revert to the pre-COVID situation.

Box 1.1. Public health policies to contain the COVID-19 pandemic appears to have had a positive impact on antibiotic consumption in EU/EEA countries

Enhanced hygiene measures and lower use of healthcare services for non-COVID-related hospitalisations reduced the use of antibiotics in hospitals and the community, possibly supporting a future reduction in AMR rates

Preliminary data covering EU/EEA countries in 2020 show that the mean total consumption of antibiotics in humans in the EU/EEA dropped by 17.6% compared to the year before, after adjusting for population size and therapeutic dose (OECD et al., 2022[5]). A majority of countries reported decreases in antibiotic consumption for both the community and the hospital sector and generally larger decreases in the community than in the hospital sector. In the community, the decrease between 2019 and 2020 was proportionally larger in countries with higher antibiotic consumption than in countries with lower antibiotic consumption.

Several reasons were suggested to explain this trend but they generally relate to actions taken by governments, healthcare providers and populations to curb the COVID-19 pandemic including:

- Decreases in antibiotic prescriptions for respiratory infections and to the youngest age groups, following changes in infectious diseases epidemiology.
- Non-pharmaceutical interventions intended to limit SARS-CoV-2 spread (e.g. restrictions on movement, physical distancing, respiratory etiquette, hand hygiene and international travel restriction).
- Lower use of primary care services, due to lockdowns and reprioritisation of healthcare resources, which could have led to changes in antibiotic prescribing patterns.

- Higher demand for intensive care beds to treat patients with COVID-19 significantly reduced the number of admissions for elective surgery or chronic care, a situation for which antimicrobials are used in a significant amount.

The impact of the reduction in the use of antibiotics in humans on AMR rates is still unclear. The AMR surveillance systems of many OECD and EU/EEA countries were severely affected during the initial phases of the pandemic. For EU/EEA countries, statistics for 2020 report a great increase in the number of isolates processed for pathogens commonly responsible for healthcare-associated infections (HAIs) and a great reduction in the number of isolates for other bacteria not directly linked to the COVID-19 response and for pathogens in the community (ECDC, 2022[6]). The COVID-19 pandemic has severely affected the soundness of the statistics and made the observed changes in AMR percentages between 2019 and 2020 difficult to interpret. Robust surveillance systems will continue to be vital to monitor the situation, assess the consequences and inform public health decisions.

Source: OECD et al. (2022[5]), *Antimicrobial Resistance in the EU/EEA: A One Health Response*, https://www.oecd.org/health/Antimicrobial-Resistance-in-the-EU-EEA-A-One-Health-Response-March-2022.pdf; ECDC (2022[6]), *Antimicrobial Resistance Surveillance in Europe*, https://www.ecdc.europa.eu/sites/default/files/documents/Joint-WHO-ECDC-AMR-report-2022.pdf.

This section looks at historical trends and projections of sales for major classes of antibiotics and resistance proportions for 12 priority antibiotic-bacterium combinations, using a new round of data and advanced statistical techniques such as machine learning. Analyses cover the period 2000-19,[2] with projections up to 2035 for 51 countries, including OECD, EU/EEA and G20 countries.

Worrisome trends in antimicrobial consumption in humans and animals remain a serious concern

Misuse of antimicrobials in human and animal health remains one of the key drivers of AMR. While sales of antibiotics for humans in OECD and EU/EEA countries have recently started decreasing, sales are still higher than 20 years ago and sales in non-OECD G20 countries have increased significantly to almost OECD levels. In 2019, just before the COVID-19 pandemic, sales of antibiotics in OECD countries monitored by ResistanceMap/IQVIA were estimated at 21.8 DDD per 1 000 inhabitants per day, slightly higher (+1.9%) than 19 years before when sales were estimated at 21.4 DDD per 1 000 inhabitants per day. Average trends across the EU/EEA mirror those in the OECD. The average trend across G20 countries shows a convergence towards the OECD levels, driven primarily by a significant increase in antibiotic sales in countries such as Brazil, China, India, Indonesia and Saudi Arabia.

The analysis of the short-term trends suggests a more optimistic picture, possibly because of the impact of increased efforts to promote prudent use of antibiotics. Between 2015 and 2019, antibiotic sales decreased by 6.5% across OECD countries, 8% across EU/EEA and 7.4% in G20 countries. Despite these trends, the analysis of historical data on sales of antibiotics for use in humans across OECD and EU/EEA countries further points to some worrying trends:

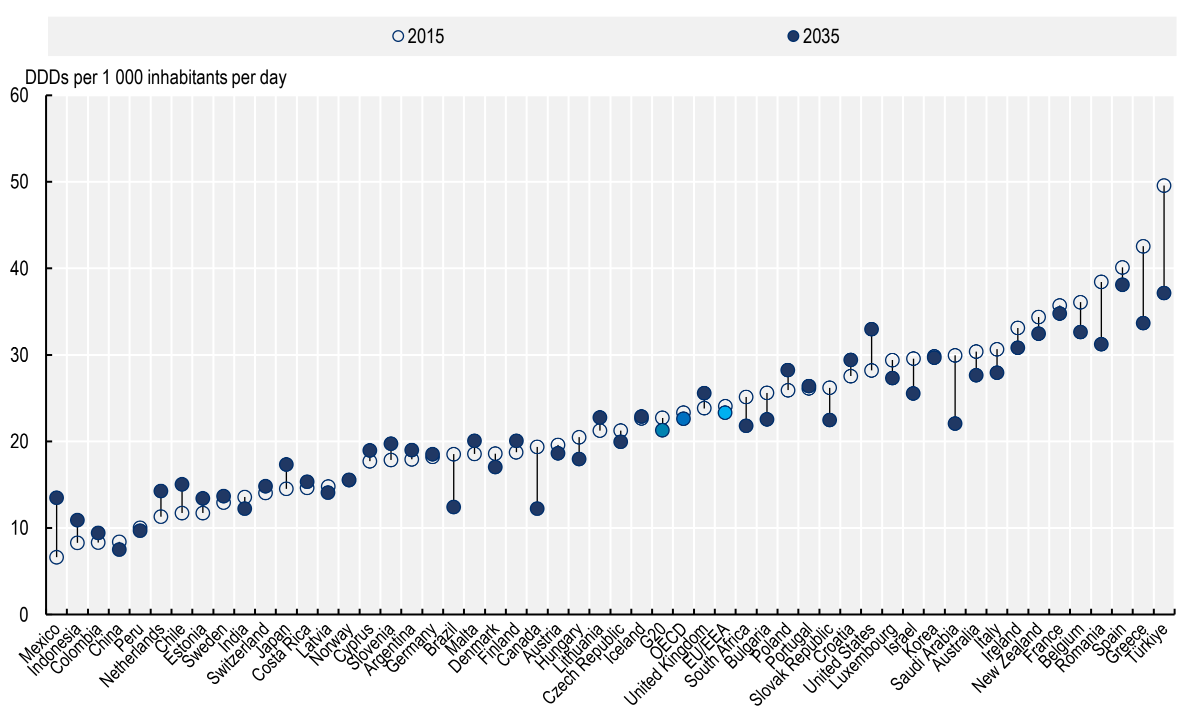
- Sales of high-priority antibiotics for human health have been increasing faster than total consumption of all types of antibiotics. For example, the consumption of carbapenems and polymixins, two last-resort antibiotics used to treat patients with multi-drug resistant infections, increased by 10% and 67% respectively across EU/EEA countries between 2011 and 2020 (ECDC, 2019[7]). Similarly, an OECD analysis found a seven-time higher increase in the use of carbapenems than total consumption across OECD countries between 2010 and 2015. The literature also suggests even higher growth rates for low- and middle-income countries (LMICs), which would account for most of the global growth in antibiotic consumption (Klein et al., 2018[8]).

- In 2015, the latest year for which data are available for all the countries included in the analysis, 14 OECD countries did not meet the target set by the WHO of having at least 60% of total national antibiotic consumption made up of antibiotics with lower resistance potential – known as the Access antibiotics in the WHO Access, Watch, Reserve or AWaRe classification of antibiotics[3] (Klein et al., 2021[9]). Large economies outside the OECD, such as Brazil, Chine and India were also among the countries that did not meet the WHO target in 2015. Since then, some OECD countries (e.g. Switzerland) have progressed on this indicator and now meet the 60% target.
- Across EU/EEA, in 2020, the consumption of broad-spectrum antibiotics in the community was 3.5 times higher than the consumption of narrow-spectrum antibiotics, which should typically be the first-line therapy.[4] Between 2011 and 2020, an increasing trend was observed in this ratio for the EU/EEA overall, indicating a shift towards broad-spectrum antibiotics to treat infections in the community (OECD et al., 2022[5]).

Should total antibiotic consumption continue to evolve following the same trends identified by the OECD model between 2015 and 2035, it is estimated that consumption would decrease by 3% in the OECD from 23.3 to 22.6 DDD per 1 000 inhabitants per day respectively (Figure 1.1). EU/EEA member states could see average total consumption decrease by 3.3%, while sales in G20 countries could drop by 6.2%. One of the main reasons underpinning this small but positive trend is that a number of countries experienced reductions in sales of antibiotics in the last few years before the COVID-19 pandemic. An emergent cause of concern that could put at risk the emerging trends identified by the model is represented by the growing shortages in the availability of antibiotics (Box 1.2).

Figure 1.1. If trends persist, total antibiotic consumption in humans in the OECD could decrease

Total antibiotic consumption in 2015 and 2035*



* Original data go as far as 2015; estimates for 2016-20 were derived through a combination of multiple imputations (data from OECD.Stat on consumption used as priors) and exponential smoothing with a damped trend. Averages for different country groups are unweighted.
Source: Chapter 2, Figure 2.3, https://stat.link/jqv4a0.

Box 1.2. Shortages of antibiotics and unavailability of forgotten antibiotics may negatively affect efforts to promote prudent use of antibiotics

In a 2019 survey of 39 European countries, 95% of participating pharmacists indicated that the shortage of medicines was a major problem in their hospitals (EAHP, 2019[10]). Antimicrobial agents were the leading cause of shortages in medicines from as far back as 2014. In 2019, around 63% of participating pharmacists indicated that they experienced shortages in antimicrobial agents, 5% more pharmacists than in 2014, indicating the situation is not improving.

Availability issues are even more evident for the so-called “forgotten antibiotics”. These are older but still clinically effective antibiotics, which are often categorised as Access antibiotics in the WHO AWaRe classification. These antibiotics are often not available in countries, either because they were never introduced or because they were withdrawn from the market at a certain point. A 2017 study found the availability of these antibiotics was low, with only about 69% (25 out of the 36 considered antibiotics) accessible in about 20 out of the 39 countries, mainly OECD and EU/EEA countries, included in the analysis (Pulcini et al., 2017[11]).

Source: EAHP (2019[10]), *2019 EAHP Medicines Shortages Report: Medicines Shortages in European Hospitals*, https://www.eahp.eu/practice-and-policy/medicines-shortages (accessed on 18 June 2022); Pulcini, C. et al. (2017[11]), “Forgotten antibiotics: A follow-up inventory study in Europe, the USA, Canada and Australia”, https://doi.org/10.1016/j.ijantimicag.2016.09.029.

Antimicrobials are used in animals for several purposes (see Chapters 2 and 5). They can be used to treat animals with bacterial infections. Antimicrobials can also be administered to animals who have been in contact with infected animals as a form of disease control (also called metaphylaxis). When no animals exhibit signs of infection, antibiotics can be used prophylactically across groups to prevent disease. Finally, antimicrobials may be used in healthy animals to accelerate weight gain and improve the efficiency of feed utilisation (WHO, 2017[12]). Metaphylaxis, prophylaxis and growth promotion can result in large volumes of antibiotics being used.

Worldwide, the consumption of antibiotics in animals far surpasses consumption in humans, with an estimated 73% of total antimicrobial sales globally being used in animals raised for food (Van Boeckel et al., 2019[13]). It is estimated that in 28 EU/EEA countries that report both animal and human consumption data, approximately 70% of the active substance of antimicrobials was sold for use in food-producing animals (ECDC/EFSA/EMA, 2017[14]). Moreover, last resort antibiotics (e.g. colistin) continue to be used for growth promotion purposes in many countries (Kumar et al., 2020[15]).

Across OECD countries, the average sales of all classes of antimicrobials used in chicken, cattle and pig systems are estimated to have halved over the last two decades, after adjusting for total production and importation of meat products. Most of this observed decline took place around 2014. The trend is similar in the EU/EEA but with the largest part of the reduction starting from 2010. Consumption in animals in the G20 is estimated to have dropped as well over the last 20 years but remains at levels higher than those in the OECD and EU/EEA.

While surveillance systems for antimicrobial consumption in animals are generally less developed than those used to monitor consumption in humans and these figures should be interpreted with caution, this is excellent news for at least two reasons. First, it is a sign that policy efforts by countries and stakeholders produced a significant impact on antimicrobial consumption in the livestock sector. Second, given that worldwide and within the EU/EEA, about 70% of total antimicrobial sales are used in animals raised for food (ECDC/EFSA/EMA, 2017[16]; Van Boeckel et al., 2019[13]), it is conceivable that if these trends continue, they could result in a significant decrease of total sales of antibiotics (i.e. humans and animals). In fact, according to the OECD analyses, if downward trends in the OECD and EU/EEA persist, these regions could see an additional 10% and 12% reduction in antimicrobial sales for food animals per animal biomass by 2035, compared to 2020.

The use of antimicrobials in aquaculture merits attention as one of the next priority areas to continue optimising the use of antimicrobials in livestock production. Aquatic animals represent 17% of global animal protein consumption and nearly 50% of the global supply of fisheries products for human consumption already comes from aquaculture. Given that consumption of aquatic animals is growing faster than the consumption of meat (with the exception of chicken), it is projected that, at current trends, the use of antimicrobials for food-producing aquatic animals will account for almost 6% of total global antimicrobial consumption by 2030, including humans and animals. In the same period, global sales of antimicrobials for use in aquaculture will rise by 33% (by 29.7% in Europe). Even most worryingly, 96% of all antimicrobial use in aquaculture comes from classes classified as highly important and critically important for humans (Schar et al., 2020[17]).

Beyond the use of antimicrobials in humans and the animal sector, other sectors are also contributing to high levels of antibiotics and are underpinning the rise in AMR. Data for these sectors are less accurate than for humans and livestock production but the available evidence suggests that these are all emerging issues deserving further attention and action. Some of the issues identified during the review of the evidence include the following:

- At least 20 countries approved the use of antibiotics to treat plant diseases (FAO, 2018[18]). In certain countries with strong regulatory oversight, antibiotic use in plants is minimal but this is not the case everywhere and significant amounts of antimicrobials were found to be used to control plant pests (WHO/FAO/OIE, 2021[4]).
- While most high-income countries either ban or restrict the use of antimicrobials in horticulture, this is not the case in many LMICs, where the sale of antimicrobials in plants is either unregulated or insufficiently enforced. Even when regulations are strong and effective, there may be disagreement over the best course of action.
- Antimicrobials may be dispersed in the environment by manufacturing plant run-off. This is particularly problematic in China and India where most antimicrobials are produced. Studies have found concentrations of antimicrobials in water downstream of manufacturing sites that were higher than blood concentrations in humans taking antimicrobials (WHO/FAO/OIE, 2020[19]). While there are no international guidelines on this matter, out of the 17 companies assessed in the Access to Medicine Foundation's report (2020[20]), 13 had an environmental risk-management strategy to address AMR and 12 set antimicrobial discharge limits at their facilities. However, only six companies asked their suppliers to set discharge limits and no company made any data from monitoring limits publicly available. The report also found that none of the 17 companies monitored the discharge levels of private waste-treatment plants that are contracted to dispose of their manufacturing waste (Access to Medicine Foundation, 2020[20]).
- Antimicrobials may also be present in the environment at large, from soil to waterways, for different reasons. A large part of the antibiotic volume ingested by both humans and animals (estimates vary, but around 80% in animals) is excreted in its active form, depending on the class of antimicrobial and how it is used. Antibiotics that have expired or are no longer necessary are also often discarded in general waste or wastewater.

Overall, AMR will grow at a slower pace than expected but worrying trends are forecasted for backup antibiotics and in certain countries

Across OECD countries, one in five infections in humans is resistant to antimicrobials, with a tenfold difference between countries with the highest and lowest resistance proportion. According to the OECD analyses of data from surveillance networks collated in ResistanceMap:

- In 2019, the estimated resistance proportions across 12 priority antibiotic-bacterium combinations were 20% in OECD countries. Denmark and Norway had the lowest estimated average resistance proportions, at nearly 6%, whereas in Greece and Türkiye, around 44% of infections were estimated to be resistant.
- In 2019, for some antibiotic-bacterium combinations such as fluoroquinolone-resistant and carbapenem-resistant *Acinetobacter baumannii* (*A. baumannii*), over 90% of infections were due to resistant bacteria in the countries with the highest resistance proportions.
- In 2019, resistance proportions in EU/EEA countries were evaluated to be similar to the OECD, with average resistance rates evaluated at 22% and higher across G20 countries at 30%.
- Data on resistance proportions in humans for infections with a large animal reservoir, such as *Salmonella* and *Campylobacter*, remain very limited but the available evidence suggests a worrying situation. In the United States, the resistance of *Salmonella typhi* was estimated to average 18% in 2018 (CDC, 2022[21]).
- Resistance to ciprofloxacin, a Watch antibiotic in the WHO AWaRe classification, was 13% in *Salmonella* spp. in 12 EU member states and 16 out of 19 EU/EEA countries reported very high or extremely high resistance to ciprofloxacin in *Campylobacter* (EFSA/ECDC, 2020[22]).

A small average increase in resistance proportions between 2009 and 2019 masks wide cross-country variation. Resistance proportions for 12 priority antibiotic-bacterium combinations[5] slightly increased across the OECD between 2009 and 2019, from 18% to 20%. The growth rate across EU/EEA and G20 was similar, at around 3%. Across all countries, the average largest increases in resistance proportions were for *A. baumannii* resistant to fluoroquinolone (+12.6%) while the largest projected reductions were in methicillin-resistant *S. aureus* (MRSA; -3.2%). While in 8 countries average resistance proportions for all the 12 antibiotic-bacterium combinations went down (-1.4 percentage points), the majority of OECD countries experienced an increase by as much as 8 percentage points between 2009 and 2019 (e.g. the Czech Republic and Italy). It is also estimated that no country has reduced resistance proportions for all 12 antibiotic-bacterium combinations between 2009 and 2019. *Salmonella* resistant to ciprofloxacin, a zoonosis, had a threefold increase in 2 years in EU member states for which data are available (from 1.7% in 2016 to 4.6% in 2018). In the United States, resistance of *Salmonella typhi* increased from close to 0 in 1999 to 18% in 2018 (CDC, 2022[21]).

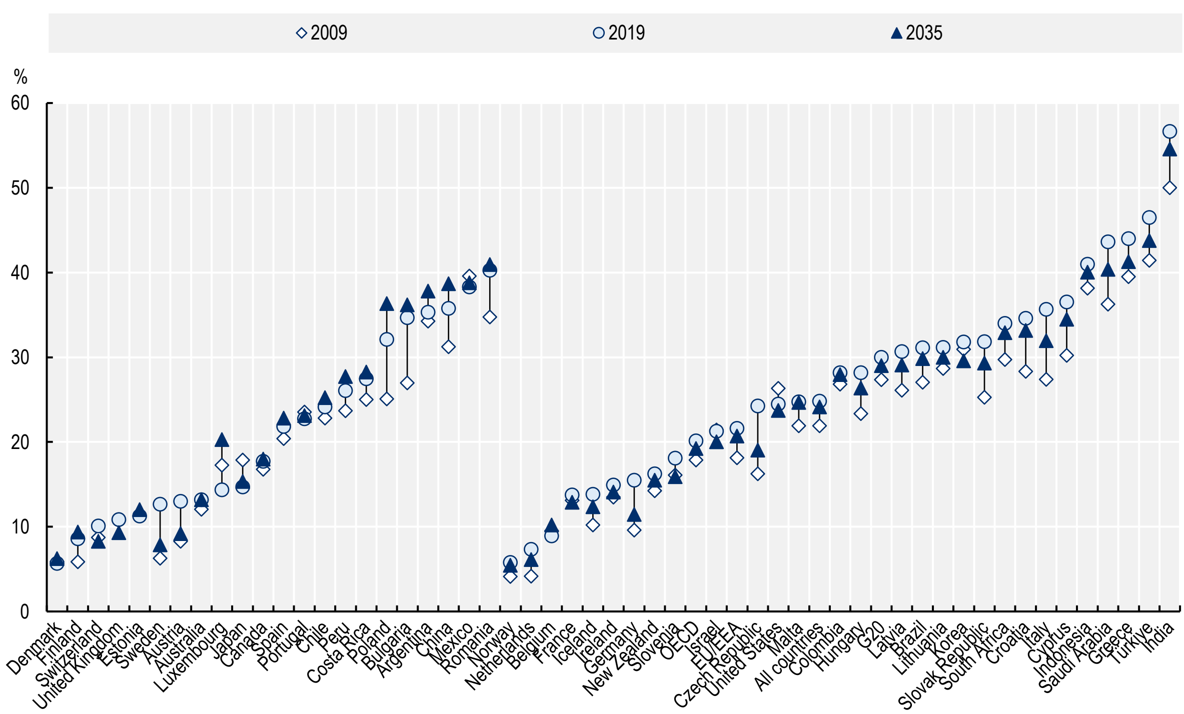
By using machine-learning techniques on updated historical data on resistance proportions and correlates of AMR (e.g. antimicrobial consumption in humans and animals), the OECD projected that between 2019 and 2035, resistance proportions averaged across 12 priority antibiotic-bacterium combinations will remain relatively flat, if trends continue into the future (Figure 1.2). Similar reductions of around 1 percentage point for average resistance proportions are also projected for EU/EEA and G20 countries. The OECD analyses also suggest that:

- Resistance proportions averaged across 12 antibiotic-bacterium combinations, are projected to increase in 18 countries, remain at their 2019 average levels in 1 country and decrease in 32 countries.
- Countries with historically low average resistance proportions are likely to maintain these into 2035. Conversely, countries with historically high average resistance proportions are estimated to have experienced most of the growth between 2009 and 2019, with average resistance proportions either flattening or dropping slightly by 2035.

- Resistance proportions for some antibiotic-bacterium combinations is expected to be dangerously high. For example, the average resistance proportions for fluoroquinolone-resistant *A. baumannii* and carbapenem-resistant *A. baumannii* can be as high as 45% and 30% across OECD by 2035 (51% and 37% in EU/EEA respectively). The projected resistance proportions for these antibiotic-bacterium combinations by 2035 are expected to exceed 70% in countries where the average resistance proportions were already high in 2019 such as India, Türkiye and Greece.
- In absolute terms, China, Luxembourg and Poland could see the largest percentage point increases, on average across 12 antibiotic-bacterium combinations, between nearly 3 and 6 percentage points higher in 2035 than in 2019. Conversely, the Czech Republic, Germany and Sweden could see the largest percentage point drops in average resistance proportions, projected to decrease around 4 to 5 percentage points.

Compared to the previous round of estimates, including data up to 2015, the new round of projections suggests a lower growth rate for future resistance levels. Keeping in mind the challenges around data availability and uncertainty related to the extrapolation process, the revised projections seem also to suggest some initial impact of the global efforts to tackle AMR. The revised estimates suggest that, compared to the previous set of analyses, there are more countries exhibiting a downward trend across the 12 antibiotic-bacterium combinations. In addition, antibiotic consumption in humans in the EU/EEA decreased between 2010 and 2019. Antimicrobial consumption in animals, which was included in the estimation procedure for the first time under a One Health approach, has also shown a downward trend in the OECD and the EU/EEA in the last few years. Finally, recent trends in AMR in the EU/EEA between 2016 and 2020 show some reductions.

Figure 1.2. Projected average proportion of infections caused by bacteria resistant to antimicrobial treatment for 12 antibiotic-bacterium combinations in 2009, 2019 and 2035



Note: For countries on the left of this graph, resistance proportions are higher in 2035, compared to 2019. For countries on the right, rates are lower in 2035. Otherwise, countries are sorted left to right based on ascending resistance proportions in 2019. Averages for different country groups are unweighted.
Source: Chapter 2, Figure 2.6, https://stat.link/8l5h7e.

Despite a projected overall stabilisation of resistance proportions, AMR is projected to remain dangerously high for certain countries and certain antibiotic-bacterium combinations. The top causes of concerns and reasons for an even tighter implementation of AMR policies include the following:

- By 2035, around half of the infections due to *A. baumannii* in G20 countries could be resistant to either fluoroquinolones or carbapenems. In the OECD, Greece and Türkiye are likely to continue to exhibit very significant average resistant proportions, with around 85% of infections in these countries due to *A. baumannii* projected to be resistant to either fluoroquinolones or carbapenems by 2035.
- Relative growth rates for resistance to second- and third-line antibiotics are forecasted to grow much more quickly than for resistance to first-line treatments. By 2035, resistance to third-line antimicrobials are projected to be 2.1 times higher in OECD countries (3.3 times in EU/EEA, 1.6 times in the G20) compared to what it was in 2005, albeit from still mostly low levels. Similarly, resistance to second-line antimicrobials is forecast to be 23-45% higher in 2035 across the same groups of countries, compared to 2005 levels.

Antimicrobial resistance damages population health and the economy

Much has already been written on a so-called “post-antibiotic” world, in which virtually no antibiotic would be effective, but AMR is already causing significant health and economic burden to the population and the economy of OECD countries and EU/EEA member states. Patients with resistant infections are more likely to develop complications and face a lower probability of recovery and a higher risk of death. Typically, resistant infections are costlier to treat compared to susceptible infections as they are more likely to require more intensive medical procedures and more aggressive antimicrobial therapies. As a result, patients with resistant infections spend a longer time in hospital, if they are hospitalised. Combined, these features of resistant infections lead to lower workforce participation and productivity.

In the longer-term, the burden caused by AMR in a post-antibiotic scenario could be significantly worse because even small infections could lead to death. In such a scenario, the burden of AMR would be greater than its direct impact because many non-essential treatments requiring the use of antibiotics (e.g. elective surgery) could be delayed or even avoided as the risk of death would be greater than the disability caused by the absence of treatment. The OECD had previously calculated that in a scenario where antibiotics would become almost completely ineffective, the ten most common procedures carried out in hospitals in the European region in 2014 would have produced an additional 435 000 infections leading to an additional 30 000 deaths (OECD, 2018[1]). A similar analysis for the United States concluded that the same scenario would produce an additional 400 000 infections and 21 000 deaths in 2010 (Teillant et al., 2015[23]). Such estimates roughly correspond to the yearly number of deaths due to motor vehicle accidents in the same regions and in the same period. While the “post-antibiotic” scenario remains a longer-term threat, it is crucial to assess the health and economic burden of AMR as new data come and evidence emerges.

The new iteration of the OECD analysis extends its previous assessment in a number of directions. For example, the new analysis increased the number of antibiotic-bacterium combinations that now include infections with a significant animal reservoir. This analysis also extended the geographical coverage to a total of 34 countries including all 29 EU/EEA countries, as well as Japan, Switzerland, Türkiye, the United Kingdom and the United States. The number of policy options modelled increased to include 11 One Health interventions. Finally, it quantified the impact of AMR on workforce productivity and the broader economy.

The analyses were carried out within the OECD SPHeP Framework using data from national surveillance systems obtained from relevant governmental agencies or other intergovernmental organisations (Box 1.3). For each country, the OECD model evaluates the impact of AMR under two different scenarios:

- A first – the elimination scenario – uses the classical burden of disease approach and assumes that antibiotic-resistant bacteria are eliminated. In practical terms, the scenario evaluates how the assessed outcomes change as a result of a fictitious elimination of the risk factor and, consequently, of all its consequences.
- A second – the replacement scenario – assumes that bacteria do not develop resistance. In this scenario, people that were infected by resistant bacteria would continue to be infected by bacteria that are susceptible to antibiotics. Outputs from this scenario are more conservative because susceptible bacteria increase the risk of complications and deaths but less than resistant bacteria.

Box 1.3. The OECD SPHeP framework – A tool to assess the medium- and long-term effects of top public health threats, including antimicrobial resistance

The OECD Strategic Public Health Planning for AMR (SPHeP-AMR) framework is an advanced systems modelling tool for public health policy and strategic planning. It is used to predict the health and economic outcomes of the population of a country, or a region, up to 2050. The model for AMR simulates synthetic populations of 34 countries, including all 29 EU/EEA countries, as well as Japan, Switzerland, Türkiye, the United Kingdom and the United States and many OECD countries.

The AMR model covers 28 antibiotic-bacterium combinations, including 6 HAIs and 7 community-acquired infections (CAIs), out of which 2 are infections with a significant zoonotic reservoir. Some infections can be both hospital- and community-acquired and some infections can be resistant to multiple antibiotics.

The incidence and prevalence of diseases in a specific country's population are calibrated to match estimates from the European Centre for Disease Prevention and Control (ECDC) estimates and official statistics obtained by national authorities and the WHO. Data provided to the OECD are collected by national surveillance systems and generally reflect the national official statistics. This approach has many advantages. Data gathered from the ECDC and official statistics are aligned with the information presented by countries in their national reports and evaluations, as well as assessments generated by the ECDC. Data from the ECDC are collated from laboratories and hospitals in countries based on procedures and methodologies that aim to harmonise data collection and management efforts across countries. On the other hand, the results presented in this chapter should be considered conservative. While there has been notable progress in recent years to strengthen AMR surveillance, detection and reporting capacity across many OECD and EU/EEA countries, important cross-country differences persist. These differences can mean that countries with more accurate reporting systems may show a greater AMR burden because they face a lower risk of under-reporting. The links between infections and complications, including deaths, are modelled through probability rates retrieved from the literature. The impact of infections on workforce productivity is also simulated through relative risk retrieved from the literature.

The model was used to simulate various scenarios, including the burden related to resistant infections (two scenarios described earlier) and policy scenarios (described in Chapter 6). Policy scenarios were modelled on evidence of the highest quality across four key dimensions, including: i) effectiveness of interventions at the individual level; ii) effectiveness over time; iii) eligible population and exposure; and iv) cost of running the intervention.

To assess the population-level impact of a scenario, model outputs were evaluated against a business-as-usual scenario, in which age- and sex-specific exposure to AMR is assumed to remain unchanged over the simulation period and the provision of preventive and health services is assumed to be implemented at the current levels in each country. A comparison of the business-as-usual scenario and the analysis scenario yields the impact on health outcomes, health expenditure and workforce productivity. The impact on workforce productivity is evaluated using the human capital approach, which is based on several assumptions including, for example, those on reserve labour force, friction costs and the impact on reserve wages.

For more information on the OECD SPHeP-AMR framework, see Box 3.1 in Chapter 3 and Box 6.1 in Chapter 6 and the SPHeP-AMR Technical Documentation (http://oecdpublichealthexplorer.org/amr-doc/).

Antimicrobial resistance worsens population health and decreases life expectancy

Findings from the OECD SPHeP-AMR model suggest that across 34 EU/EEA and OECD countries starting from 2021 (or earlier depending on the availability of historical data) up to 2050, AMR is expected to cause the following detrimental impacts on health:

- On average, every 7.3 seconds someone is infected by a resistant bacterium, most often in the community. Nearly 4.3 million infections are estimated to occur each year in the 34 countries included in the analysis (Almost 1.7 million across the EU/EEA) due to resistant infections. Around 2 in 3 resistant infections (around 69% in the EU/EEA) are acquired in the community with the remaining cases developing in healthcare settings.
- Every year, on average, 79 000 people (nearly 22 000 in the EU/EEA) die due to resistant infections. This corresponds to about 2.4 times the number of deaths due to TB, influenza and HIV/AIDS in 2020 combined. Countries in southern Europe and Mediterranean countries face a greater burden, with most of the cross-country variability explained by a higher incidence of infections as well as other factors like clinical management practices.
- Resistant strains of *E. coli*, *K. pneumoniae* and *S. aureus* are the top killers causing around three in four deaths. Resistant *E. coli* alone represents about one-third of all deaths caused by AMR, while resistant *K. pneumoniae* accounts for about 21% of all deaths due to AMR. In contrast, resistant strains of *Salmonella* spp., *Campylobacter jejuni* (*C. jejuni*), *Campylobacter coli* (*C. coli*) and *Mycobacterium tuberculosis* represent a small share of the AMR burden. However, these bacteria remain a top public health threat elsewhere: diarrheal diseases caused more than 1.5 million deaths worldwide in 2019, with a high burden in children under 5 years of age (Vos et al., 2020[24]). Similarly, TB was estimated to kill 1.6 million people worldwide in 2021 (WHO, 2022[25]).
- Resistant HAIs present a greater risk of death compared to those acquired in the community. HAIs account for more than 60% of AMR-related deaths even though they only represent about 31% of resistant infections. For instance, hospital-acquired *K. pneumoniae* represents only around 4% of all resistant infections but causes around 13% of all AMR-related deaths. In contrast, community-acquired *C. jejuni* and *C. coli* cause about 36% of all resistant infections but account for less than 1% of all AMR-related deaths. These findings underline the importance of hospital-based measures to reduce the burden of HAIs.
- Deaths due to AMR are concentrated among the elderly populations, with around 2 in 3 AMR-related deaths occurring among people above 65 years of age. About 4% of deaths due to AMR occur among people under 20 years of age, particularly in newborns or young children.
- AMR is linked with reductions in life expectancy at birth in the order of magnitude of about 2.6 months (1.6 months across the EU/EEA). This is roughly equivalent to one-third of the impact caused by COVID-19 between 2019 and 2020, which was estimated to be around 7.5 months across the 34 countries included in the analysis based on OECD data (OECD, 2022[26]).

AMR accounts for a significant share of total health expenditure

As for the analyses on the health burden, the OECD model was run on the same group of 34 countries for the period from 2021 (or earlier depending on the availability of historical data) up to 2050 to calculate the use of healthcare resources and the related costs caused by the growing rates of AMR. Under the elimination scenario, the model calculates that:

- Resistant infections are estimated to result in more than 32.5 million extra days spent in hospital every year across the 34 included countries (more than 9.5 million extra hospital days across the EU/EEA countries). The total amount of extra hospital days due to AMR is roughly equivalent to using the entire acute bed capacity in Spain for the whole of 2020.
- The annual cost of treating complications caused by AMR is estimated to average more than USD 28.9 billion adjusting for PPP across all of the countries included in the analysis, corresponding to almost USD PPP 26 per capita. In the EU/EEA, the healthcare cost of AMR is estimated to reach around USD PPP 7.5 billion every year corresponding to around USD PPP 15.3 per capita.
- The cost of inaction to tackle AMR up to 2050 is expected to exceed treatment costs due to COVID-19 in 2020. In 17 OECD countries and EU/EEA countries for which data are available, the total health expenditure incurred each year due to AMR is about 19% of the total health expenditure due to treating COVID-19 patients in 2020.

AMR negatively affects workforce productivity and the economy

The OECD SPHeP-AMR model was also used to quantify the impact of AMR on workforce productivity, which is measured as a combination of: i) participation (assessed through employment rate); and ii) productivity (measured through absenteeism and presenteeism). Changes in labour supply and workforce productivity are translated to monetary losses using the human capital approach, whereby the duration of foregone work is multiplied by the estimated national average wage in the simulation period, to provide a high-level impact of AMR on the broader economy. As for the other analyses, the OECD SPHeP-AMR model was run on the same group of 34 countries for the period from 2021 (or earlier depending on the availability of historical data) up to 2050.

Under the elimination scenario, the model evaluates the following:

- AMR is expected to cause a decline in the labour market output of about 734 000 FTEs in the working population every year, which corresponds to about a 0.12% decline in the labour market output. In the EU/EEA, the average yearly loss in labour market output stands at around 161 000 FTEs, which is equivalent to about a 0.06% decline in productivity. The magnitude of this decline may seem smaller compared to other public health threats. However, as discussed in the section on the impact on population health, resistant infections primarily develop among people aged 65 and over who – very often – have already left the labour market.
- Around 84% of the decline in labour market output is due to a reduction in workforce participation – mainly caused by the death of people in active employment – with most of the remaining share attributable to increased absenteeism.
- The estimated declines in workforce productivity translate into considerable financial losses. The model estimates a total economic loss of USD PPP 36.9 billion each year across the 34 countries included in the analysis, corresponding to around USD PPP 32.7 per capita. In the EU/EEA, AMR is estimated to depress workforce productivity by around USD PPP 5.8 billion per year by 2050, corresponding to approximately USD PPP 11.8 per capita every year.

- Italy, Ireland and Malta are estimated to incur the greatest losses in per capita labour market output across the EU/EEA countries, with losses ranging from around USD PPP 16.5 in Malta to USD PPP 23.8 in Italy. Across the non-EU/EE member OECD countries, the greatest losses occur in the United States (USD PPP 61.8 per capita per year) and Türkiye (USD PPP 56.9 per capita per year).

Figure 1.3 summarises the health and economic burden of AMR across the 34 countries included in the analysis and key findings for the replacement scenario are presented in Box 1.4, together with the results for all the other dimensions.

Box 1.4. The health and economic impact in the replacement scenario

As discussed earlier, the replacement scenario assumes that resistant infections would be replaced by infections caused by susceptible bacteria. This is the more conservative assumption as susceptible infections are generally less dangerous but still pose significant a burden of disease. Results from the OECD SPHeP-AMR model suggest that across the 34 countries included in the analysis:

- The estimated deaths due to resistant infections exceed 24 000 every year up to 2050, with around 6 000 of these deaths occurring across the EU/EEA countries.
- Resistant infections acquired in healthcare settings are estimated to represent about 3 in 4 (73%) of all deaths due to resistant infections. This figure is 11% higher than in the elimination scenario, underlying the significantly higher mortality caused by HAIs compared to CAIs.
- Resistant infections are estimated to result in 6.9 million extra days spent in hospitals every year up to 2050, corresponding to around USD PPP 5.9 billion in healthcare expenditure (USD PPP 5.2 per capita).
- Annual losses in the labour market productivity are estimated to average around 119 000 FTEs (18.7 FTEs per 100 000 working population) and nearly 27 000 (9.6 FTEs per 100 000 working population) across the EU/EEA countries.
- After converting reductions in workforce productivity in labour market outputs, resistant infections are estimated to produce losses of more than USD PPP 6.6 billion (USD PPP 5.9 per capita) up to the year 2050. Across the EU/EEA countries, annual losses amount to nearly USD PPP 960 million (USD PPP 1.9 per capita).

Figure 1.3. Summary of health and economic impact of AMR across the 34 countries included in the analysis

79 thousand people
lose their lives each year due to resistant infections

32.5 million days
Spent in hospitals additionally every year to treat resistant infections

USD 28.9 billion
Spent annually to treat complications caused by resistant infections

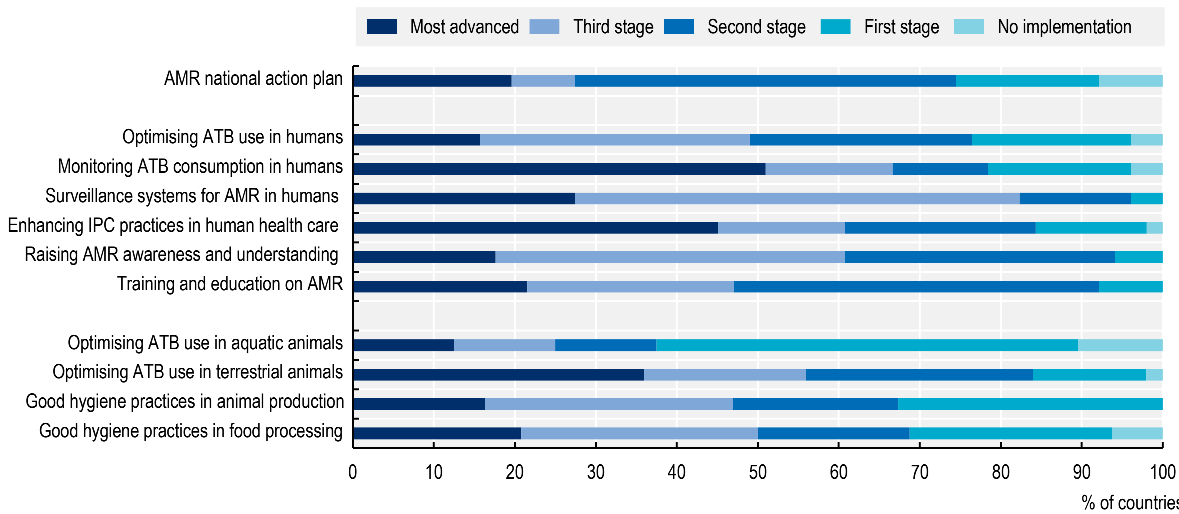
USD 36.9 billion
Cost of AMR caused by reduced workforce participation and productivity

Notes: The infographic above summarises the health and economic impact of AMR under the elimination scenario.

OECD countries have national action plans for AMR (AMR-NAP) that are aligned with the Global Action Plan on AMR (AMR-GAP) but only nine of the counties put in place financial provisions for implementation in national plans and budgets

In recent years, the global community has made important strides to tackle AMR. In May 2015, all members of the WHO made a commitment to tackling AMR by adopting the AMR-GAP (WHO, 2015[27]). Since then and up to 2021-22, 149 countries released their own action plan (WHO/FAO/OIE, 2021[4]) although only 10% (17/166) of action plans proceeded to the most advanced stage of implementation, including financial provisions for the implementation of AMR-NAPs in national action plans and budgets. OECD, EU/EEA and G20 countries report a more advanced stage of implementation (Figure 1.4). Nonetheless, only around 20% (10/51) of OECD countries and key partners and EU/EEA countries had proceeded to the final stage of implementation by 2020-21, where financial provisions for the implementation of the AMR-NAP are incorporated in national action plans and budgets (WHO/FAO/OIE, 2021[4]).

Figure 1.4. National action plans for AMR are usually well-developed but there are significant gaps in policy implementation



Note: The data presented in the graph are based on 51 countries included in the OECD analysis. ATB: Antimicrobial.
Source: OECD analysis based on WHO/FAO/OIE (2021[4]), *Tripartite AMR Country Self-Assessment Survey (TrACSS) 2020-21*, https://www.who.int/publications/m/item/tripartite-amr-country-self-assessment-survey-(tracss)-2020-2021.

A multi-sectoral approach has been endorsed by the majority of countries while developing their AMR-NAPs. In nearly all OECD countries, EU/EEA and G20 members, at least two sectors actively participated in the development and implementation of these action plans by 2021-22, with animal health and food safety being the two sectors most often involved. Conversely, plant health was the sector less often involved in the development process with, respectively, only 63% and 55% of OECD and EU/EEA countries involving these sectors. Involvement of the various sectors was most often sought by establishing multi-sectoral co-ordination mechanisms, such as steering committees or joint working groups, which are considered best practices.

By using natural language processing techniques, the OECD has assessed the level of alignment between the GAP-AMR and 21 national action plans from OECD, EU/EEA and G20 countries as well as the level of emphasis that each plan places on key policy dimensions to contain AMR (Özçelik et al., 2022[28]). The considered policy dimensions were selected based on their recognised role in driving success in tackling AMR (Ogyu et al., 2020[29]; Chua et al., 2021[30]; Anderson et al., 2019[31]) and include: i) funding and budgetary considerations; ii) optimising use of antimicrobials; iii) strengthening surveillance mechanisms; iii) strengthening AMR surveillance; iv) IPC policies; v) promoting research and development (R&D); and vi) enhancing AMR awareness and understanding. The key findings of this analysis include the following:

- There is a high degree of convergence between AMR-NAPs and the AMR-GAP in terms of their strategic objectives. Optimising the use of antimicrobials in human and animal health is the most frequently featured strategic objective, followed by strengthening AMR surveillance, reducing the incidence of infections and making an economic case for sustainable investments. In comparison, improving awareness and understanding of AMR is the least frequently discussed objective.
- Only 12 out of 21 AMR-NAPs from OECD, EU/EEA and G20 countries discuss budgetary considerations and less than half refer to the cost-effectiveness of AMR-relevant interventions.
- With respect to strategies to optimise antimicrobial use, strengthening antimicrobial stewardship, improving the availability of antibiotic prescribing guidelines, encouraging the use of older

antimicrobials and scaling up electronic prescribing programmes are the most emphasised interventions.

- Strengthening AMR surveillance is widely recognised as a top priority across the AMR-NAPs but countries would benefit from deepening their engagement with global and regional AMR surveillance networks, enhancing laboratory network capacity and integrating information from new data sources into AMR surveillance.
- In terms of reducing the incidence of infections, the highest emphasis is placed on improving water, sanitation, hygiene and waste management practices and vaccination coverage in human health. There is a need to put more emphasis on veterinary vaccines and enhancing biosecurity.
- In terms of strategies to spur AMR-related R&D, AMR-NAPs primarily focus on incentivising the early stages of drug development, whereas emerging evidence points to the need to supplement these incentives with incentives that can help improve the expectations around future revenues.
- With respect to strategies to enhance AMR awareness and understanding, frequently highlighted interventions include those targeting medical professionals and the general public while less emphasis is given to interventions targeting young children.

Important gaps exist in the implementation of AMR-relevant policies

By using data from the latest wave of the 2021-22 Tripartite AMR Country Self-Assessment Survey (WHO/FAO/OIE, 2021[4]), the OECD has assessed the level of actual implementation of the policy actions across OECD, EU/EEA and G20 countries (Figure 1.4). Findings from this analysis point to significant gaps in implementation:

- In 76% of countries, guidelines for the appropriate use of antimicrobials are available at the national level. But, in only eight countries, policies promoting the optimal use of antibiotics are implemented for all major syndromes and data are used systematically to provide feedback to prescribers.
- Around half of the countries, most often part of the OECD or EU/EEA, have developed monitoring and surveillance systems that are able to collect data and report on antibiotic sales or consumption at the national level for human use, as well as antibiotic prescribing and appropriate use in a representative sample of public and private health facilities.
- Only 61% of countries report having IPC programmes developed in accordance with the WHO IPC core components and functioning at the national and health facility levels. These countries also confirm that actions are evaluated and updated on a regular basis. An additional 16% of countries report having IPC programmes meeting the highest standards but implementation cannot be assured nationwide.
- Information campaigns for the public and training for healthcare personnel are implemented nationwide and at a high standard in 61% and 47% of countries respectively. Figures do not substantially differ for OECD and EU/EEA countries.
- More than 90% of countries confirm that they have in place high-quality regulatory frameworks to promote prudent use of antimicrobials in animals though around 1 in 3 countries confirm that controls are in place to ensure compliance with legislation.
- Around half of the countries – similar but slightly better results are also found for OECD and EU/EEA countries – report that their plans for good management and hygiene practices in animal production and food processing are not implemented nationwide.
- While OECD countries and the European Commission remain the main source of funding for AMR innovations, additional funding is crucial to promote the development, particularly the later stages, and to bring to the market new antimicrobials, vaccines and devices (Box 1.5).

Box 1.5. OECD countries are the leading source of financing for R&D relevant to AMR

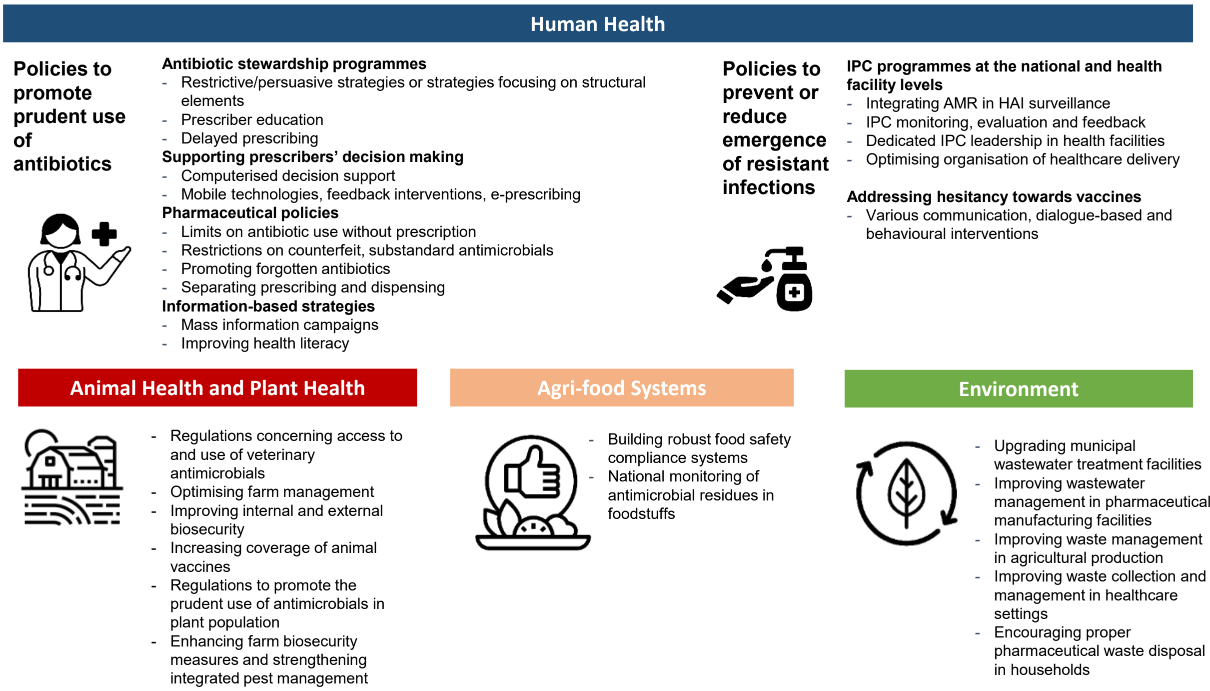
Between 2017 and 2020, the total spending on R&D for AMR declined slightly from USD 1.67 billion in 2017 to USD 1.92 billion in 2020 (Global AMR R&D Hub, 2023[32]). In 2020, OECD countries, including Germany, the United Kingdom and the United States, as well as the EU/EEA countries, were the lead source of financing for R&D allocated to AMR. Most of the R&D funding for AMR is allocated to funding basic research, development of therapeutics, operational and implementation research that can help support decision-making and management strategies, and diagnostics and capacity-building activities. This finding is coherent with studies that examined earlier periods, which concluded that the majority of R&D funding for AMR is allocated to supporting basic research and preclinical trials (Simpkin et al., 2017[33]). While this emphasis on the early stage of antimicrobial development is essential, increasing financial resources available for the later stages of clinical development can offer an important incentive that facilitates timely access to pharmaceutical markets in newly developed antibiotics. Moreover, increasing late-stage incentives can help attract greater private investments.

Source: Simpkin, V. et al. (2017[33]), "Incentivising innovation in antibiotic drug discovery and development: progress, challenges and next steps", https://doi.org/10.1038/ja.2017.124.

Countries can count on a comprehensive set of policy options to tackle antimicrobial resistance in human health, agriculture and the food supply chain

To inform the next phase of the fight to tackle AMR and help countries implement evidence-based interventions to close the gaps identified in the previous section, the OECD carried out a review of best practices and innovative policy options. Available evidence and datasets identify a comprehensive set of policy actions that countries can implement to tackle AMR (Figure 1.5). Policies are categorised on the target area span across four domains: i) human health; ii) agriculture; iii) food supply chain; and iv) the environment; and based on whether the policy aimed to promote prudent use of antibiotics or prevent the spread of infections. In total 29 policies were identified, with the highest number of policies targeting human health and the promotion of prudent use of antibiotics.

Figure 1.5. Multi-sectoral AMR-relevant strategies included in the OECD review



Policies focusing on human health

Most policies that tackle AMR in human health recognise that behaviours and choices made by individuals play an important part in promoting prudent use of antimicrobials and preventing the spread of infections. Health professionals' behaviours – whether related to antibiotic prescription or the correct implementation of IPC practices – are influenced by a range of factors including their training, whether the system supports the clinical decision-making process, provider compensation methods, professional and social preferences and norms. Similarly, patient knowledge, preferences and attitudes play an important role in antibiotic use and the decision to be vaccinated. Complex interactions between healthcare providers and patients have also been shown to influence behaviours around antibiotics.

The review identified three categories and six policy interventions (Table 1.1). Overall, the available evidence supports the implementation of all policies identified. The use of new technologies, for example, to support prescribers' decision making or for surveillance purposes, and removal of barriers to action emerge as successful enablers of policy implementation. The use of behavioural approaches also shows a promising impact in supporting policy actions. Finally, the evidence suggests that the design of the interventions is another very important determinant of success, particularly in the case of awareness-raising or education-based interventions that should deliver clear and consistent messages.

Table 1.1. Key findings on the impact of policy actions to tackle AMR in human health

Category of intervention	Policy interventions	Key findings
Policies to promote prudent use of antibiotics	Antibiotic stewardship programmes (ASPs)	• ASPs are effective in reducing imprudent use of antibiotics without increasing the risk of death • Restrictive or persuasive ASPs can be effective in reducing imprudent use of antibiotics and supplementing restrictive interventions with persuasive ones enhances the effectiveness of former • Effectiveness of ASPs will be enhanced by tracking performance over time in congruence with the context of care • Effectiveness of ASPs can be elevated by addressing the existing gaps in the available antibiotic guidance and extending guidance for relatively new modes of healthcare delivery (e.g. telehealth)
	Supporting prescribers' decision making	• Computerised decision support tools improve access to accurate antibiotic information relevant to prescribers' decisions around dose optimisation and de-escalation while facilitating AMR surveillance • Mobile health technologies promote greater compliance with antibiotic guidelines • Feedback interventions, including audits, real-time feedback and peer comparisons, encourage the prudent use of antibiotics • E-prescribing systems can enhance the quality of medical records that are used to inform the design and implementation of interventions to optimise prudent use of antibiotics
	Pharmaceutical policies	• Removing economic and regulatory barriers to the market registration of forgotten antibiotics can help enhance access to these antibiotics • Addressing the shortages in medicines to ensure adequate access to forgotten antibiotics • Promoting local and global collaborations can help accelerate access to forgotten antibiotics • Separate prescription and dispensing of antibiotics can lower the overall volume of antibiotic prescription
	Information-based strategies	• AMR awareness campaigns should ensure to have clear public health messaging to dispel confusion and misconceptions about antibiotic use • Improving the health literacy of the general population promotes more prudent use of antibiotics
Policies to reduce the incidence of infections	IPC programmes at the national and health facility levels	• Integrating AMR in HAI surveillance facilitates systematic data collection and analysis • Building dedicated IPC teams helps monitor ongoing IPC practices, educate health workers and promote a work environment that enables the best IPC practices • Scaling up of IPC monitoring, regular audits, evaluation and feedback interventions can promote greater compliance with IPC guidelines among health workers • Addressing high rates of bed occupancy and overcrowding in health facilities can help reduce the likelihood of AMR HAIs
Policies to improve vaccination coverage	Addressing hesitancy towards vaccines	• A wide range of communication and dialogue-based interventions can be used to build and sustain public confidence vaccines among different stakeholders • Behavioural interventions are showing promising results in nudging people to take up vaccines

Policies focusing on animal health, plant health and agri-food systems

Much like policies to tackle AMR in humans, policies in the agriculture domain aim to both promote prudent use of antimicrobials and prevent the spread of infections in livestock and crop production. Most of the attention in terms of policy implementation is focused on livestock production with much less evidence on plant production, which is another potentially important driver of antimicrobial use in agriculture. Previous OECD work in the field identified five key recommendations in this domain (Ryan, 2019[34]), which emphasised the need to adopt a flexible and step-by-step approach based on a mix of management and biosecurity measures. A strong call for more evidence on the economic benefits of each intervention as well as a need to ensure rapid availability of the evidence was also made.

The current analysis is designed by taking into consideration these recommendations, specifically those related to the type of policy and approaches, and identified four main areas of action in the agriculture and food supply chain and seven policy interventions (Table 1.2). Overall, the available body of evidence seems to be smaller and less consolidated than for human health, particularly in the case of plant health. Nonetheless, interventions such as regulation and optimising farm management emerge as effective in decreasing the use of antimicrobials in agriculture settings and decreasing AMR emergence and transmission. Supporting the sector in the transition towards tighter implementation of best practices, for example, by increasing the accessibility of alternatives or by supporting market mechanisms pushing in the desired direction, would help enhance the overall coverage and effectiveness of the interventions.

Table 1.2. Key findings on the impact of policy actions to tackle AMR in animal health, plant health and agri-food systems

Category of intervention	Policy interventions	Key findings
Policies to promote prudent use of antimicrobials in animals	Regulations concerning access to and use of veterinary antimicrobials	• Regulations that restrict the use of veterinary antibiotics can result in reductions in AMR but the precise magnitude of the effectiveness of each type of regulation varies by setting • Flexible regulations and step-by-strategies that enable adjustments at the farm level often appear as the preferred approach by many countries • While considering regulatory options, priority should be given to regulations that limit antimicrobial use for growth promotion purposes • The effectiveness of regulatory measures may be enhanced through the use of market mechanisms, voluntary initiatives, improving the availability of options alternative to antimicrobials and financial incentives for producers
Policies to prevent the emergence and spread of infectious diseases in animals	Optimising farm management	• Investing in farm management, biosecurity and animal vaccines contribute to reductions in the likelihood of the emergence and spread of resistant pathogens in farm settings • Additional expenses incurred due to investing in farm management and biosecurity measures can be offset by savings achieved from reducing reliance on antibiotics
	Improving internal and external biosecurity	
	Increasing the coverage of animal vaccines	
Plant health	Policies to promote prudent use of antimicrobials in plants	• Regulations to limit the use of antimicrobials in plant populations may help lower AMR transmission but important gaps exist in the existing regulatory arrangements across G7 countries, OECD members and key partners • Mechanisms are lacking for monitoring pesticide use in plant production • Improving farm biosecurity and strengthening integrated pest management approaches can help reduce the likelihood of the emergence and spread of diseases in plants
	Policies to prevent the emergence and spread of diseases in plants	
Agri-food systems	Scaling up food safety compliance systems	• The hazard analysis and critical control points (HACCP) system, a popular food safety compliance approach, can help reduce the burden of food-related AMR by supporting the implementation of food hygiene standards • Evidence from OECD countries demonstrates that the introduction and robust enforcement of regulations that are aligned with international food hygiene and safety standards can help enhance the effectiveness of HACCP systems • National AMR surveillance can help systematically monitor antimicrobial residues in foodstuffs

Policies to tackle AMR in the agri-food systems are also gaining momentum, given the non-negligible burden of foodborne diseases, including in high-income countries, and the risk that resistant bacteria can spread through the farm-to-fork chain. The review identified the hazard analysis critical control points (HACCP) system as the key code of practices that can help minimise such burden and disrupt the AMR transmission in the food supply chain. For this reason, some OECD countries have started incorporating the implementation of the HACCP system in their AMR-NAPs. Evidence also highlights how strong surveillance systems are a key factor in supporting the implementation of an effective HACCP approach as they can identify antimicrobial residues throughout the chain in a timely manner.

Policies focusing on the environmental reservoir

Policies to tackle AMR in the environment generally focus on improving the management of waste produced by sectors at high risk for contamination with antimicrobials or high prevalence of AMR such as the agriculture and health sectors and pharmaceutical production. Identified interventions generally focus on improving industry standards or coverage of policies already in place. For example, only about 20% of wastewater that is directly discharged into the environment is treated at the global level (FAO, 2018[35]). Production of guidelines and support of self-regulatory approaches are also identified among the most common policy practices.

The review identified five policy actions falling in this category (Table 1.3). Overall, available evidence appears to be in development, with a smaller number of studies and study designs that, often due to the own nature of the interventions, tend to be of lower quality than for interventions targeting humans or the agriculture sector. Even so, the evidence does suggest that interventions in this domain are associated with reductions in the transmission of AMR. However, at least for now, these interventions should be seen as complementary to others as, in isolation, they are unlikely to halt AMR transmission in the environment due to limitations in existing technologies. For this reason, the use of new technologies is consistently identified as a very promising approach to improving the effectiveness of action. Additional investments in waste management programmes, whether these are for sewage systems or more effective disposal systems for antimicrobials, are also identified as a top priority for upscaling action in this domain.

Table 1.3. Key findings on the impact of policy actions to tackle AMR in the environment

Category of intervention	Policy interventions	Key findings
Measures to dispose and remove antibiotics from the environment	Upgrading municipal wastewater treatment facilities	• Upgrading technologies used in municipal wastewater treatment facilities can help reduce AMR transmission in the environment but none of these technologies can eliminate resistant bacteria and genes in their entirety
	Improving waste management in agricultural production	• In agricultural production, investing in integrated waste and manure management in the continuum of production can help reduce the likelihood of AMR transmission in the environment
	Improving wastewater management in pharmaceutical manufacturing facilities	• Promoting co-operation and collaboration across different stakeholders is paramount to developing industry standards for the management of waste/wastewater in pharmaceutical manufacturing facilities and achieving high rates of compliance among manufacturers
	Improving waste collection and management in healthcare settings	• In healthcare settings, waste management, coupled with antimicrobial inventory control measures and environmental risk assessments, offer a promising avenue for interrupting AMR transmission
	Encouraging proper pharmaceutical waste disposal in households	• Drug take-back programmes can help curb the inappropriate disposal of antimicrobials in households

Long-term care is an emerging priority area for tackling AMR with a great potential for improvement

Tackling AMR and inappropriate antibiotic use in LTCFs is a key part of addressing the threat of AMR in settings other than acute care facilities more broadly. It is recognised that inappropriate antibiotic use and AMR in LTCFs are not just a problem for their residents but they can have negative consequences for the broader community, putting wider populations at risk. When staff, visitors and residents move in and out of LTCFs, so do organisms, including resistant pathogens. The movement of residents between LTCFs and acute care facilities is particularly important, as LTCFs can act as an incubator and reservoir for resistant infections. Some of the key underpinning reasons include:

- The majority of residents in LTCFs are old and frail, very often with multiple morbidities requiring the use of invasive devices. All this significantly increases the likelihood of developing hospital-acquired infections, including resistant infections (Bonomo, 2000[36]; Moyo et al., 2020[37]; Tandan et al., 2018[38]; Nicolle, 2001[39]).
- IPC practices are more difficult to implement in LTCFs than in hospital settings due to a number of issues such as longer stays, increased number of interactions between staff and patients and increased risk of cross-contamination, more limited budget for IPC policies and lower staff-to-resident ratios (Marra et al., 2018[40]; Stone et al., 2018[41]).
- In LTCFs, antibiotics are frequently prescribed for prevention rather than to treat infections. In Europe, between 54% and 96% of antibiotic prescriptions in LTCFs are given without laboratory or diagnostic testing and up to one in four antibiotic prescriptions is unnecessary or inappropriate in terms of choice and duration (Patterson et al., 2019[42]; Furuno and Mody, 2020[43]; Latour et al., 2012[44]).
- Patients in LTCFs are more likely to be infected by resistant pathogens, including multi-drug resistant organisms, than community-dwelling older adults due to the high probability of concurrence of all of the factors mentioned above (Cassone and Mody, 2015[45]).
- Surveillance and monitoring of antibiotic use and AMR in LTCFs are still limited in many countries (Haenen et al., 2019[46]) – much more than in the hospital sector – severely hindering the implementation of benchmarking and auditing practices as well as goal setting.

Residents of LTCFs show high consumption of antibiotics driving high rates of AMR

Around 5% of residents of LTCFs are under treatment with systemic antibiotics – antibiotics that impact the whole body – at any moment across OECD countries for which data are available. Data from point prevalence surveys for 25 OECD and EU countries carried out in 2016-17 show that around 1 in 20 patients were under treatment with systemic antibiotics at the time of the survey, with the share of patients, ranging from 0.7% in Lithuania to 10.5% in Denmark and Spain. This figure was similar but slightly lower in 2013-14. Analyses on a longer time perspective conclude that, over a year, about 62% of residents of LTCFs and up to 4 in 5 residents in certain OECD countries are expected to be prescribed antibiotics at least once (Raban et al., 2021[47]).

Prescription of antibiotics in LTCFs may have decreased during the COVID-19 pandemic. While there is still a paucity of data on changes in prescriptions of antimicrobials during the COVID-19 pandemic in LTCFs, data from specific studies suggest that antibiotic consumption in this setting may have decreased in 2020, compared to previous years, due to a reduction in procedures and treatments as well as potential changes in the resident population. For example, a the United States study on almost 2000 LTCFs finds a 16% reduction in overall antibiotic use between January and June 2020 – compared to the 9% seasonal decrease observed in 2019 (Gouin et al., 2022[48]).

The OECD analysis suggests that the majority of antibiotics prescribed in LTCFs are unnecessary or inappropriate. Despite it being crucial to ensure that antibiotics are used wisely, up to three in four antibiotic prescriptions in LTCFs are unnecessary or inappropriate. One of the main drivers of inappropriate prescription relates to the decision on whether a patient needs to be treated with antibiotics or not, followed by the length of the therapy. One of the key reasons behind these worrying statistics is that, in Europe, between 54% and 96% of antibiotic prescriptions in LTCFs are given without laboratory or diagnostic testing and medical decisions are not always in alignment with evidence-based guidelines (Latour et al., 2012[44]; Szabó and Böröcz, 2014[49]).

Residents of LTCFs are at high risk of developing infections that are often resistant to first-line antibiotics. In 2016-17, 3.8% of residents of LTCFs sampled for a point prevalence survey of 25 OECD and EU countries reported being affected by a hospital-acquired infection. An analysis carried out by the ECDC for a sub-group of ten European countries, all OECD members, concluded that almost one in three isolates from hospital-acquired infections among LTCF residents were resistant to first-line antibiotic treatments. The percentages of isolates resistant to first-level AMR markers in hospital-acquired infections from LTCF residents ranged from 6.8% in Finland to 42.9% in Poland (Suetens et al., 2018[50]). High levels of resistance to first-line antibiotics increase the chances of prescription of second- and third-line antibiotics, eventually driving up resistance rates for these backup therapeutic options. While no cross-country consistent analysis exists, a study in the United States suggests that, over 11 years, the percentage of *K. pneumoniae* isolates resistant to carbapenems and third-generation cephalosporins increased from 5.3% to 11.5% (Braykov et al., 2013[51]). In Italy, urine cultures from LTCF residents found a prevalence of carbapenem-resistant Enterobacteriaceae of 20% (Marinosci et al., 2013[52]).

Country response to tackling AMR in LTCFs is still limited

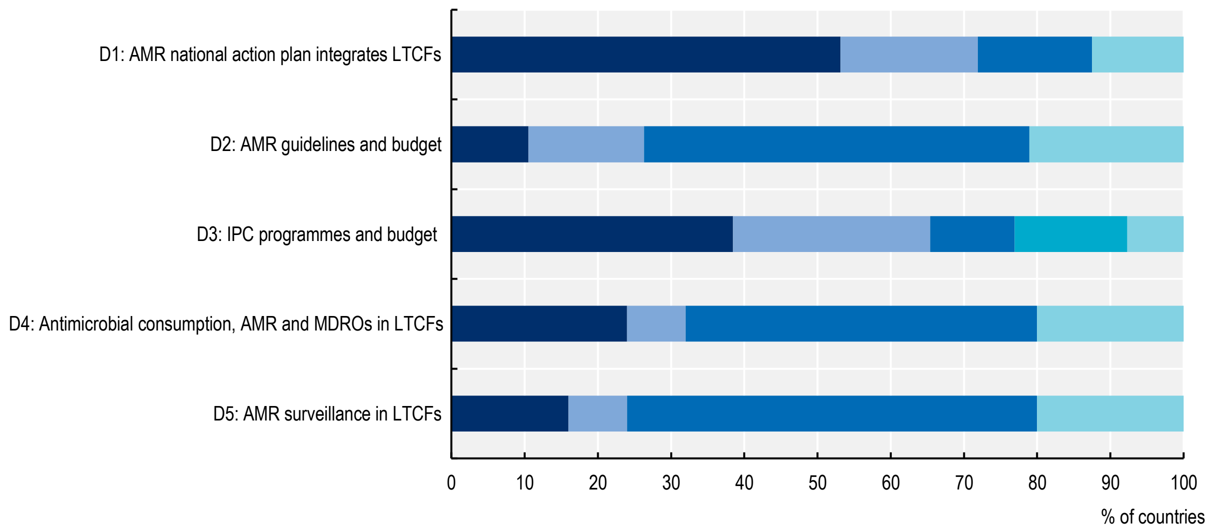
Many countries have legislation and policies to tackle AMR in LTCFs but there are important gaps in the effective use of ASPs and IPC practices. To assess the policy response to AMR in LTCFs, the OECD has rolled out a survey among member countries investigating policies in place and plans for the next steps. The survey also assessed how the COVID-19 pandemic affected the implementation of AMR policies in these settings, which was shown as one of the most critical during the pandemic (Rocard, Sillitti and Llena-Nozal, 2021[53]).

A total of 33 countries, including both OECD and EU/EEA countries, participated in the survey. Findings from the survey show a growing interest in policy making in this field (Figure 1.6). The main findings include the following:

- Just over half of reporting countries (17 out of 33 countries) have an AMR-NAP that specifically references LTCFs, while an additional 6 countries report addressing AMR in LTCFs through other legislation or programmes. Among countries reporting no policy in place, five countries confirm they plan to include references to LTCFs in their next AMR-NAP. Only 12 out of 25 reporting countries confirmed they monitor and evaluate such plans.
- Antimicrobial stewardship action is very limited with only nine countries that report having either guidelines on the use of antimicrobials in LTCFs or restrictive lists for antimicrobials. Among this group of countries, only three report a specific budget dedicated to stewardship in LTCFs. Usually, such policies are implemented at the national level but some countries instead enforce policies at the subnational or, even, institutional level. Other related interventions include training on antimicrobial prescription, antimicrobial committees and reminders with each policy generally enforced by four to five countries, most often at the national level.
- IPC measures are more likely to be implemented, with 21 countries reporting to have a programme in place, in 14 cases at the national level. However, only around 50% of the countries reporting such programmes (i.e. 11 countries) confirm that there is a dedicated budget for IPC in LTCFs. Appointment of focal points in LTCFs, specific surveillance programmes for residents with multi-drug resistant infection and training for personnel are implemented by 13-17 countries, depending on the programme.

- Surveillance is a weak spot in preventing AMR in LTCFs. Just nine countries conduct surveillance of antibiotic consumption and eight countries track AMR (either AMR or AMR for multi-drug resistant pathogens) in LTCFs. Additionally, four countries monitor AMR or multi-drug resistant pathogens but not antibiotic consumption. Implementation of policies is even less monitored, with only four countries having surveillance programmes for both IPC and stewardship interventions.

Figure 1.6. Summary findings from the OECD LTCF survey



Note: D: Dimension; MDRO: Multidrug-resistant organism.
Across all questions, the last colour indicates “no answer”, “do not know” and other responses.
For D1, dark blue indicates that AMR-NAP mentions LTCFs; light blue indicates there is no mention of LTCFs in the AMR-NAP but there are other relevant legislation and programmes; medium blue indicates that the next AMR-NAP will mention LTCFs but that the current action plan does not and there are no other relevant legislation and programmes.
For D2, dark blue indicates that there are either antimicrobial guidelines or restrictive lists for antimicrobials in LTCFs and a specific budget dedicated to LTCFs; light blue indicates that there are either antimicrobial guidelines or restrictive lists for antimicrobials in LTCFs but there is no budget dedicated to LTCFs; medium blue indicates that there are neither antimicrobial guidelines nor restrictive lists for antimicrobials in LTCFs.
For D3, dark blue indicates that there is an IPC programme and a dedicated IPC budget; light blue indicates that there is an IPC programme but no dedicated IPC budget; medium blue indicates that there is an IPC programme but whether there is a dedicated IPC budget is unknown; and the last colour indicates that there is no IPC programme.
For D4, dark blue indicates that antimicrobial consumption is being monitored as well as AMR and multi-drug resistant organisms; light blue indicates that AMR and multi-drug resistant organisms are being monitored but antimicrobial consumption is not; medium blue indicates that antimicrobial consumption is not being monitored, neither are AMR nor multi-drug resistant organisms.
For D5, dark blue indicates that there are surveillance programmes both for antimicrobial stewardship and IPC; light blue indicates that there are surveillance programmes for IPC but not for antimicrobial stewardship; medium blue indicates that there is no surveillance programme for IPC or antimicrobial stewardship.

The COVID-19 pandemic had a significant impact on policy actions related to antibiotic use and AMR in LTCFs. Predictably, the major level of disruption relates to the developing, approving or operationalising of the AMR-NAPs as infectious diseases experts in charge of this task were diverted to work on the pandemic. Among countries reporting this information, delays ranged between six months and one year but the survey was carried out before the end of the most acute phase of the pandemic so further delays may be possible. Countries also reported varying impacts of COVID-19 on ASPs (11 countries) and vaccination campaigns (10 countries). Many countries also reported a positive impact of the pandemic on the adoption of IPC components, such as hand hygiene.

Investing in better surveillance and promoting ASPs and IPC measures should be top priorities to tackle AMR in LTCFs

With all of the countries responding to the questionnaire reporting that they plan to include reference to LTCF in their next national action plan on AMR, it is clear that OECD and EU/EEA countries recognise that tackling AMR and inappropriate antibiotic use in LTCFs requires targeted policy actions. However, as illustrated in the previous section, there are a number of important gaps in the design, adoption and effective use of ASPs, IPC and surveillance in LTCFs. Policy options for countries seeking to reduce the threat of inappropriate antibiotic use and AMR in LTCFs include:

- Setting up routine surveillance systems that can collect and report data on antibiotic use and AMR in LTCFs. Routine surveillance is needed to establish a baseline situation, design policies that are fit for LTCFs and monitor and evaluate the impact of those policies.
- Promoting the design, implementation and effective use of ASP programmes that are fit for LTCFs, including more integration with prescribers (e.g. general practitioners), better feedback on antibiotic use and AMR profiles, regular training and a budget specifically dedicated to ASPs.
- Incentivising adoption and compliance with IPC practices that are tailored to LTCFs, emphasising the need for budgets specifically earmarked for IPC, the creation of IPC committees and adoption of procedures for surveillance and auditing of IPC processes in LTCFs.

Guidelines and centralised policy advice are helpful but may be insufficient to ensure change at scale. Many LTCFs face enormous challenges, from staff shortages to limited financial resources, to significant and complex demands from their residents. A survey of over 1 000 LTCFs in the United States concluded that LTCFs may not follow voluntary IPC guidelines if doing so requires significant financial investment, such as recruiting staff or investing in infrastructure (Ye et al., 2015[54]). Without appropriate financial and technical support, it is unlikely that all LTCFs will be able to implement the surveillance, ASPs and IPC protocols that can make a difference in the fight against AMR.

A combination of well-funded mandates and financial incentives may be a way forward. Financial strategies targeting healthcare providers to promote the prudent use of antibiotics have been shown to improve the appropriateness of antibiotic prescribing in various healthcare settings (Yoshikawa et al., 2021[55]). Both financial penalties and rewards can be effective and the choice of whether to use financial rewards or penalties should be informed by the context (Yoshikawa et al., 2021[55]). More research is needed on whether such strategies could work in LTCFs so pilot projects and experimentation could be useful.

Upscaling public health actions to tackle AMR offers an excellent investment with positive impacts on population health and economies

To tackle AMR, countries should upscale their efforts both by implementing new policy options and by strengthening policies currently in place. Drawing on available evidence, the OECD used its microsimulation model to assess the impact of a comprehensive set of highly effective policy actions on population health, health expenditure and the broader economy (Box 1.6). The analysis assumes that interventions are implemented at the beginning of 2021 (or the first year of the simulation period) and the impact of interventions is assessed to 2050. The analysis covers 34 OECD and EU/EEA countries for which data were available.

Box 1.6. Policy actions to tackle AMR included in the analysis

The OECD analysis covers 11 policy actions selected on a number of criteria including: i) availability of quantitative evidence to feed the OECD model; ii) consistency with actions highlighted in the AMR-GAP and featured among countries' policy priorities, as identified in the analysis of AMR-NAPs discussed in the previous section; and iii) help to bridge the current gaps in policy implementation by covering a multitude of targets and by providing a comprehensive menu of alternatives.

The modelled interventions can be implemented in hospitals, community settings and agrifood systems. As much as possible, the modelled policies are designed following international standards when available, as in the case of the WHO Core Components for IPC policies such as improving hygiene practices in healthcare settings, best practices from countries or, for more innovative policies, on available evidence discussed with experts. In line with the AMR-GAP, policies can be classified in four categories (Table 1.4), including actions to optimise the use of antibiotics in human health, to reduce the incidence of infections, to promote AMR awareness and understanding, and One Health policies to reduce the incidence of infections in agrifood systems.

Table 1.4. One Health policy actions to tackle AMR included in the analysis, by sector of implementation

Policies to optimise the use of antibiotics in human health	Policies in human health to reduce the incidence of infections	Policies to promote AMR awareness and understanding	Policies outside of human health sector to reduce the incidence of infections
Strengthen antimicrobial stewardship	Enhance hand hygiene practices	Enhance health professional training on communication skills	Improve biosecurity practices in farms
Financial incentives	Enhance environmental hygiene practices	Scale up mass media campaigns	Improve food handling practices
Delayed antimicrobial prescription	Improve vaccination coverage		
Scale up use of rapid diagnostic tests			

A brief explanation of the policies modelled can be found below, with a more comprehensive description of the evidence and the interventions' characteristics presented in Chapter 6 in Annex 6.A.

- Strengthening antimicrobial stewardship entails the scaling up of a hospital-based programme with multidisciplinary teams providing antibiotic stewardship and the monitoring of antibiotic consumption.
- Delayed antimicrobial prescription looks at the potential impact of the roll-out of antimicrobial prescribing guidelines promoting the use of delayed prescription – patients unlikely to have a bacterial infection can collect the antibiotic only a few days after the prescription – in primary healthcare settings.
- Scaling up the use of rapid diagnostic tests (RDTs) entails increasing the availability of point-of-care RDTs in ambulatory care settings in combination with antibiotic treatment guidelines.

- Using financial incentives to optimise antimicrobial use entails the implementation of a nationwide pay-for-performance programme in primary care settings by rewarding bonuses to prescribers that meet preset antibiotic prescribing targets.
- Improving hand hygiene practices involves the nationwide scale-up of a facility-based intervention in all healthcare settings that enhances the standards of hand hygiene practices among health workers.
- Enhancing environmental hygiene practices in healthcare facilities models the potential impact of the nationwide scale-up of a facility-based intervention that supplements standard cleaning strategies.
- Improving 23-valent polysaccharide vaccine (PVV23) coverage shows the potential impact of a nationwide campaign for an existing vaccine with low levels of coverage against a bacterium susceptible to developing resistance.
- Enhancing health professional training on enhanced communication skills entails the rollout of a nationwide training programme to improve communication on prudent use of antibiotics during consultations with patients in outpatient care settings.
- Scaling up mass media campaigns involves the rollout of a nationwide mass media campaign involving traditional and social media to raise AMR understanding and awareness across key stakeholders and the general population.
- Enhancing biosecurity practices in farms entails the rollout of a procurement programme facilitating farmers to buy personal protective equipment in farm settings by farmers and professional visitors like veterinarians.
- Enhancing food handling practices entails the scale-up of a food safety control training programme targeting food service workers in food establishments, coupled with visual reminders and regular audits based on checklists.

Substantial health gains may be achieved by scaling up the assessed policies

All 11 modelled interventions are estimated to reduce the number of yearly infections, with hospital-based infections offering the greatest reductions ranging from 113 000 to 298 000 resistant infections per year across the 34 countries included in the analysis.

- Among hospital-based interventions, ASPs have the highest level of effectiveness. IPC measures such as enhancing environmental hygiene and improving hand hygiene are also highly effective. Enhancing environmental hygiene and improving hand hygiene are estimated to prevent more than 123 000 and 113 000 resistant infections respectively. In addition, these two interventions can also prevent susceptible infections. On average, improving hand hygiene can help avoid an additional 392 000 susceptible infections every year whereas enhancing environmental hygiene can prevent more than 461 000 susceptible infections each year.
- Community-based interventions also lead to reductions in the number of resistant infections but at a lower level, particularly in the case of interventions that already have some grade of implementation across countries or because they target specific population groups. For example, this is the case of campaigns to increase PVV23 coverage for *Streptococcus pneumoniae*, which is often implemented, although at a sub-optimal level, across OECD countries and is targeted at the elderly population.
- Outside of the human health sector, enhancing food safety and improving farm biosecurity are both associated with reductions in the number of infections, highlighting the importance of the One Health approach. Each year, improving food safety is expected to prevent, on average, more

than 424 000 resistant and susceptible infections in humans. Improving farm biosecurity would instead avert more than 150 000 infections per year in humans.

- In line with the reductions in infections, all 11 modelled interventions are associated with reductions in AMR-related mortality. Once again, hospital-based interventions are the most effective, with the number of deaths prevented ranging more than 4 500 and 10 000 deaths per year across the 34 countries included in the analysis by preventing resistant infections. ASPs are estimated as the most effective intervention in avoiding more than 10 000 deaths per year in the elimination scenario, which is roughly equivalent to preventing around 30% of deaths due to TB, influenza and HIV/AIDS in 2020 (or the latest year for which data are available). In comparison, community-based interventions can be expected to avoid up to a maximum of 8 000 deaths per year. The EU/EEA member states in the southern part of Europe, as well as Japan, Switzerland and Türkiye, are among the countries most often showing the highest reductions in AMR-related deaths following a coverage increase of the interventions.

All of the modelled interventions increase the number of life years (LYs) lived and the number of disability-adjusted life years (DALYs), which is a measure accounting both for an increase in life expectancy and quality of life. Specifically, under the elimination scenario, the OECD SPHeP-AMR model finds that:

- When the impact of health is measured in LYs and DALYs, the ranking of the interventions from the most effective to the least effective broadly mirrors the ranking identified when considering mortality. ASPs promise the greatest gains in LYs (153 000) and DALYs (178 000), whereas IPC interventions show the highest gains in absolute terms but a significant share of such gains are derived from averting susceptible infections. For example, improving environmental hygiene, the most effective IPC intervention produces a gain of more than 206 000 LYs (including 71 000 LYs from preventing resistant infections) and more than 253 000 DALYs (including more than 83 000 DALYs from preventing resistant infections).
- Interventions implemented in community settings and One Health interventions offer lower but still significant gains. Interventions such as delaying antimicrobial prescription and scaling up the use of RDTs show significant gains both in terms of LYs (121 000 and 114 000 respectively) and DALYs (141 000 and 133 000 respectively), which places them among the most effective actions. The produced gains are lower for the remaining community-based interventions with interventions to improve biosecurity practices in farm settings offering the lowest gains.
- The effectiveness of all interventions on morbidity as measured in DALYs surpasses their effectiveness on mortality as measured in LYs saved. This means that interventions are more effective in improving the quality of life of individuals after they have developed a resistant infection than their probability of dying. One of the reasons for this finding is that many infections develop in patients aged 65 and above and such patients continue being more prone to the competing risks of mortality for other causes, even after a successful recovery from an infection.

Many interventions have a significant impact on health expenditure and are cost-saving

Investing in AMR policies can also help reduce the pressure on hospital resources and improve the resilience of healthcare services as described below:

- Interventions such as ASPs could avoid more than 3.7 million extra days spent in hospital per year across the 34 countries included in the analysis, which is equivalent to freeing up the entire acute bed capacity in Ireland in 2020 for nearly 1 year. Community-based interventions can also contribute to shorter hospital stays, with predicted impacts ranging between more than 3.1 million (delayed antibiotic prescribing) and 40 000 (increasing vaccination coverage) days of hospitalisation avoided.

- Reductions in the number of days that patients spend in hospital due to a lower incidence of resistant infections translate into savings in health expenditure. IPC interventions such as improving environmental hygiene and hand hygiene practices promise the greatest impacts by eliminating both resistant and susceptible infections, with yearly savings across the 34 countries included in the analysis estimated at nearly USD PPP 7.2 billion (corresponding to USD PPP 6.3 per capita) and more than USD PPP 6 billion (corresponding to USD PPP 5.3 per capita) respectively. Scaling up ASPs is also expected to reduce health expenditure by more than USD PPP 2.7 billion annually, corresponding to USD PPP 1.2 per capita. This is roughly equivalent to 10% of healthcare spending in Greece in 2020.
- Broadly, countries with higher incidences of resistant infections stand to achieve the greatest reductions in health expenditure by investing in the modelled interventions. For instance, Italy can reduce health expenditure by USD PPP 9.9 per capita per year by investing in improved hand hygiene practices.

All of the interventions show the potential to increase workforce participation and productivity

All of the modelled policy interventions yield productivity gains that can be achieved primarily through increasing workforce participation, followed by reducing absence from work due to ill health and presenteeism at work. Scaling up ASPs is associated with the highest estimated gains in productivity. On average, this intervention is estimated to generate close to 67 000 FTEs per year combined across the 34 countries included in the analysis. Of these potential gains, more than 56 000 FTEs are expected to be produced through increased participation in the workforce while more than 9 300 FTEs can be gained by reducing absenteeism. Combined, these productivity gains would amount to around USD PPP 3.9 billion (corresponding to USD PPP 3.5 per capita) each year across all of the countries included in the analysis. In many countries, the estimated productivity gains exceed savings in health expenditure.

All of the interventions are affordable and, in the majority of cases, the return on investment is significantly greater than the implementation costs

The average annual cost of implementing the assessed interventions varies between USD PPP 0.2 to USD PPP 2.6 per capita. These are all affordable investments, given the level of income of the assessed countries, corresponding only to a fraction of the healthcare budget of these countries. Using financial incentives to optimise antimicrobial use has the highest estimated annual implementation cost per capita, given that the intervention includes a rewarding bonus corresponding to 1% of the base salary of medical practitioners in primary care that achieves a preset antibiotic prescribing target. For ASPs, expenses associated with building multidisciplinary stewardship teams, which include both salaries and training expenses, are the main cost drivers. Enhancing environmental hygiene and increasing the use of RDTs are, respectively, the third and fourth most expensive interventions, mainly due to the cost of purchasing all of the disposables needed to upscale the implementation of the interventions. The costs associated with implementing other interventions each average below USD PPP 1 per capita. Improving vaccination coverage has the lowest estimated annual cost of implementation per capita.

Gains produced by upscaling the implementation of policies to tackle AMR are substantially higher than their implementation costs when both savings in healthcare expenditure and gains in workforce productivity are considered (Figure 1.7). Across the 34 countries included in the analysis, the average implementation annual costs associated with improving hand hygiene are expected to be around 24.6 times lower than the savings generated by estimated reductions in health expenditures and productivity gains made through increased participation in the workforce and productivity at work. Scaling up delayed prescription practices in primary healthcare settings is another highly attractive intervention, with a benefit to cost ratio of around 17. The average annual cost of scaling up each of these interventions across all countries included in the analysis is around five times lower than the expected savings from reducing health expenditure and productivity gains.

Figure 1.7. Health and economic impacts of interventions to tackle antimicrobial resistance

Average per year for the period 2020-50,* 34 countries included in the analysis

Interventions and packages	DALYs gained per year (per 100 000 population)	Health expenditure saved per year (per capita USD PPP)	Additional full-time workers per year (in thousands of workers), total	Return on investment (USD PPP)
Enhance farm biosecurity	897	0.001	1 414	1.0
Improve PVV23 coverage	2 927	0.033	1 316	2.4
Enhance food handling practices	3 096	0.004	4 427	5.2
Financial incentives	33 264	0.617	15 255	0.5
Improve prescriber education and training	40 021	0.688	17 066	4.5
Mass media campaigns	42 598	0.771	19 321	2.8
Improve hand hygiene	78 153	1.054	26 843	24.6
Enhance environmental hygiene	83 030	1.206	29 213	5.0
Scale up the use of RDTs	133 648	2.484	54 299	4.0
Delayed prescription	141 488	2.642	57 311	17.2
Strengthen antimicrobial stewardship	178 894	2.854	66 580	2.3
Community-based package	308 780	2.241	129 912	2.5
Mixed package	556 795	5.913	222 916	5.0
Hospital-based package	618 875	7.871	242 694	4.7

Note: * For some countries, the first year of analysis is earlier than 2020 depending on the availability of historical data. The figure above presents health and economic outcomes attributable to each policy under the replacement scenario. Estimates for the return on investment are the result of the total savings in healthcare expenditure and productivity gains in the 34 countries produced by the policy divided by the total cost of implementing the policy.
Source: OECD analyses based on the OECD SPHeP-AMR model.

Combining policies into a coherent prevention strategy helps countries reach a critical mass with a greater impact

Policy packages offer important advantages over implementing single policies. By scaling up policies as packages, multiple drivers of AMR can be addressed at the same time. Policy packages can also target different population groups and sectors simultaneously while facilitating and reinforcing desirable changes in behaviour. Combined, the potential protective effects of policy packages can go beyond simply adding up the effectiveness of each intervention (i.e. super-additivity of policy packages). Across all modelled policy packages, the elimination scenario was used for interventions that impact antibiotic prescription patterns. The OECD analysis evaluated the effectiveness and cost-effectiveness of three policy packages:

- The **hospital-based** package includes improving hand hygiene, enhancing environmental hygiene and scaling up ASPs, and has an estimated per capita cost ranging between USD PPP 1.4 and USD PPP 9.4.

- The **community-based** package includes delayed antimicrobial prescriptions, introducing financial incentives to optimise antimicrobial use, scaling up the use of RDTs, scaling up mass media campaigns and scaling up prescriber training, and has an estimated cost ranging between USD PPP 0.8 and USD PPP 11.9 per capita.
- The **mixed** package includes improving hand hygiene, scaling up ASPs, delaying antimicrobial prescription, increasing mass media campaigns and enhancing food handling practices and has an estimated cost ranging between USD PPP 0.7 and USD 3.7 per capita.

Results from the OECD SPHeP-AMR model suggest that the choice of the policy packages has important implications:

- The results suggest that the different packages respond to different policy objectives and priorities. For example, depending on their own resistant infection burden, countries may choose to prioritise tackling AMR in hospitals or the community. The hospital-based package shows the highest impact on population health and the economy but the mixed package avoids the highest number of infections, many of which are in the community.
- Another important implication of the OECD analysis is that hospital infections tend to be more costly to treat and more likely to lead to fatal outcomes. Consistently, the hospital-based package shows the highest impact across multiple outcomes, including life expectancy, quality of life and healthcare costs. At the same time, the average implementation cost for this package tends to be higher than for the mixed package.
- Third, a high number of infections develops in the community but health outcomes from these infections are generally milder compared to those from HAIs, particularly in the case of foodborne diseases. This explains the significantly higher impact of the mixed package on the number of infections but its lower – nevertheless significant – impact on morbidity-related dimensions.
- Finally, the lower but still considerable impact of community-based interventions should not discourage investments given that many of the interventions included in this package help reinforce the implementation and effectiveness of the other two packages while preventing hospitalisations, which can expose people to the risk of HAIs.

More in detail, the OECD model quantifies that the three packages produce the following yearly impact across the 34 countries included in the analysis:

- The mixed package had the highest impact in terms of reducing the number of resistant infections (more than 1.6 million per year), followed by the hospital- (around 1.3 million) and community-based packages (more than 900 000 infections).
- The hospital-based package prevents the highest number of deaths (more than 33 000 per year) compared to the mixed package (around 30 000) and the community package (more than 17 000). In effect, the hospital package would prevent a number of deaths equivalent to preventing all deaths due to TB, influenza and HIV/AIDS in 2020 (or the nearest year for which data is available).
- The hospital-based package also produces the highest gains in terms of LYs (more than 511 000) and DALYs (more than 618 000). The mixed package also offers important health gains amounting to more than 466 000 LYs and 557 000 DALYs. The community-based package is expected to generate gains equivalent to nearly 263 000 LYs and 308 000 DALYs per year.
- The hospital-based package is estimated to have the greatest impact on health expenditures, saving more than USD PPP 11 billion each year (or USD PPP 9.8 per capita), roughly corresponding to half of all health spending in the Czech Republic in 2020. The mixed package would save USD PPP 9.4 billion (corresponding to USD PPP 8.3 per capita) while USD PPP 5.3 billion (corresponding to USD PPP 4.7 per capita) would be saved by the community-based package.

- The hospital-based package is predicted to yield the greatest productivity gains amounting to USD PPP 14.9 billion (corresponding to USD PPP 13.2 per capita). In comparison, the mixed package is expected to produce productivity gains amounting to around USD PPP 13.8 billion (corresponding to USD PPP 12 per capita).
- The average cost of implementing the mixed package is around five times lower than the estimated benefits accrued through the reduction in health expenditure and productivity gains. This is followed by the hospital-based and community-based packages where the potential benefits are around 4.7 and 2.5 times that of the cost of implementing these packages respectively.

Conclusion: Tackling AMR remains a top public health priority with important health and economic consequences

Tackling antimicrobial resistance is widely acknowledged as a top public health priority with important implications for population health and the economies of the OECD countries and EU/EEA countries. There has been a significant global effort to scale up a wide array of policy interventions in line with the AMR-GAP since the last OECD analysis in 2018. The new OECD analysis suggests that these efforts may have borne fruit in terms of limiting the health and economic burden of AMR. Yet, important gaps persist in policy action against AMR. The current and projected health impact of AMR remains high, with important cross-country variation. Mirroring the health burden, the cost of AMR to health systems and economies remains worrisome. The real burden of AMR to society is likely to be substantially greater considering its impact on non-human health sectors such as the environment and animal health, for which assessments are ongoing (OIE, 2023[56]).

The OECD analysis demonstrates that more can be achieved by investing in policies in line with the One Health approach. To tackle AMR, policy makers can choose from a wide range of options across sectors. In the human health sector, hospital-based interventions such as scaling up ASPs and improving environmental hygiene and hand hygiene yield important health and economic gains. Community-based interventions are also effective interventions. Beyond the human health sector, the OECD analysis highlighted that enhancing farm biosecurity and improving food handling practices can yield reductions in the number of reduction infections and prevent deaths while resulting in savings in healthcare expenditures and improving workforce participation and productivity.

Investments in policy packages that combine individual interventions can potentially save thousands of lives and yield sizeable savings that far exceed implementation costs. The mixed package promises the highest impact in terms of reducing the number of resistant infections whereas the hospital-based package prevents the highest number of deaths. The implementation of all three policy packages assessed by the OECD can more than make up for their costs.

The OECD analysis underlines the importance of adopting a One Health approach. For example, the simulations show that every USD PPP 1 invested in a mixed policy package that brings together policies which could be implemented in healthcare and community settings as well as in the agriculture and food sectors can return USD PPP 5 in economic benefits. Combined, results from the OECD analysis demonstrate that policy action that is grounded in the One Health approach offers excellent investments to tackle AMR.

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Notes

[1] DDD is a standard measure for drugs, calculated as the assumed average maintenance dose per day for a drug used for its main indication in adults (WHO, 2003[59]). The unit used throughout this chapter is DDD per 1 000 inhabitants per day.

[2] 2020 data were not used to feed the analysis due to their preliminary status and limited geographical coverage.

[3] As part of the Model Lists of Essential Medicines, the WHO Access, Watch, Reserve or AWaRe classification of antibiotics is a tool to improve the use of antibiotics and has the ultimate goal of reducing antimicrobial resistance. The tool classifies 180 antibiotics (WHO, 2022[58]). *Access* antibiotics are mostly first-line and second-line therapies with lower resistance potential than other antibiotics. *Watch* antibiotics have higher AMR potential and should be prioritised in stewardship and monitoring efforts. Watch antibiotics include most of the highest-priority agents in the WHO *Critically Important Antimicrobials for Human Medicine* (WHO, 2019[57]). *Reserve* antibiotics include antibiotics of last resort and should be saved for treatment of confirmed or suspected infections due to multi-drug-resistant organisms.

[4] Broad-spectrum antibiotics include: broad-spectrum penicillins (ATC groups J01CR, J01CD), broad-spectrum cephalosporins (J01DC, J01DD), macrolides (J01 FA) except erythromycin (J01FA01), and fluoroquinolones (J01MA); and narrow-spectrum antibiotics such as narrow-spectrum penicillins (J01CA, J01CE, J01CF), narrow-spectrum cephalosporins (J01DB) and erythromycin (J01FA). Consumption expressed in DDD per 1 000 inhabitants per day.

[5] Twelve priority antibiotic-bacterium combinations included in the analysis are vancomycin-resistant *Enterococcus faecalis* (*E. faecalis*), vancomycin-resistant *E. faecium,* third-generation cephalosporin-resistant *E. coli*, carbapenem-resistant *K. pneumoniae*, third-generation cephalosporin-resistant *K. pneumoniae*, carbapenem-resistant *Pseudomonas aeruginosa* (*P. aeruginosa*), meticillin-resistant *S. aureus*, penicillin-resistant *Streptococcus pneumoniae* (*S. pneumoniae*), fluoroquinolone-resistant *A. baumannii*, carbapenem-resistant *A. baumannii*, fluoroquinolone-resistant *E. coli* and carbapenem-resistant *E. coli*.

2 Trends and patterns in antibiotic use and antimicrobial resistance

This chapter presents trends and patterns in antibiotic consumption and antimicrobial resistance (AMR) from a One Health perspective for up to 52 countries including OECD countries, OECD accession and selected partner countries, Group of 20 (G20) countries and European Union (EU) and European Economic Area (EEA) member states. The chapter looks at historical data, presenting projections on AMR proportions for up to 2035 for 12 priority antibiotic-bacterium combinations and lines of antimicrobial treatment. Finally, it analyses the latest evidence to shed some light on the impact of the COVID-19 pandemic on AMR.

Key findings

- Between 2000 and 2019, on average across OECD countries, sales of all classes of antibiotics increased slightly from 21.4 to 21.8 defined daily doses (DDD) per 1 000 inhabitants per day. The levels and trends across individual countries were very heterogeneous. In more recent years, between 2016 and 2019, there have been reductions in total antibiotic consumption in most European countries. In G20 countries, the average trend shows a convergence, over the last two decades, towards OECD levels of antibiotic use, indicating significant increases in countries like Brazil, China, India, Indonesia and Saudi Arabia.
- In line with recent trends in Europe and should total antibiotic consumption continue to evolve along the same lines as in the period 2000-15, it is projected that consumption will decrease between 2015 and 2035 by 3% in the OECD. However, consumption of the highest priority and third-line antibiotics, like carbapenems, is projected to increase, albeit from currently low levels. The impact of COVID-19 remains unclear and antibiotic consumption may not follow along with the previous trends due to the pandemic.
- Over the last two decades, on average across OECD countries, sales of all classes of antimicrobials used in chicken, cattle and pig systems, adjusted for total production and importation of meat products, are estimated to have halved, with most of the decrease taking place from around 2014 in the OECD and 2010 in the EU/EEA member states. Reductions in antimicrobial consumption in animals per animal biomass have been driven by both reductions in total antimicrobial consumption and increases in food animal biomass.
- If downward trends in OECD and EU/EEA persist in the future, these regions could see further reductions in antimicrobial consumption in food animals per animal biomass. Consumption could decrease an estimated 10% in the OECD and 12% in the EU/EEA by 2035 compared to 2020 while stabilising in the G20 at 2020 levels.
- It is estimated that, in 2019, resistance proportions, averaged across 12 priority antibiotic-bacterium combinations, were 20% in OECD countries, 22% in the EU/EEA and 30% in the G20. Average resistance proportions, across all 12 antibiotic-bacterium combinations, in 2019, differed considerably: Denmark and Norway had the lowest estimated average resistance proportions, almost 6%, while in Greece and Türkiye, more than 44% of infections were estimated to be due to resistant bacteria. India had estimated average resistance proportions in excess of 55%. For some antibiotic-bacterium combinations, over 95% of infections were from resistant bacteria in the countries with the highest resistance proportions.
- Based on new historical data on resistance proportions and correlates of AMR, it is projected that between 2019 and 2035, resistance proportions, averaged across 12 priority antibiotic-bacterium combinations, will remain mostly flat if current trends in resistance, and correlates of resistance, continue into the future and no other policy actions are taken beyond the ones currently in place. A stabilisation of average resistance proportions at 2019 levels is also projected for EU/EEA countries and G20 countries. These estimates should be interpreted with caution, given the fundamental uncertainty surrounding the impact of the COVID-19 pandemic.
- Despite a projected overall stabilisation of resistance proportions, for certain countries (e.g. Greece, India, Türkiye) and antibiotic-bacterium pairs, resistance is projected to remain dangerously high. Furthermore, it is projected that the range between the countries with the most resistance and those with less resistance will slightly widen in 2035, indicating countries on the higher end of the range (e.g. Greece and Türkiye) need to do more to reverse current trends, or they will continue to face persistently high resistance. And more can be done. In the context of limited new antibiotics reaching the market, older antibiotics may be a useful resource

yet older antibiotics are often not available in countries. Also, studies have shown that increases in vaccination coverage for influenza are associated with declines in antibiotic prescribing but average vaccination rates in the OECD have actually dropped between 2008 and 2018.

- Finally, gaps in the collection and reporting of comprehensive, internationally comparable, standardised data on antimicrobial consumption and resistance make it more difficult to understand the AMR challenge, its consequences, evolution and whether actions to tackle the challenge are effective. Modelling is helpful but it is not a substitute for comprehensive high-quality surveillance and should not detract from efforts to expand and improve surveillance networks, especially from a One Health perspective.

Introduction

In recent years, there have been multiple calls to action to stem the rise of superbugs. These calls have pointed to the catastrophic impact of AMR and its present as well as future health and economic burden. The threat of a post-antibiotic world has driven multiple policy initiatives, from actions seeking to curtail the use of antimicrobials for the growth promotion of food animals, to antibiotic stewardship in human health, to infection and prevention control. An influential driver for action was provided by the publication, in 2016, of the widely cited Review on Antimicrobial Resistance, which projected that 10 million lives would be lost every year due to AMR infections by 2050 (Review on Antimicrobial Resistance, 2016[1]). Beyond the health burden, there could be serious economic costs by 2050, estimated at 3.8% of annual gross domestic product (GDP), USD 1.2 trillion annually in additional healthcare spending and 28 million more people in extreme poverty (World Bank, 2017[2]).

The OECD *Stemming the Superbug Tide* report (2018[3]) highlighted the huge benefits of early and comprehensive action to tackle AMR. The report also pointed out that, under a business-as-usual scenario in which no policy changes were made, resistance proportions, averaged across 8 priority antibiotic-bacterium combinations, could increase by 1 percentage point between 2015 and 2030 (OECD, 2018[3]). Not only did there seem to be a slowing down of the growth rate of resistance proportions for the period 2015-30 compared to the period 2005-15 but also there was very broad heterogeneity in the estimated trends, from significant increases to decreases in resistance proportions, depending on the country-antibiotic-bacterium combination. One of the key contributions of the report was to highlight that AMR was not a public health threat that all countries could tackle in the same way by focusing on one or two antibiotic-bacterium combinations. Rather the challenge was multifaceted, spanning numerous antibiotic-bacterium combinations, with levels and trends of antimicrobial use and resistance widely disparate across countries and antibiotic-bacterium combinations, and very different drivers of resistance across countries.

As new data have become available, it is timely to assess progress in curtailing the threat of inappropriate antimicrobial consumption, and the emergence and spread of AMR. This chapter starts by discussing recent developments in international data collection on antimicrobial use and resistance and presents new trends in antimicrobial use and concentrations in humans, animals and the environment. Next, it shows new data and estimates of historical and future resistance proportions for 12 priority antibiotic-bacterium combinations. Naturally, it is impossible to address the topic of AMR without mentioning another infectious disease with serious health and economic costs: COVID-19. As discussed below, the impact of COVID-19 on AMR remains to be seen for a number of reasons, yet it is clear that the pandemic has had both positive and negative effects on the emergence and spread of drug-resistant pathogens. As time passes, the net effects should become clearer, though there is a risk that important data may not have been collected as attention turned to the health emergency.

A One Health approach to global surveillance is slowly developing

In May 2016, the final report and recommendations of the Review on Antimicrobial Resistance called for global surveillance of antimicrobial consumption and resistance, both in humans and animals, specifically along three strands (Review on Antimicrobial Resistance, 2016[1]): i) on consumption in both animals and humans; ii) on resistance proportions of bug-drug combinations as well as their health effects on humans; and iii) on molecular biological data of the types of resistant bacteria and the genetic reasons for their resistance. Less than one year before, in October 2015, the World Health Organization (WHO) established the Global Antimicrobial Resistance and Use Surveillance System (GLASS) as the first global system to collect official national AMR data for selected bacterial pathogens causing common infections in humans (WHO, 2020[4]). As of April 2020, 92 countries, territories and areas were enrolled in GLASS: 91 in the AMR surveillance module (GLASS-AMR) and 9 in the antimicrobial consumption surveillance module (GLASS-AMC), which was launched in 2019 (WHO, 2020[4]).

Enrolment data from December 2020[1] show that 21 OECD countries, 16 G20 countries and 19 EU/EEA countries are enrolled in GLASS-AMR. Indeed, according to Wellcome (2020[5]), relative enrolment in GLASS of low-income countries (42%) and lower-middle-income countries (47%) is higher than relative enrolment of high-income countries (3%) and upper-middle-income countries (27%). Despite close collaboration between GLASS and AMR regional networks, among them the European Antimicrobial Resistance Surveillance Network (EARS-Net), only 19 of the 29 EARS-Net countries[2] are enrolled in GLASS-AMR. Similarly, 29 EU/EEA countries are enrolled in the European Surveillance of Antimicrobial Consumption Network (ESAC-Net),[3] yet only 9 countries globally were enrolled in GLASS-AMC in April 2020.

While there has been undeniable progress, gaps remain in the scope and quality of the data provided to GLASS. In 2019 alone, GLASS received data on specimens from 2 365 972 infected patients, 5 551 hospitals and 56 808 outpatient clinics (WHO, 2020[4]). However, experts are concerned by the highly variable quality of the data, including in the numbers of pathogens screened for and submitted isolates, but also the selection of priority pathogens and potential hospital bias in sampling (Wellcome, 2020[5]). There are undoubtedly important challenges to establishing international AMR surveillance networks, including factors related to the communities involved, the hospitals and clinics, the laboratories and the aggregation and reporting of data from different stakeholders (OECD, 2018[3]). Other constraints are due to national policies and agendas, difficult logistics, lack of resources and problems of data management (WHO, 2020[4]).

One overarching challenge is that AMR is actually an umbrella term that includes many different types of drug resistance. Resistance is typically reported in terms of classes of microorganisms and antimicrobial agents (e.g. third-generation cephalosporin-resistant *Enterobacterales*) but in the laboratory, resistance is defined and measured at the level of a specific microorganism (e.g. *Klebsiella pneumoniae [K. pneumoniae]*) and a specific antimicrobial drug (e.g. ceftriaxone, which is a third-generation cephalosporin). Collecting and aggregating international data on resistance across multiple antibiotic-bacterium combinations is thus not straightforward. Even in the most advanced countries, coverage is uneven. For example, in Europe, just 23 out of 37 countries had a surveillance system for reporting carbapenem-resistant *Acinetobacter baumannii (A. baumannii)*, 15 had national recommendations or guidelines for its control and 8 countries had a national plan for its containment (Lötsch et al., 2020[6]). In another example, in Canada, only eight hospitals from six of ten provinces are able to provide resistance data for clinically relevant bacteria (e.g. *Staphylococcus aureus [S. aureus]*) for the period 2007-16 (Lagacé-Wiens et al., 2019[7]).

In the animal sector, there is yet no global framework for the comparable collection, analysis and dissemination of AMR data in animals. In Europe, the European Food Safety Authority (EFSA) co-ordinates mandatory active monitoring of AMR in bacteria (e.g. *Salmonella*, *Campylobacter* and *Escherichia coli [E. coli]*) from healthy food-producing animals and food derived from those animals (Mader et al., 2021[8]). Mader and colleagues (2021[8]) from the EU Joint Action on Antimicrobial Resistance and Healthcare-Associated Infections (EU-JAMRAI) have recently proposed creating EARS-Vet to monitor antimicrobial consumption and resistance in animals, in the same way that EARS-Net and ESAC-Net monitor consumption and resistance in humans. This would go a long way towards reducing the heterogeneity in current monitoring efforts (Schrijver et al., 2018[9]).

With respect to consumption in animals, the World Organisation for Animal Health (WOAH), supported by the United Nations (UN) Food and Agriculture Organization (FAO) and the WHO within the tripartite collaboration, launched in October 2015 a global database on antimicrobial agents intended for use in animals. In its fourth and latest round of data collection, 153 countries participated in the questionnaire, 118 provided quantitative data, 111 of which for only 1 year between 2016 and 2018 (OIE, 2020[10]). At this stage, the WOAH is still reporting data at the regional level, as it continues to assess data validity and robustness. Unlike GLASS, European participation in the WOAH database is largely aligned with participation in the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) project, which collects information on how antimicrobial medicines are used in animals across the EU. The ESVAC project was started by the European Medicines Agency in January 2010, and while participation is voluntary, it has increased since 2010 from 9 to 31 countries. From 2024, EU Regulation 2019/6 has made it mandatory for EU countries to provide antimicrobial use data by animal species (Mader et al., 2021[8]).

There are no formal standardised global efforts to measure antimicrobial concentrations or antimicrobial-resistant bacteria and genes in the environment, specifically in plants and crops, as well as soil and water systems. In the EU, since 2015, member states should monitor surface waters for potential water pollutants included in a watch list, as part of the Water Framework Directive (OECD, 2019[11]). The watch list, which is reviewed every two years and is now in its 3rd version, includes amoxicillin, ciprofloxacin, sulfamethoxazole, and trimethoprim (Gomez Cortes et al., 2020[12]). Three macrolide antibiotics (erythromycin, clarithromycin, azithromycin) that featured in the 1st and 2nd watch list were dropped in 2019, as monitoring is not supposed to exceed four years. In a recent technical brief on the role that water, sanitation and hygiene (WASH) play in the emergence and spread of AMR, the WOAH, FAO and WHO proposed that surveillance in wastewater be incorporated into national surveillance activities and that surveillance mechanisms and regulatory authorities for wastewater aspects of AMR should be strengthened (OIE/FAO/WHO, 2020[13]).

Modelling can help fill gaps but it is not a substitute for surveillance

In the absence of comprehensive, internationally comparable, standardised data on antimicrobial consumption and resistance, researchers have turned to various types of modelling to fill surveillance gaps and inform decision and policy making. Different modelling approaches have been used to estimate global trends for antimicrobial consumption in humans (Klein et al., 2018[14]), AMR in humans (Cravo Oliveira Hashiguchi et al., 2019[15]; Oldenkamp et al., 2021[16]; Hendriksen et al., 2019[17]), antimicrobial consumption in animals (Tiseo et al., 2020[18]; Schar et al., 2020[19]), and AMR in animals (Van Boeckel et al., 2019[20]). Another set of studies used expert elicitation methods to derive estimates on AMR in humans (Colson et al., 2019[21]) and attribution of foodborne diseases to specific foods (Hoffmann et al., 2017[22]).

Either explicitly (in statistical modelling) or implicitly (in expert elicitation), modelling methods are essentially making use of posited or empirical associations between variables for which there are ample historical data (e.g. indicators of economic development, experts' own observations in the field) and antimicrobial consumption and resistance, for which data are scarcer, to fill gaps in surveillance (Box 2.1). Modelling can be useful when data are unavailable or are difficult to compare without manipulation. However, modelling is not a substitute for comprehensive high-quality surveillance and should not detract from efforts to expand and improve surveillance networks. Data-driven models of AMR have limited explanatory power (OECD, 2018[3]) and the relationships the models are based on may be changing over time, or be simply biased by the lack of data on certain bug-drug pairs, countries, species or all of these.

Box 2.1. Modelling methodology used to estimate antimicrobial consumption and resistance

Updates to methodology and new sources of data aligned with a One Health approach

As in the OECD (2018[3]) report titled *Stemming the Superbug Tide: Just a Few Dollars More*, historical and future antimicrobial consumption and resistance were estimated using a combination of statistical techniques making use of as much publicly available, internationally comparable, data as possible, while explicitly incorporating uncertainty in the underlying data, models and assumptions. As before, missing data were imputed using best guesses from theoretically hypothesised and empirically-tested relationships with correlates (Harbarth and Samore, 2005[23]; Byarugaba, 2004[24]; Chatterjee et al., 2018[25]; Holmes et al., 2016[26]). The methodology was updated to reflect best practices in predictive modelling, like the use of cross-validation to select most predictive models (Kuhn and Johnson, 2013[27]) and newly available data and estimates were included, especially new sources relevant from a One Health perspective.

Historical data on antimicrobial consumption and resistance in humans were collected from the Center for Disease Dynamics, Economics & Policy's ResistanceMap, as in the previous report (OECD, 2018[3]). These data were complemented with historical time series for a wide range of indicators (from health and sanitation to agricultural and livestock production) collected from databases of the World Bank, the WHO, the FAO, the European Centre for Disease Prevention and Control (ECDC), the UN World Population Prospects (UN WPP), the UN Development Programme Human Development Database (UNDP-HDD), the United States Department of Agriculture (USDA), the Institute for Health Metrics and Evaluation (IHME) and the OECD's databases. Forecasts for economic growth (USDA), population (UN WPP), health spending (IHME) and antimicrobial consumption in animals (Tiseo et al., 2020[18]; EMA, 2020[28]) were also collected. Whenever multiple sources of data on the same indicator were available, the source with the most comprehensive geographical and temporal coverage was chosen.

Besides the eight antibiotic-bacterium combinations (third-generation cephalosporin-resistant *E. coli*, fluoroquinolones-resistant *E. coli*, penicillin-resistant *Streptococcus pneumoniae (S. pneumoniae)*, methicillin-resistant *S. aureus* (MRSA), carbapenem-resistant *K. pneumoniae*, third-generation cephalosporin-resistant *K. pneumoniae*, carbapenem-resistant *Pseudomonas aeruginosa (P. aeruginosa)*, and vancomycin-resistant *Enterococcus faecalis* (*E. faecalis)* and *Enterococcus faecium (E. faecium*) included in *Stemming the Superbug Tide* (OECD, 2018[3]), carbapenem-resistant *A. baumannii* and fluoroquinolones-resistant *A. baumannii* were also included. Complete estimates of resistance proportions were produced for 51 OECD (including partner countries) and G20 countries from 2000 to 2035, with uncertainty intervals.

The modelling framework is broadly the same as that used in *Stemming the Superbug Tide* (2018[3]), with multiple imputations of missing historical values using a large dataset of covariates (and priors whenever feasible), forecasting of antibiotic consumption in humans using exponential smoothing, forecasting of resistance proportions using an ensemble of three equally weighted models (a mixed-effects linear regression, exponential smoothing with an additive damped trend and a random forest), and incorporation of uncertainty from imputation of missing values, model selection and specification, and some model parameters. As before, the forecasts do not incorporate any potential future policy action or intervention. Methodological updates have focused on the parameterisation of the random forest, optimising hyperparameters using cross-validation (Kuhn and Johnson, 2013[27]) as well as a more exhaustive search of specifications for the mixed-effects linear regression.

There are limited data collected during COVID-19 to inform the trends shown in this report

Most publicly available and internationally comparable datasets available today do not include numbers for 2020 or 2021. As such, it is not yet possible to quantitatively assess the impact of COVID-19 on both antibiotic consumption and AMR at an international level. While the WHO is confident that GLASS will provide important insights once the pandemic subsides (Hsu, 2020[29]), there is also concern from experts that COVID-19 may be undermining surveillance, monitoring and evaluation efforts. Interviews conducted by Wellcome (2020[5]) show that, as attention turned almost exclusively to COVID-19, hospital surveillance activities, like the Global Point Prevalence Survey, have been "almost completely abandoned", while many five-year national action plans that were now entering the evaluation and updating phase may risk being deprioritised.

To project resistance proportions for the next 13 years in this context is naturally very challenging. If the pre-pandemic patterns observed resume in the short term, then the estimates presented here are well-founded. If, on the other hand, COVID-19 constitutes a paradigm shift with a longer-term impact, then any projection of resistance proportions today will be subject to substantial fundamental uncertainty. As new data become available in the next months and years, it will become clearer what impact COVID-19 will have and estimates can be updated to reflect the most up-to-date information.

Note: See Hashiguchi et al. (2019[30]), "Resistance proportions for eight priority antibiotic-bacterium combinations in OECD, EU/EEA and G20 countries 2000 to 2030: a modelling study", https://doi.org/10.2807/1560-7917.ES.2019.24.20.1800445. ResistanceMap aggregates data from international surveillance networks like the EARS-Net, the Central Asian and Eastern European Surveillance of Antimicrobial Resistance (CAESAR), GLASS and others, which in turn aggregate data from national surveillance networks.

Source: OECD (2018[3]), *Stemming the Superbug Tide: Just A Few Dollars More*, https://doi.org/10.1787/9789264307599-en; Harbarth, S. and M. Samore (2005[23]), "Antimicrobial resistance determinants and future control", https://doi.org/10.3201/eid1106.050167; Byarugaba, D. (2004[24]), "Antimicrobial resistance in developing countries and responsible risk factors", https://doi.org/10.1016/J.IJANTIMICAG.2004.02.015; Chatterjee, A. et al. (2018[25]), "Quantifying drivers of antibiotic resistance in humans: A systematic review", https://doi.org/10.1016/S1473-3099(18)30296-2; Holmes, A. et al. (2016[26]), "Understanding the mechanisms and drivers of antimicrobial resistance", https://doi.org/10.1016/S0140-6736(15)00473-0; Kuhn, M. and K. Johnson (2013[27]), *Applied Predictive Modelling*; https://doi.org/10.1007/978-1-4614-6849-3; Tiseo, K. et al. (2020[18]), "Global trends in antimicrobial use in food animals from 2017 to 2030", https://doi.org/10.3390/antibiotics9120918; EMA (2020[28]), *Sales of Veterinary Antimicrobial Agents in 31 European Countries in 2018: Trends from 2010 to 2018, Tenth ESVAC Report*, European Medicines Agency, European Surveillance of Veterinary Antimicrobial Consumption; Hsu, J. (2020[29]), "How COVID-19 is accelerating the threat of antimicrobial resistance", https://doi.org/10.1136/bmj.m1983; Wellcome (2020[5]), *The Global Response to AMR: Momentum, Success, and Critical Gaps*, https://wellcome.org/sites/default/files/wellcome-global-response-amr-report.pdf.

Trends in antibiotic consumption, sales and concentrations

Antibiotics play a crucial role in modern medicine. Since their discovery, they have not only been instrumental in the treatment of infections but have also made possible the development and everyday use of invasive surgical procedures and complex medical interventions, from organ transplantations to treatment of cancers to care of premature neonates (Cecchini and Lee, 2017[31]). There is no doubt that antibiotics have significantly improved population health.

While they are often called "miracle drugs", antibiotics are not infallible. The use of antibiotics exerts selective pressure on microorganisms and invariably leads to AMR, as pathogens develop or acquire mechanisms that allow them to survive and reproduce in environments where antibiotics are present. Historically, it can take only a few years following the discovery of a new antibiotic for bacteria to develop resistance against that antibiotic (OECD, 2018[3]). The more antibiotics are used, the less effective they become. It is vital that antimicrobials be used wisely. When antimicrobials are inappropriately used, there is likely to be very little clinical value for the patient or animal being treated, despite the negative consequence of the emergence of resistance. The benefits of using antibiotics need to be compared with the costs of drug resistance (Cecchini, Langer and Slawomirski, 2015[32]). Many antimicrobials are used in human and veterinary medicine as well as to control plant diseases. While other chemicals promote resistance (e.g. metals, fungicides and biocides), the discussion below focuses on antibiotics.

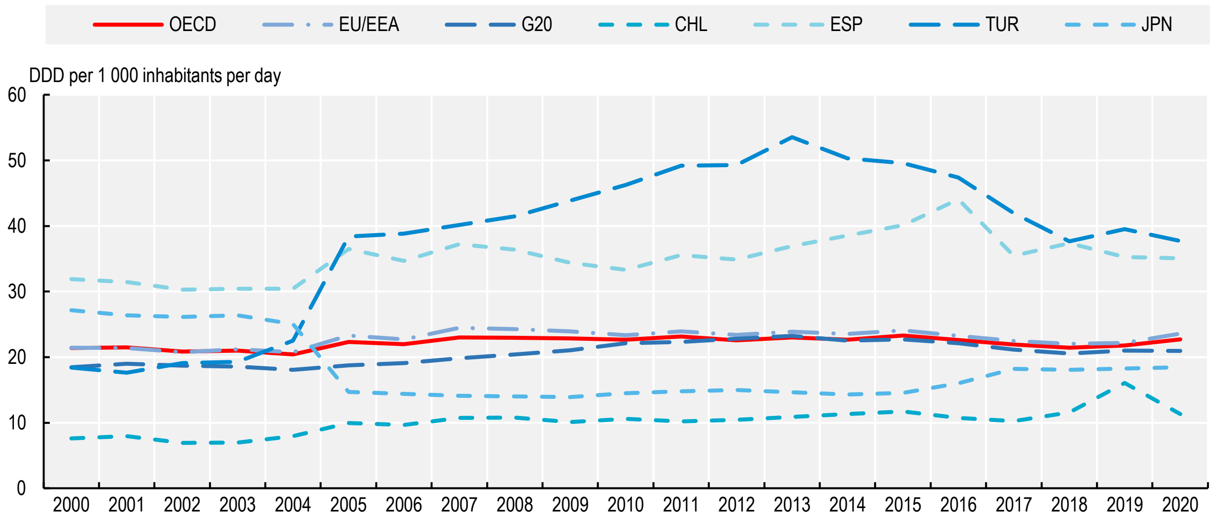
Antibiotic consumption in humans

> *Global consumption of antibiotics has increased in the last 20 years, with consumption rates in the G20 converging towards mostly stable rates in the OECD*

In the last 20 years, on average across OECD countries, sales[4] of all classes of antibiotics monitored through ResistanceMap/IQVIA increased by 1.9%, from 21.4 DDD[5] per 1 000 inhabitants per day in 2000 to an estimated 21.8 in 2019 (Figure 2.1). The levels and trends across individual countries were very heterogeneous. Spain was one of the OECD countries with the highest total consumption, with rates increasing by an estimated 10.6% over the last two decades from 31.9 to 35.3 DDD per 1 000 inhabitants. In Chile, consumption rose an estimated 111% but from much lower starting rates of 7.6 and 16.1 DDD per 1 000 Chileans per day in 2000 and 2019 respectively. Total consumption in Türkiye rose an estimated 115% from 18.4 to 39.5 DDD per 1 000 inhabitants per day, making it the OECD country with the highest growth rate in the last 20 years. Conversely, consumption decreased the most in Japan, dropping an estimated 32.9% from 27.2 to 18.2 DDD per 1 000 inhabitants per day.

Figure 2.1. Average total antibiotic sales in the human sector in the OECD have been largely stable

All antibiotic sales, in DDD per 1 000 inhabitants per day, 2000-19*



Note: *Original data go as far as 2015; estimates for 2016-19 derived through multiple imputations (data from OECD.Stat on consumption used as priors). Averages for different country groups are unweighted. See Note 4 for more details on IQVIA MIDAS database.
Source: OECD analysis of OneHealthTrust/IQVIA (2022[33]), *ResistanceMap – Antibiotic Use*, https://resistancemap.cddep.org/AntibioticUse.php.

StatLink https://stat.link/4qca1t

Average trends across the EU/EEA mirror those in the OECD. While the data are not strictly comparable, the patterns are well aligned with the latest *Annual Epidemiological Report 2019* published by the European Centre for Disease Prevention and Control (ECDC) (2020[34]), which shows a statistically significant decrease in total consumption (community and hospital sector) of antibacterials for systemic use in the EU/EEA overall, between 2010 and 2019. In G20 countries, the average trend shows a convergence, over the last two decades, towards OECD and EU/EEA levels of total antibiotic consumption, indicating significant increases in non-OECD, non-EU and G20 countries like Brazil, China, India, Indonesia and Saudi Arabia. These five G20 countries, along with Peru and Türkiye, exhibit the highest growth rates in total antibiotic consumption.

Globally, total antibiotic consumption rose by 39% between 2000 and 2015, from 11.3 to 15.7 DDD per 1 000 individuals per day, with low- and middle-income countries (LMICs) topping growth rates (Klein et al., 2018[14]). In LMICs, between 2000 and 2015, total antibiotic consumption increased by 77%, from 7.6 to 13.5 DDD per 1 000 inhabitants per day (Klein et al., 2018[14]). For comparison, in the OECD, over the same period (2000-15), total consumption grew on average across countries by 9% from 21.4 to 23.3 DDD per 1 000 inhabitants per day. While total consumption rates remain much lower in LMICs, there has been a clear convergence over the last two decades.

Most antibiotic consumption in humans takes place in the community. On average across 25 EU/EEA countries, 90% of all DDDs are consumed in the community (country range in 2020: 81-94%) (OECD et al., 2022[35]), while the remaining takes place in the hospital sector. In the United States, most antibiotic expenditure and consumption are associated with the outpatient setting. Similar patterns are observed in Mexico.

Overall antibiotic consumption in humans dropped during the first year of the COVID-19 pandemic in EU/EEA countries and Australia

According to the latest data from the ECDC, in 2020, the mean total consumption of antibiotics in humans in the EU/EEA dropped by 17.6% compared to the year before (OECD et al., 2022[35]). Between 2019 and 2020, there was a decrease of 3.5 DDD per 1 000 inhabitants per day. A majority of countries reported decreases in antibiotic consumption for both the community and the hospital sector and generally larger decreases in the community than in the hospital sector. In the community, the decrease between 2019 and 2020 was proportionally larger in countries with high antibiotic consumption than in countries with low antibiotic consumption. In Australia, the number of antibiotic prescriptions decreased by 40% from 2.3 million in March 2020 to 1.4 million in April 2020, with DDD per 1 000 inhabitants per day falling 39% between April and December 2020 compared with the same period in 2019 (ACSQHC, 2021[36]). In the United States, between March and October 2020, close to four in five patients hospitalised with COVID-19 received an antibiotic (CDC, 2022[37]). However, as in other countries, overall antibiotic use in hospitals, outpatient settings and nursing homes was lower in 2021 than in 2019 (CDC, 2022[37]). There are limited data on the consumption of antibiotics in humans during the pandemic in other OECD countries. There is concern that, in some countries, the pandemic may have led to higher – if perhaps temporary – consumption of antibiotics as a means to treat COVID-19, an approach that is not clinically effective.

Interventions to limit the health impact of the COVID-19 pandemic are likely to be behind changes in antibiotic consumption in humans observed in 2022

Reductions in total antibiotic consumption in humans in EU/EEA countries in 2020 could be related to actions taken by governments and populations to curb the COVID-19 pandemic, including (OECD et al., 2022[35]):

- Changes in infectious disease epidemiology, with particularly prominent decreases in groups of antibiotics prescribed for respiratory infections and to the youngest age groups.
- Non-pharmaceutical interventions intended to limit SARS-CoV-2 (coronavirus disease, COVID-19) spread, including restrictions on movement, physical distancing, respiratory etiquette, hand hygiene and travel restriction. These interventions likely had an impact on the transmission and prevalence of other infectious diseases and may have led to fewer antibiotics being dispensed. In the United States, an analysis of a dataset covering 92% of all retail prescriptions of antibiotics, found that from January to May 2020, the number of patients dispensed antibiotics decreased from 20.3 to 9.9 million (King et al., 2020[38]). Over 6 million fewer outpatients were dispensed antibiotics from retail pharmacies than would be expected based on the same timeframe in previous years (King et al., 2020[38]).
- Lower use of primary care services, due to lockdowns and reprioritisation of healthcare resources, which could have led to a decrease in inappropriate prescribing for milder and self-limiting infection.

Across the EU/EEA, hospitals have been hit hard by COVID-19. As demand for intensive care beds increased rapidly, the number of admissions for elective surgery or chronic care decreased. These changes are not captured by the indicator "DDD per 1 000 inhabitants per day". If the total number of hospitalised patients decreased substantially in 2020 because of the COVID-19 pandemic, the apparent decrease in hospital antibiotic consumption expressed in "DDD per 1 000 inhabitants per day" could actually become an increase, if expressed in "DDD per 100 bed-days" (OECD et al., 2022[35]). Primary care data from the United Kingdom indicate higher rates of prescribing per patient: when taking into account the drop in the number of medical appointments, the number of antibiotic prescriptions was 7% higher than expected (Armitage and Nellums, 2020[39]). As such, changes in hospital consumption between 2019 and 2020 should be interpreted with caution until further data and analyses are available. Moreover, it is still unclear whether reduced community antibiotic consumption was sustained in 2021 and what implications recent trends in consumption may have on AMR. In the United States, the overall antibiotic use was lower in August 2021 compared to 2019, though the use of some antibiotics such as azithromycin and ceftriaxone increased (CDC, 2022[40]).

In Australia, in April 2020, changes to the Pharmaceutical Benefits Scheme (PBS) reduced the number of repeat prescriptions permissible (typically from one to zero) for the five most dispensed antibiotics in the country, with the objective of reducing inappropriate prescribing (ACSQHC, 2021[36]). It is likely that these changes are behind some of the reductions in antibiotic use observed in 2020. However, the use of some antibiotics that were not subject to this policy change also fell, which suggests that other factors such as the prevalence of respiratory illnesses and reduced health-seeking behaviour could have also contributed to the fall in antibiotic consumption in humans.

Consumption of highest priority antibiotics in humans has been increasing relatively faster than total consumption, both globally and in OECD countries

In 2017, the WHO introduced the Access, Watch, Reserve (AWaRe) classification of antibiotics in its Essential Medicines List, as a tool for improving the use of antibiotics at the local, national and global levels, with the ultimate goal of reducing antimicrobial resistance (WHO, 2019[41]). The tool classifies 180 antibiotics. Access antibiotics are mostly first-line and second-line therapies with lower resistance potential than other antibiotics. Watch antibiotics have higher AMR potential and should be prioritised in stewardship and monitoring efforts. Watch antibiotics include most of the highest priority agents in the WHO list of Critically Important Antimicrobials for Human Medicine (2019[42]). Reserve antibiotics include antibiotics of last resort and should be saved for treatment of confirmed or suspected infections due to multidrug-resistant organisms.

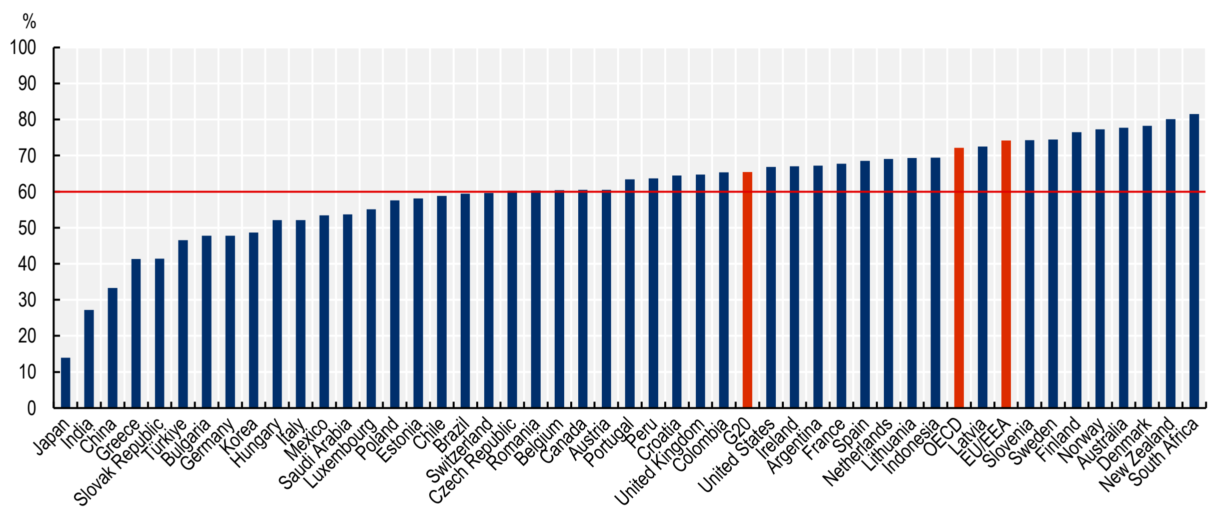
Globally, the consumption of last-resort antibiotics, such as carbapenems and colistin, has been increasing (Klein et al., 2018[14]). Carbapenems are a last-line group of antimicrobials used mainly in hospitals to treat patients with confirmed or suspected serious infections (ECDC, 2020[34]). They act as the last line of defence against multidrug-resistant bacteria. While much of the global growth in last-resort antibiotics has been in low- and middle-income countries (LMICs), growth has not been restricted to LMICs. In relative terms consumption of carbapenems has increased faster than total consumption in OECD, EU/EEA and G20 countries in the last 20 years. As stated, total consumption rose 9% in the OECD between 2000 and 2015, while consumption of carbapenems grew 71% over the same period, albeit from very low levels of consumption. These trends are aligned with data from ECDC (2020[34]) showing that between 2010 and 2019, several European countries exhibited a statistically significant increasing trend in the consumption of last-line groups of antimicrobials. In the EU/EEA, consumption of last-line antibiotics in humans, such as carbapenems and polymyxins (mainly colistin), increased between 2011 and 2020, by 10% and 67% respectively (OECD et al., 2022[35]). These antibiotics are the last line of defence against multidrug-resistant bacteria.

Klein and colleagues (2021[43]) have used ResistanceMap/IQVIA data on a large array of antibiotic agents to understand how the consumption of antibiotics in AWaRe groups has evolved between 2000 and 2015. In 76 countries, the median per capita consumption of Access antibiotics increased by 26% (from 8.4 to 10.6 DDD per 1 000 inhabitants per day), while consumption of Watch antibiotics increased by 91% (from 3.3 to 6.3 DDD per 1 000 inhabitants per day). In high-income countries, consumption of Access antibiotics increased by 15% while consumption of Watch antibiotics grew by 28%. The WHO has proposed that countries should aim for Access antibiotics to make up at least 60% of total national consumption by 2023, a target that the WHO believes would result in better use of antibiotics, reduced costs and increased access (WHO, 2019[41]). In 2015, there were 14 OECD countries that did not meet this target (Figure 2.2). Large economies outside the OECD, like Brazil, China and India were among the countries not meeting the WHO target in 2015. In Japan, some antibiotics are not included in the WHO AWaRe classification, somewhat limiting comparability. In recent years (data not shown), Japan has increased the share of all antibiotics that are Access antibiotics. Since 2015, some countries – particularly OECD countries such as Switzerland – have made important strides on this indicator and now meet the at least 60% target.

A growing consumption of Watch antibiotics, relative to Access antibiotics, could be due to a number of reasons. Klein and colleagues (2021[43]) suggest six, mostly focusing on trends in LMICs. In higher-income countries, drivers could include the promotion of certain antibiotics, over-the-counter sales of antibiotics without a prescription (still allowed in Europe for certain medications like eye drops), diagnostic uncertainty and empirical antibiotic use, and higher rates of AMR infections which require second-line and last-resort antibiotics (Klein et al., 2021[43]; Paget et al., 2017[44]).

Figure 2.2. Consumption of Access antibiotics as a share of total consumption in humans in 2015

The WHO has set a national-level target that 60% of all antibiotic consumption be for Access antibiotics by 2023



Note: No estimates were available for Costa Rica, Cyprus, Iceland, Israel and Malta. Averages for different country groups are unweighted. See Note 4 for more details on IQVIA MIDAS database.
Source: OECD compilation of estimates in Klein, E. et al. (2021[43]), "Assessment of WHO antibiotic consumption and access targets in 76 countries, 2000-15: An analysis of pharmaceutical sales data", https://doi.org/10.1016/S1473-3099(20)30332-7 and IQVIA data provided by Canada.

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Despite overall reductions in 2020, the relative use of broad-spectrum antibiotics in humans increased and variability across EU/EEA countries suggests reductions are possible

On average across the EU/EEA, in 2020, consumption of broad-spectrum antibiotics in the community was 3.5 times higher than the consumption of narrow-spectrum antibiotics, which should typically be the first-line therapy.[6] Between 2011 and 2020, an increasing trend was observed in this ratio for the EU/EEA overall, indicating a shift towards broad-spectrum antibiotics to treat infections in the community (OECD et al., 2022[35]). In the hospital sector, the proportion of broad-spectrum antibiotic consumption[7] also exhibits an increasing trend overall for the EU/EEA between 2011 and 2020, with only one country (Slovenia) with a decreasing trend.

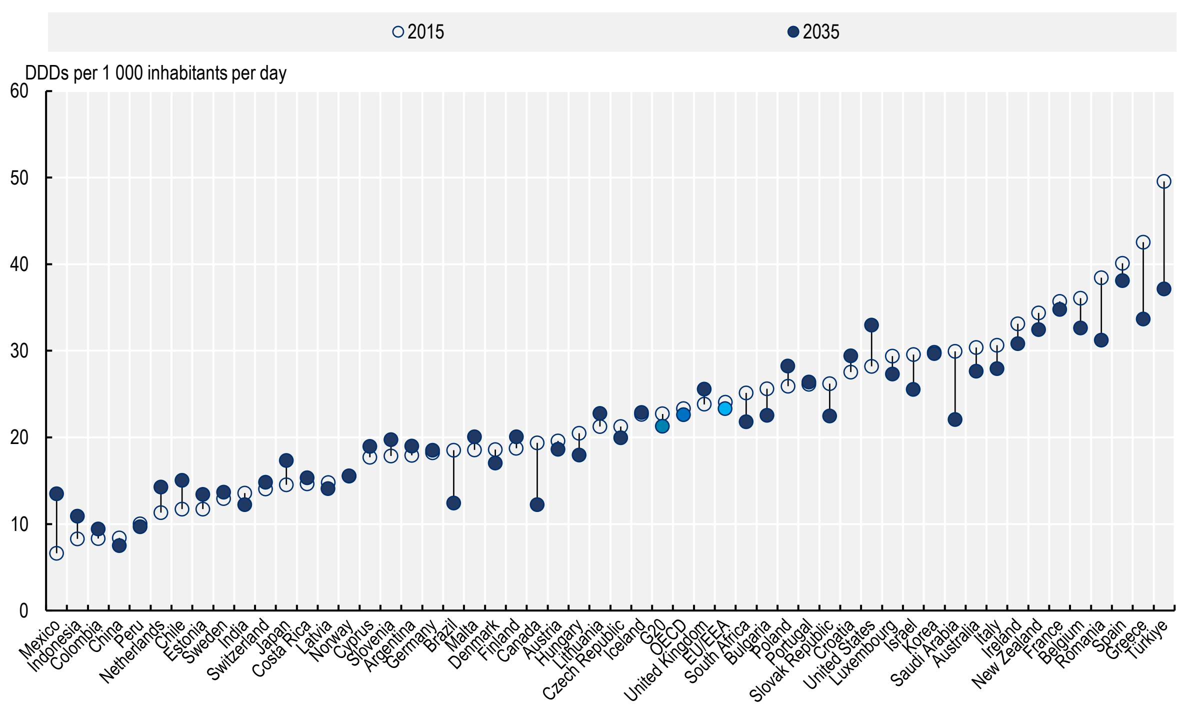
Antibiotic use in humans could decrease slightly in the OECD if trends persist

Should total antibiotic consumption continue to evolve along the same lines as in the period 2000-15, then it is estimated that consumption will decrease between 2015 and 2035 by 3% in the OECD from 23.3 to 22.6 DDD per 1 000 inhabitants per day respectively (Figure 2.3). Countries in the EU/EEA could see average total consumption decrease by 3.3% from 24.1 to 23.3 DDD per 1 000 inhabitants per day, while average total consumption in G20 countries could drop by 6.2% from 22.7 to 21.3 DDD per 1 000 inhabitants per day. Colombia, India and Mexico could see the largest increases in total antibiotic consumption, while Finland, Germany and Luxembourg could exhibit the most significant drops by 2035.

These projections are substantially lower than previous estimates of up to 200% growth in global antibiotic consumption by 2030 (Klein et al., 2018[14]). Reasons for the differences between the two sets of projections are likely to be multiple including, for example, due to a different methodology. However, the most significant factor behind the differences is likely to be the reduction in total antibiotic consumption experienced in most European countries between 2016 and 2019 (ECDC, 2020[45]), which was not captured in the work by Klein and colleagues (2018[14]) but was included as priors in the multiple imputations of missing values in this analysis.

Figure 2.3. If trends persist, total antibiotic consumption in humans in the OECD could decrease

Total antibiotic consumption in 2015 and 2035* in DDD per 1 000 inhabitants per day



Note: * Original data go as far as 2015; estimates for 2016-20 were derived through a combination of multiple imputations (data from OECD.Stat on consumption used as priors) and exponential smoothing with a damped trend. Averages for different country groups are unweighted.
Source: OECD analysis of OneHealthTrust/IQVIA (2022[33]), *ResistanceMap – Antibiotic Use*, https://resistancemap.cddep.org/AntibioticUse.php and IQVIA data provided by Canada.

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A recent challenge that might warrant more attention in the near future is the shortage of medicines, especially antibiotics. In a 2019 survey of 39 European countries, 95% of participating pharmacists indicated that the shortage of medicines was a major problem in their hospital (EAHP, 2019[46]). Antimicrobial agents were the leading cause of shortages in medicines from as far back as 2014. In 2019, around 63% of participating pharmacists indicated that they experienced shortages in antimicrobial agents, 5% more pharmacists than in 2014 indicating the situation is not improving (EAHP, 2019[46]). Antibiotic shortages can lead to delays or inappropriate substitutions.

Older "forgotten" antibiotics are not widely available, despite the potential benefit

With AMR increasingly becoming a global threat and with the approval of antibiotics having dropped significantly (OECD et al., 2017[47]), the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) Study Group for Antibiotic Policies (ESGAP) set out in 2011 to investigate if potentially useful older antibiotics were being marketed in Europe, Australia, Canada and the United States (Pulcini et al., 2012[48]). Since 2000, only five new classes of antibiotics have been put on the market and none of these targets gramme-negative bacteria, which pose the biggest resistance threat (OECD et al., 2017[47]). In this context, older antibiotics may be a useful resource, until new antibiotics reach the market. Yet, despite many of these older antibiotics being categorised as Access antibiotics in WHO AWaRe, they are often not available in countries, either because they were never introduced in the first place or they were withdrawn at some stage (Pulcini et al., 2012[48]).

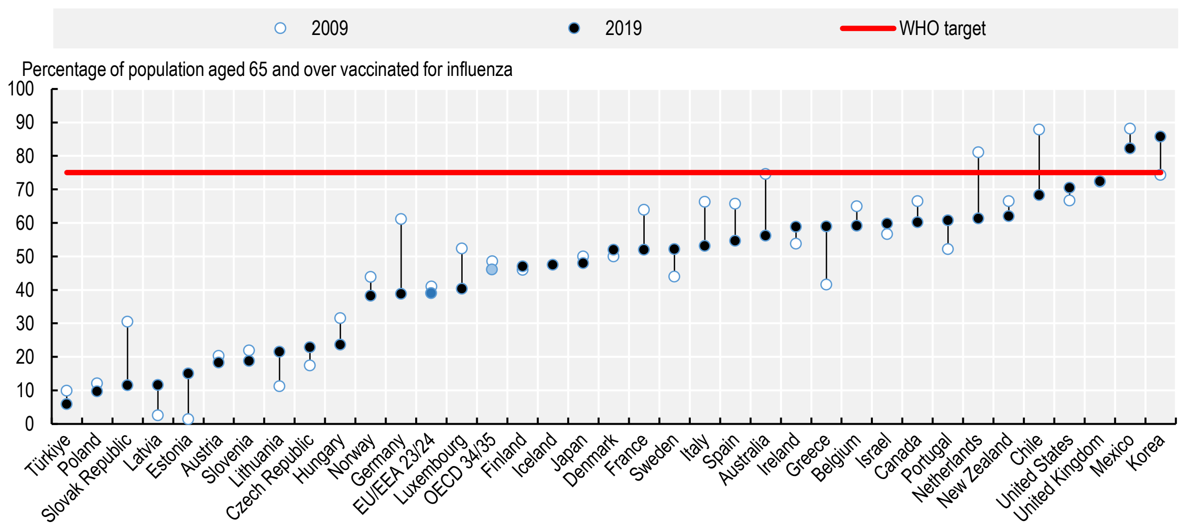
The 2011 ESGAP study showed that 22 out of 33 older but potentially useful antibiotics were marketed in fewer than 20 of the 38 included countries (including European countries, Australia, Canada and the United States, Canada and Australia). More than half of countries (20 out of 38) made only about 66% of forgotten antibiotics (22 out of 33) available. A study update in 2017 found the availability of these antibiotics remained low, with only about 69% (25 out of 36) accessible in about half (20 out of 39) of countries (Pulcini et al., 2017[49]). The lack of market availability of "forgotten" antibiotics extends to LMICs, where only a small number of countries have approved these older yet potentially useful antibiotics (Tebano et al., 2019[50]). Reasons for no longer producing or supplying "forgotten" antibiotics include low profitability, lack of awareness of clinical usefulness and limited demand (Access to Medicine Foundation, 2020[51]). Economic motives seem to be a major driver (Pulcini et al., 2017[49]).

Vaccination can reduce the need for antibiotics, yet there are gaps in vaccination

Vaccines trigger an immune response that can protect individuals against bacterial carriage and infection (Sevilla et al., 2018[52]). Vaccines can also help prevent people from getting sick by conferring immunity before the pathogen takes a foothold in the host, reducing the need for outpatient and inpatient care, in turn lessening the likelihood of antibiotics being used for treatment (Buchy et al., 2020[53]). Pneumococcal conjugate vaccines (PCVs), specifically the 10-valent PCV (PCV10) and 13-valent PCV (PCV13), have been found to lead to a 17% and 31% reduction respectively, in hospitalisations due to clinically and radiologically confirmed cases of pneumonia among children under 2 years of age (Alicino et al., 2017[54]). Pneumococcal vaccination is also associated with reductions in antibiotic use in children aged 6 weeks to 6 years, as well as reductions in illness episodes that require antibiotics in children aged 12-35 months (Buckley et al., 2019[55]). In the United States, it has been estimated that the increased coverage of the 7-valent PCV (PCV7) resulted in a 5.4% reduction in all-cause antimicrobial prescribing (Tedijanto et al., 2018[56]). Remarkably, increased PCV7 coverage was associated with nearly the same proportional reduction in total antibiotic exposures for *S. pneumoniae*, *S. aureus*, and *E. coli*, even though PCV7 does not target the latter two pathogens.

Other studies have shown that increases in vaccination coverage for influenza are associated with declines in antibiotic prescribing. One recent meta-analysis found that influenza vaccines were associated with a 28.1% rate reduction in the number of days antibiotics were used among healthy adults (Buckley et al., 2019[55]). Similarly, a study using data between 2010 and 2017 in the United States found that a 10 percentage point increase in the influenza vaccination rate was associated with a 6.5% decrease in antibiotic use, the largest reductions observed among children (aged 0-18 years) and the elderly, i.e. those aged 65 years and over (Klein et al., 2020[57]). While the WHO recommends that 75% of elderly people be vaccinated against seasonal influenza (OECD, 2019[58]), average vaccination rates in the OECD have actually dropped between 2008 and 2018 (Figure 2.4). Only Mexico and Korea have vaccination rates of over 75%.

Figure 2.4. Vaccination rates for influenza among older people falling short of WHO target of 75%



Note: Three-year average for Iceland and Luxembourg for both years. Data are estimated for Norway. Averages for different country groups are unweighted.
Source: *OECD Health Statistics 2021*, https://doi.org/10.1787/health-data-en.

Sales of antibiotics for food-producing animals

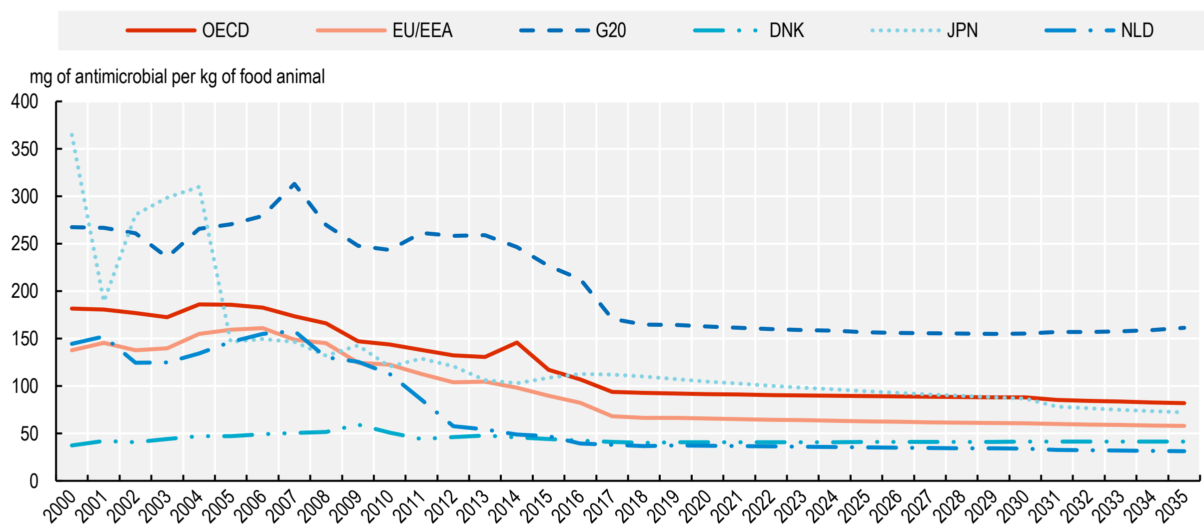
Worldwide, the consumption of antibiotics in animals far surpasses consumption in humans, with an estimated 73% of total antimicrobial sales globally being used in animals raised for food (Van Boeckel et al., 2019[20]). In 28 EU/EEA countries that report both animal and human consumption data, it is estimated that 70% of the active substance of antimicrobials was sold for use in food-producing animals (ECDC/EFSA/EMA, 2017[59]). Antimicrobials used in animals can serve different purposes, as discussed by Innes and colleagues (2020[60]). First and foremost, they can be used to treat animals with bacterial infections. Antimicrobials can also be administered to animals who have been in contact with infected animals as a form of disease control (also called metaphylaxis). When no animals exhibit signs of infection, antibiotics can be used prophylactically across groups to prevent disease. Finally, antimicrobials may be used without the purpose of treating, controlling or preventing disease but, for growth promotion, as a way to increase the rate of weight gain and the efficiency of feed (Wellcome, 2020[5]). Metaphylaxis, prophylaxis and growth promotion can result in large volumes of antibiotics being used.

Sales of antibiotics for animals in the OECD decreased over the last two decades

Over the last two decades, on average across OECD countries, sales of all classes of antimicrobials used in chicken, cattle and pig systems, adjusted for total production and importation of meat products, are estimated to have halved, with most of the decrease taking place from around 2014 (Figure 2.5). The trend is very similar in the EU/EEA but with the largest part of the reduction starting from 2010. While the figures are not directly comparable, these results are well aligned with the analyses in the latest ESVAC (2020[28]) report for Europe (see Figure 23 in the report). Consumption in animals in the G20 is estimated to have dropped as well over the last 20 years but remains at levels higher than those in the OECD and EU/EEA.

Historical data on antimicrobial consumption in animals are still developing and the figures presented here should be interpreted with caution. However, globally, countries in the EU/EEA and OECD have been collecting and reporting data for the longest periods, going as far back as 1980 (in Sweden). Three countries with established data reporting, Denmark, Japan and the Netherlands, are shown in Figure 2.5. The evolutions of antimicrobial consumption in animals in these countries illustrate that patterns are diverse. While consumption in both Japan and the Netherlands decreased over time, the levels are very different. In Denmark, consumption was mostly flat in the last two decades and at a lower level than in the EU/EEA and OECD averages.

Figure 2.5. Average total sales of antibiotic for animals in the OECD have dropped over the last two decades (2000-20)



Note: Averages for different country groups are unweighted. The denominator used to standardise antimicrobial consumption in animals was derived from data on total meat production and import quantities of bovine, poultry, pig and other meat from the Food and Agriculture Organization Corporate Statistical Database FAOSTAT. Because of this, data in this graph are not directly comparable to data in EMA (2020[28]), OIE (2020[10]) and Tisseo et al. (2020[18]). While numbers differ across studies, trends should be qualitatively similar. Estimates are not available for Cyprus. An EU-wide ban on the use of antibiotics as growth promoters in animal feed entered into effect on 1 January 2006. The US Food and Drug Administration banned the use of antibiotics as feed supplements to help livestock and poultry grow faster on 1 January 2017. In Canada, as of 1 December 2018, all Medically Important Antimicrobials for veterinary use can be sold by prescription only and growth promotion claims and related directions for use are no longer allowed on labels.
Source: OECD analysis of estimates and data from Tiseo, K. et al. (2020[18]), "Global trends in antimicrobial use in food animals from 2017 to 2030", https://doi.org/10.3390/antibiotics9120918.

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To ensure comparability across countries with very different systems of animal food production, antimicrobial consumption in animals is typically reported in the total weight of antibiotics consumed over the total weight of food animals produced and imported (commonly called animal biomass), in a given year. Changes over time in this ratio could then be driven by changes in total antimicrobial consumption, total food animal biomass or both. An exploration of both the numerator and denominator, suggests that the reductions in antimicrobial consumption in animals per animal biomass have been driven by both reductions in total antimicrobial consumption and increases in food animal biomass. Food animal production has increased in the last 20 years (OECD/FAO, 2019[61]) at the same time that total antimicrobial consumption in animals has decreased in most high-income countries (Tiseo et al., 2020[18]).

Shifts in policies and attitudes towards the use of antibiotics for growth promotion in high-income countries are likely behind reductions in antimicrobial use in animals. The use of medically important antibiotics (antibiotics used in human medicine that are classified by the WHO as important, highly important and critically important) for growth promotion is considered inappropriate by the WHO, WOAH and FAO. The EU, Canada and the United States have banned the use of antimicrobials for growth promotion and, more recently, India and Pakistan have moved toward banning or phasing out critically important antimicrobials for human use from animal use (Wellcome, 2020[5]). The WHO has recommended that, when the use of antimicrobials in animals is justified, priority should be given to antimicrobials of least importance for human health (WHO, 2017[62]).

Sales of antibiotics for animals could decrease further in the OECD if trends persist

If downward trends in the EU/EEA and OECD persist in the future, these regions could see further reductions in antimicrobial consumption in food animals per animal biomass. Antimicrobial consumption in food animals per animal biomass could decrease an estimated 10% in the OECD and 12% in the EU/EEA by 2035 compared to 2020, while stabilising in the G20 at 2020 levels. These estimates differ somewhat from forecasts by Tiseo et al. (2020[18]), who project a 6.7% increase in Europe, a 4.3% rise in North America and a 3.1% increase in Oceania by 2030. Reasons for these differences include the distinct geographical scope (Tiseo et al. report rates for continents rather than country groupings), though much more likely these differences reflect the inclusion in estimates presented here of recent data for 2017 and 2018 from ESVAC (2020[28]). Indeed, projections by Tiseo et al. of an 11.5% global increase by 2030 were already revised downward compared to previous estimates of a 53% increase in consumption by 2030 using sales data from 2013 (Van Boeckel et al., 2017[63]).

With aquatic animals representing 17% of global animal protein consumption, with global food fish consumption growing faster than consumption of meat from all terrestrial animals combined except poultry and with nearly 50% of the global supply of fisheries products for human consumption coming from aquaculture, antimicrobial consumption in aquaculture merits attention (Schar et al., 2020[19]). Drawing on a relatively limited collection of antimicrobial use point prevalence surveys,[8] Schar et al. (2020[19]) project that global antimicrobial consumption in aquaculture will rise by 33% between 2017 and 2030. In Europe, consumption could increase by 29.7% by 2030, yet the region's share of global consumption was small in 2017 (around 1.8%) and is projected to decrease (1.7%) by 2030 (Schar et al., 2020[19]). Estimates indicate that consumption per biomass is significantly higher in aquaculture than in humans and terrestrial animals and, worryingly, 96% of all antimicrobial use in aquaculture was for classes classified as highly important and critically important for humans. By 2030, Schar et al. (2020[19]) predict that aquatic food-producing animal use will account for almost 6% of total global antimicrobial consumption, including humans and animals.

The majority of sales of antibiotics for animals take place outside the OECD

According to estimates by Tiseo et al. (2020[18]), the largest consumer of antimicrobials in food animals in 2017 was China, representing almost half of global consumption. The top ten countries by estimated total consumption were China, Brazil, the United States, Thailand, India, Iran, Spain, Mexico and Argentina, which together accounted for a projected 75% of all antimicrobials used in food animals in 2017 (Tiseo et al., 2020[18]). In aquaculture, the Asia-Pacific region accounts for the overwhelming majority of global consumption, with China, India, Indonesia and Viet Nam being the largest consumers (Schar et al., 2020[19]). The African and Latin America regions are projected to grow significantly but the Asia-Pacific region is likely to remain the largest consumer globally by 2030 (Schar et al., 2020[19]).

Naturally, these rankings mirror, to a large extent, the ranking of countries with the largest meat and aquaculture productions (OECD/FAO, 2019[61]; Schar et al., 2020[19]). While individual European countries remain relatively small meat producers in comparison to Brazil and China, the EU as a whole is one of the largest producers globally. Global aquaculture production is dominated by the Asia-Pacific region, with China alone accounting for 61% of global production in 2016 (Schar et al., 2020[19]). Beyond being a One Health issue, AMR is also a One World issue, with resistant microorganisms spreading across populations, regions and national borders (OECD, 2018[3]).

While meat trade growth is expected to slow down compared to the last decade, meat exports at the global level (excluding live animals and processed products) are still projected to be 18% higher in 2028 than in 2019 (OECD/FAO, 2019[61]). Brazil and the United States will continue to contribute the majority of meat exports. The Asian region is projected to continue to dominate meat imports, with Japan's younger populations increasingly favouring meat over fish (OECD/FAO, 2019[61]). As for fish, the EU, China, Japan and the United States will remain top importers. While most consumption of antimicrobials in animals may be taking place outside the OECD, global trade requires global antibiotic stewardship.

Antimicrobials in plants and the environment

Besides causing infections in humans and animals, bacteria can also cause plant disease, which in turn can lead to both health (foodborne disease) and economic (production losses) costs. At least 20 countries have approved the use of antibiotics to treat plant diseases (FAO, 2018[64]). In certain countries with strong regulatory oversight, antibiotic use in plants is minimal (FAO, 2018[64]) but this is not the case everywhere, with the Commission on Phytosanitary Measures, which governs the International Plant Protection Convention, finding that significant amounts of antimicrobials are used to control plant pests (WHO/OIE/FAO, 2020[65]). As discussed, the more antibiotics are used the less effective they become. There is concern that climate change may exacerbate plant disease, in turn increasing the need for antibiotics, which in turn will make these agents less effective in fighting bacteria (FAO, 2018[64]).

Experts interviewed by Wellcome (2020[5]) have indicated that while most high-income countries either ban antimicrobials in horticulture or restrict their use to plant health emergencies, this is not the case in lower-middle-income countries (LMICs), where the sale and use of antimicrobials in plants are either unregulated or insufficiently enforced. Based on recent studies, care should be taken when combining antibiotics with herbicides as this may massively increase the rate at which AMR develops (Wellcome, 2020[5]).

Antimicrobials may also be present in the environment at large, from soils to waterways, exerting selective pressure on microorganisms and promoting the development or acquisition of mechanisms that allow microorganisms to survive and reproduce where antimicrobials are present. Antimicrobials can be present in the environment for different reasons. A large part of the antibiotic volume ingested by both humans and animals (estimates vary, but around 80% in animals) is excreted in its active form, depending on the class of antimicrobial and how it is used (Wellcome, 2020[5]; OIE/FAO/WHO, 2020[13]; Singer et al., 2016[66]). Animal and human waste goes into sewage systems, directly in soils and waterways or can be used in the form of manure. Both human and animal waste may or may not be treated. A study conducted in 40 swine and cattle farms in the Netherlands found antibiotics in animal waste, with over 1 in 3 samples containing more than 1 antibiotic, and concentrations that exceeded those needed to select for resistance (Singer et al., 2016[66]; Berendsen et al., 2015[67]).

Antibiotics that have expired or are no longer necessary are often discarded in general waste or wastewater. Antibiotics that are sprayed onto crops will naturally go into the soil and waterways. Fish feed containing antibiotics may also lead to concentrations in rivers and seabeds (Wellcome, 2020[5]). Finally, antimicrobial manufacturing can also release antibiotics into the environment (OECD, 2019[11]). Studies have found concentrations of antimicrobials in water downstream of manufacturing sites that were higher than blood concentrations in humans taking antimicrobials (OIE/FAO/WHO, 2020[13]).

Concentrations of antimicrobials in manufacturing plant run-off are particularly problematic in China and India, where most antimicrobials are produced (OIE/FAO/WHO, 2020[13]). While there are no international guidelines on this matter, the pharmaceutical industry has made steps to address the issue. Of 17 companies assessed in an Access to Medicine Foundation report (2020[51]), 13 had an environmental risk-management strategy to address AMR and 12 set antimicrobial discharge limits at their facilities. However, only six companies ask their suppliers to set discharge limits and no company makes any data from monitoring limits publicly available. None of the 17 companies monitor discharge levels of private waste-treatment plants that are contracted to dispose of their manufacturing waste (Access to Medicine Foundation, 2020[51]).

Trends in antimicrobial resistance in humans

Recent trends in national resistance proportions are very heterogeneous

Average resistance proportions in the OECD in 2019 differ by more than a factor of seven

According to OECD analyses of the latest figures from national and international surveillance networks collated in ResistanceMap, the unweighted average of estimated resistance proportions, across 12 priority antibiotic-bacterium combinations, was 20% in OECD countries in 2019 (Table 2.1). Denmark and Norway had the lowest estimated average resistance proportions, at around 6%, while in Greece and Türkiye, more than 44% of infections were estimated to be due to resistant bacteria, on average, across all 12 antibiotic-bacterium combinations. India had projected average resistance proportions in excess of 55%. For some antibiotic-bacterium combinations, over 95% of infections were from resistant bacteria in the countries with the highest resistance proportions. Average resistance proportions in 2019, across 12 antibiotic-bacterium combinations, were estimated to be higher in G20 countries (30%), followed by countries in the EU/EEA (22%).

The lowest resistance proportion across all country-antibiotic-bacterium combinations was 0% (multiple examples), while the highest was 97% (for fluoroquinolone-resistant *A. baumannii*). There was enormous variation in resistance proportions across countries, across antibiotic-bacterium combinations, across countries within antibiotic-bacterium combinations and across antibiotic-bacterium combinations within countries. The estimated average resistance proportion, across 12 antibiotic-bacterium pairs, was almost ten times higher in India than in Norway. In Ireland, where resistance proportions across 12 antibiotic-bacterium pairs average just under 15%, the resistance proportion for vancomycin-resistant *E. faecium* was 38%, double the OECD average (19%).

Data on resistance proportions in the EU/EEA, G20 and OECD countries for infections due to *Salmonella* and *Campylobacter* in humans remain very limited and these bacteria are thus not shown in Table 2.1. The ECDC and the European Food Safety Authority (EFSA) have reported that resistance to ciprofloxacin, a fluoroquinolone that is categorised as a Watch antibiotic in WHO AWaRe, was 13% in *Salmonella* spp. in 12 member states and that 16 out of 19 countries reported very high or extremely high resistance to ciprofloxacin in *Campylobacter* (EFSA/ECDC, 2020[68]). In the United States, the National Antimicrobial Resistance Monitoring System (NARMS)[9] shows resistance to *Salmonella Typhi* increasing from close to zero in 1999 to 18% in 2018. On a positive note, simultaneous resistance to two critically important antibiotics in these bacteria remains low and resistance in *Salmonella* to carbapenems, a last-line antibiotic, remains rare (EFSA/ECDC, 2020[68]). Again, there was significant heterogeneity in resistance proportions, with, for example, 3% of infections due to *Salmonella* spp. in Latvia being resistant to ciprofloxacin compared to 27% in Belgium.

Table 2.1. Estimated resistance proportions for 12 priority antibiotic-bacterium combinations, 2019

Country	FRAB	CRAB	3GCRKP	FREC	CRPA	3GCREC	MRSA	VREFm	PRSP	CRKP	CREC	VREFs	Average
India	87.9*	71	90	86	44.6*	83	68	26.0*	12.5*	65	41	4.8*	56.7
Türkiye	97	91	73	57	41	54	31	13	51	45	4	1	46.5
Greece	97	94	65	33	49	21	43	47	17.0*	59	2	1	44
Saudi Arabia	76.7*	82	72	50	32.7*	58	49	29.2*	23.0*	46	3	1.9*	43.6
Indonesia	76.3*	53	76	72	33.4*	71	40	26.7*	19.3*	17	5	2.1*	41
Romania	91	88	64	28	55	20	47	36	20	32	1	1	40.2
Mexico	86.7*	68.5*	44.2*	68.7*	31.4*	58.8*	44.8*	25.8*	17.4*	9.5*	2.5*	1.2*	38.3
Cyprus	91	91	50	48	21	20	36	50	14.2*	14	0	3	36.5
China	3.5*	68.9*	54.0*	65.9*	25.3*	59.1*	33.5*	12.3*	8.6*	24.4*	2.9*	0.9*	35.8
Italy	91	80	58	44	19	34	35	21	12	31	1	2	35.7
Argentina	75.0*	69	56	31	28.3*	18	42	57.2*	25	19	1	2.1*	35.3
Bulgaria	100	72	76	40	26	39	15	12	9	27	0	0	34.7
Croatia	94	94	54	30	32	16	25	26	27	15	0	2	34.6
South Africa	69.2*	80	73	30	39.9*	31	21	15.6*	28	18	1	0.9*	34
Poland	90	72	58	36	27	17	15	44	15	8	0	3	32.1
Slovak Republic	94	58	58	39	42	24	27	29	5	6	0	0	31.8
Korea	61.1*	77	25	42	24.5*	38	49	20.9*	42	1	0	1.0*	31.8
Lithuania	99	90	55	19	20	21	9	40	11	4	0	6	31.2
Brazil	65.6*	67	54	49	28.4*	28	21	21.1*	16.3*	21	1	1.0*	31.1
Latvia	87.2*	85	37	28	45	19	8	40	10	1	0	8	30.7
Hungary	99	54	37	31	34	21	19	36	6	1	0	0	28.2
Colombia	67.5*	59.0*	43.6*	23.1*	28.2*	30.8*	30.6*	21.0*	15.4*	14.5*	2.5*	1.7*	28.2
Costa Rica	69.8*	61.4*	42.5*	21.5*	29.7*	25.1*	31.1*	16.0*	16.5*	12.0*	2.4*	1.5*	27.4
Peru	64.3*	49.5*	38.7*	23.7*	23.7*	28.9*	27.4*	26.3*	14.6*	11.3*	1.8*	2.4*	26
Malta	58.9*	47.1*	42	42	13	19	23	16.7*	21.3*	14	0	0	24.8
United States	50.1*	26.3*	16.4*	25.3*	15.8*	11.3*	43.6*	68.7*	22.4*	8.0*	1.1*	4.3*	24.5
Czech Republic	100	32	52	26	25	16	13	20	5	1	1	0	24.2
Chile	57.9*	48.1*	34.8*	29.6*	22.2*	21.8*	26.3*	21.2*	15.0*	10.4*	1.2*	1.4*	24.2
Portugal	57	31	50	29	19	17	35	9	14	12	0	0	22.8
Spain	57	58	26	30	25	14	22	1	20	7	2	0	21.8
Israel	53.4*	37.0*	27.7*	24.3*	17.4*	18.0*	23.3*	26.9*	14.7*	9.0*	1.4*	2.1*	21.3
Slovenia	100	25	17	20	23	10	7	3	11	1	0	0	18.1
Canada	43.0*	33.6*	12.9*	25.3*	22.5*	12.8*	16.0*	27.8*	9.8*	7.0*	1.1*	0.8*	17.7
New Zealand	44.5*	30.0*	16.3*	11.3*	17.2*	9.8*	20.3*	23.2*	14.5*	5.2*	0.7*	2.1*	16.3
Germany	60	3	13	19	39	12	7	26	6	1	0	0	15.5
Ireland	45	3	18	22	9	14	15	38	14	1	0	0	14.9
Japan	40.0*	1	6	31	14.9*	21	36	24.3*	1	0	0	1.2*	14.7
Luxembourg	39.4*	29.6*	26	23	10	12	6	3	21	1	1	0	14.3
Iceland	43.7*	28.5*	8.8*	13	16.1*	8	7	20.3*	16	3.4*	1.0*	0	13.8
France	42	10	31	15	19	9	12	1	25	1	0	0	13.8
Australia	23.2*	3	10	19	10.7*	13	18	45.0*	14.2*	1	0	0.8*	13.2
Austria	74	9	13	19	16	9	5	3	6	2	0	0	13
Sweden	85	6	9	19	15	8	2	1	7	0	0	0	12.7
Estonia	41.8*	27.4*	13	20	10	12	3	4	4	0	0	0	11.3
United Kingdom	30	4	15	19	8	13	10	22	5	2	0	2	10.8

Country	FRAB	CRAB	3GCRKP	FREC	CRPA	3GCREC	MRSA	VREFm	PRSP	CRKP	CREC	VREFs	Average
Switzerland	48	5	7	18	13	10	3	2	6	0	9	0	10.1
Belgium	15	0	21	23	16	11	7	1	10	2	0	1	8.9
Finland	49	0	7	14	11	8	2	0	12	0	0	0	8.6
Netherlands	35	1	10	21	7	7	2	1	4	0	0	0	7.3
Norway	14.5*	9.1*	9	13	10	6	1	1	6	0	0	0	5.8
Denmark	18	0	8	12	4	8	2	11	5	0	0	0	5.7
G20 Countries	64	49	43	42	27	35	32	27	19	18	4	2	30
All countries	65.3	44.8	36.7	31	23.7	22.9	22.3	21.8	14.6	11.6	1.8	1.3	24.8
EU/EEA countries	67	40	33	26	22	16	15	19	12	8	0	1	22
OECD countries	59	33	27	26	21	17	18	19	13	7	1	1	20

Note: * Indicates value was imputed and the mean of 300 multiple imputations is shown.
The colour scheme is based on a two-point scale (minimum in light grey, maximum in blue and points in between coloured proportionally). Countries (and country groupings) are sorted from top to bottom from highest to lowest average resistance proportions (across antibiotic-bacterium combinations). Antibiotic-bacterium combinations are sorted from left to right from highest to lowest average resistance proportions (across countries).
VREFs: vancomycin-resistant *E. faecalis*; VREFm: vancomycin-resistant *E. faecium*; 3GCREC: third-generation cephalosporin-resistant *E. coli*; CRKP: carbapenem-resistant *K. pneumoniae*; 3GCRKP: third-generation cephalosporin-resistant *K. pneumoniae*; CRPA: carbapenem-resistant *P. aeruginosa*; MRSA: meticillin-resistant *S. aureus*; PRSP: penicillin-resistant *S. pneumoniae*; FRAB: fluoroquinolone-resistant *A. baumannii*; CRAB: carbapenem-resistant *A. baumannii*; FREC: fluoroquinolone-resistant *E. coli*; CREC: carbapenem-resistant *E. coli*.
Averages for different country groups are unweighted.
Source: OECD analyses of data from surveillance networks included in OneHealthTrust/IQVIA (2022[33]), *ResistanceMap – Antibiotic Use*, https://resistancemap.cddep.org/AntibioticUse.php.

A small average increase in resistance between 2009-19 masks wide variation

Between 2009 and 2019, predicted resistance proportions for 12 antibiotic-bacterium combinations in OECD countries, increased, on average, by only 2 percentage points from 18% in 2009 to 20% in 2019 (Table 2.2). Average resistance proportions increased by 3 percentage points in G20 countries and in EU/EEA countries. Across all EU/EEA, G20 and OECD countries, the average largest projected increases in resistance proportions were for *A. baumannii* resistant to fluoroquinolone while the largest projected reductions were in meticillin-resistant *S. aureus*.

In 8 countries, projected resistance proportions went down, on average across all antibiotic-bacterium-country combinations, by 1.4 percentage points. In the majority of countries, however, resistance proportions, averaged across all 12 antibiotic-bacterium pairs increased between 2009 and 2019, by as much as 8 percentage points in OECD countries (e.g. the Czech Republic and Italy). However, these averages mask significant variation within countries across antibiotic-bacterium combinations. Despite average reductions in a few countries, it is estimated that in no country have resistance proportions for all 12 antibiotic-bacterium combinations gone down between 2009 and 2019. In all countries, both increases and reductions were predicted, in some cases are very significant. This is also true for *Salmonella* and *Campylobacter* in the EU/EEA, where trends varied by country for different serotypes and antimicrobials (EFSA/ECDC, 2020[68]). Resistance to ampicillin and tetracyclines in *Salmonella Typhimurium* declined in many countries between 2013-18, but in certain types of *Salmonella*, resistance to high concentrations of ciprofloxacin increased overall from 1.7% in 2016 to 4.6% in 2018 (EFSA/ECDC, 2020[68]).

In Italy, for example, the proportion of *K. pneumoniae* resistant to carbapenem increased by 30 percentage points (from 1% to 31%) between 2009 and 2019, while the proportion of *P. aeruginosa* resistant to carbapenem went down by 16 percentage points (from 35% to 19%) over the same 10 years. In Poland, while the proportion of *S. pneumoniae* resistant to penicillin went down by a projected 15 percentage points (from 30% to 15%), the proportion of *E. faecium* resistant to vancomycin increased by an estimated 37 percentage points (from 7% to 44%).

It is likely that differences in baseline resistance proportions and rates of change across countries and antibiotic-bacterium combinations are associated with differences in antimicrobial use, infection prevention and control, as well as the use of healthcare services, not to mention differences in measurement. However, the problem goes beyond the human health sector with links to the animal sector and the environment. The list of potential correlates and drivers of resistance is long, ranging from human and animal health and sanitation, agricultural and livestock production, urbanisation and population density, migration and trade, economic growth and governance, immunisation and population structure (Harbarth and Samore, 2005[23]; Byarugaba, 2004[24]; Chatterjee et al., 2018[25]; Holmes et al., 2016[26]). A 2018 systematic review of risk factors for antibiotic resistance in humans over the previous 10 years found the most supporting evidence for underlying disease, antibiotic use and invasive procedures in healthcare settings as main drivers (Chatterjee et al., 2018[25]). However, the review highlighted the lack of inclusion of community-level risk factors in studies, and that there was a general paucity of studies seeking to establish causal relationships between risk factors and resistance (Chatterjee et al., 2018[25]).

Table 2.2. Estimated percentage point changes in resistance proportions for 12 priority antibiotic-bacterium combinations between 2009 and 2019

Country	FRAB	VREFm	3GCREC	CRKP	FREC	3GCRKP	CREC	PRSP	CRAB	VREFs	CRPA	MRSA	Average
Italy	12.4	16.0*	16.0*	30.0*	8.0*	20.0*	1.0*	6.0*	10	-2.0*	-16.0*	-2.0*	8.3
Czech Republic	66.3*	14.0*	6.0*	1.0*	3.0*	0.0*	1.0*	1.0*	9.7	0.0*	-4.0*	-2.0*	8
Bulgaria	27.7	6	20.0*	26.0*	10.0*	7.0*	-1.0*	-9.8	10.7	0.0*	-3.0*	-1.0*	7.7
Saudi Arabia	6.4	8.5	14.2*	19.0*	12.3	15.4	0.9	-0.2	8.5	-0.3	-1.1	5	7.4
Poland	13.4	37.0*	7.0*	7.0*	11.0*	9.0*	0.0*	-15.0*	15.8	3.0*	1.0*	-5.0*	7
India	-3.1	1.7	1.0*	31.0*	-4.0*	3.0*	36.0*	0.5	-16.0*	1	-10.4	39.0*	6.6
Slovak Republic	42.3*	14.8	3.1	2.9	6.8	0.8	-0.7*	-9.6	18.2	-0.9*	-3	4	6.6
Sweden	65.7*	-2	3.2	-2.3*	5.7*	2.9	-0.5*	1.4	-0.7	-0.5*	5.6*	-1.5	6.4
Cyprus	15.9	10	6.0*	-5.0*	5.0*	8.0*	0.0*	-0.3	22	3.0*	8.0*	3.0*	6.3
Croatia	10.4	16.1*	8	10.5*	13.6*	4.9	-1.1*	7.3	11	0.6	-1.5	-4.9	6.3
Germany	43.3*	20.0*	3.0*	1.0*	-4.0*	-1.0*	0.0*	4.0*	-8.6	-1.0*	25.0*	-11.0*	5.9
Romania	12.9	16.2*	6.0*	11.2	10.0*	0.6	0.6	-16.0*	13.8	-1.4	-0.7	13.0*	5.5
Türkiye	7.2	0.4	10.7*	14.7*	14.3	10.1	0.1	3.1	2.3	-0.8	-1.2	-0.1	5.1
Hungary	30.3*	35.0*	8.0*	0.0*	0.0*	-1.0*	0.0*	-6.0*	-2.3	0.0*	4.0*	-10.0*	4.8
Austria	50.6*	-1.0*	1.0*	2.0*	-2.0*	5.0*	0.0*	1.0*	-4	-1.0*	6.0*	-1.0*	4.7
Latvia	8	29.9*	6.0*	1.0*	3.0*	-18.0*	-2.0*	10.0*	8	5.2*	4.7	-1.0*	4.6
China	9.2	4.9	5.3	6.4	19.8	5.6	0.6	1.2	4.9	-0.5	-0.4	-2.5	4.6
Greece	9.1	18.0*	9.0*	7.0*	9.0*	-6.0*	1.0*	-2	11.1	-7.0*	2.0*	3.0*	4.5
South Africa	5.7	3.7	9.6	11.6*	5.3	9.1	0.3	4.2	8.7	-0.3	2.8	-9.8	4.2
Brazil	2.7	1.7	7.7	6.7	15.7	9.4	0.1	-0.7	9.7	-0.9	0	-3.6	4.1
Iceland	4.5	4.3	6.0*	1.1	6.0*	1.5	0	16.0*	-0.4	-1.1*	-1.5	7.0*	3.6
Netherlands	22	0.0*	3.0*	0.0*	10.0*	4.0*	0.0*	3.0*	-7	0.0*	2.0*	1.0*	3.2
Indonesia	-1	6.1	12.2	4.9	16.9	8.6	0.4	-0.3	-5.1	-0.3	-3.6	-4.7	2.9
Malta	0	4.5	4.0*	14.0*	12.0*	42.0*	-1.0*	4	-0.3	0.0*	-9.0*	-36.0*	2.8
Finland	28.5	-1.0*	5.0*	-1.0*	4.0*	6.0*	0.0*	-1.0*	-8.9*	0.0*	1.0*	0.0*	2.7
Lithuania	10.5	17.1*	12.0*	4.0*	2.0*	-2.0*	0.0*	2.0*	2.1	-5.0*	-10.6	-2.0*	2.5
Costa Rica	0.2	0.5	4.9	2.6	7.1	7.8	0.4	0.6	5	-0.6	2.6	-1.6	2.4
Peru	5.3	4.3	5.5	4.5	6.1	3.9	0.5	-0.1	0.4	-0.6	-0.8	-0.7	2.4
New Zealand	5.3	6.5	5.8	5.2	2.3	3.3	0.7	-1.1	0.7	-0.2	-0.7	-3.6	2
Slovenia	44.8*	-1.0*	3.0*	0.0*	1.0*	-16.0*	0.0*	-4.0*	-7.8	0.0*	7.0*	-3.0*	2
Norway	4.1	1.0*	3.0*	-1.0*	1.0*	4.0*	0.0*	4.0*	1.9	0.0*	1.0*	1.0*	1.7
Spain	-5	-2.0*	3.0*	7.0*	-3.0*	15.0*	2.0*	-2.0*	0.3	0.0*	6.0*	-4.0*	1.4
Ireland	30.3*	0.0*	7.0*	1.0*	0.0*	7.0*	0.0*	-6.0*	-8.2	-1.0*	-1.0*	-12.0*	1.4

Country	FRAB	VREFm	3GCREC	CRKP	FREC	3GCRKP	CREC	PRSP	CRAB	VREFs	CRPA	MRSA	Average
Switzerland	26.8	-2.4	3	-1.7*	1.9	-2	7.5*	-1.9	-7.2	-0.9*	-0.2	-6.6	1.4
Colombia	2.9	6	4.2	3.3	3.8	2.4	0.5	-0.3	-0.1	-0.2	-2.5	-3.9	1.3
Chile	1.1	6.1	4	2.3	7.6	2.3	0.2	0	-1.6	-0.1	-2.9	-3.1	1.3
Australia	4.6	5.5	5.4	-1.1	8.9*	1.7	-0.7*	0.4	-7.6	-0.2	-0.1	-3.3	1.1
Argentina	-2.9	9.4	-1.4	5.7	6.5	5	-0.1	3.7	-4.4	-0.7	-6	-2	1.1
Canada	3.6	6	2.1	3.6	2.6	1.3	0.5	-1.3	-0.9	-0.1	-2.5	-3.5	1
Korea	-2.3	3.9	8.2	-1.7	9	-6.8	-0.6*	9	4.9	-1	-4.8	-7.5	0.9
France	20.3	0.0*	1.0*	1.0*	-6.0*	11.0*	0.0*	-2.0*	-1.5	0.0*	-5.0*	-11.0*	0.7
United Kingdom	13.1	8.0*	3.0*	1.0*	1.0*	7.0*	0.0*	2.0*	-8.8	0.0*	-7.0*	-18.0*	0.1
Estonia	-1.4	4.0*	10.0*	0.0*	11.0*	-4.0*	0.0*	3.0*	-6.3	0.0*	-16.8*	0.0*	0
Israel	1.7	5.2	1.6	-0.2	2.9	-1.2	0	-0.3	-7	0.4	-2.6	-2.2	-0.2
Denmark	4.3	9.0*	1.0*	0.0*	-3.0*	-4.0*	0.0*	1.0*	-9.0*	-2.0*	0.0*	0.0*	-0.2
Belgium	-3.9	-3.0*	3.0*	1.0*	3.0*	6.0*	-0.6*	10.0*	-11.7*	-1.0*	4.0*	-14.0*	-0.6
Portugal	5	-14.0*	7.0*	11.0*	1.0*	21.0*	0.0*	-4.0*	-17.4	-4.0*	-1.0*	-14.0*	-0.8
Mexico	2.7	4.1	-8.2	3.9	-4.3	0.9	1	-1.1	-9.5	0	0.4	-5.3	-1.3
United States	-10.9	-3.3	4.3	3	-2.7	1.4	1.1	17.4*	-23.7	-1.7	-1.2	-6.4	-1.9
Luxembourg	-5.7	-6.8	3.0*	-0.9	-3.0*	7.6	1.0*	2.0*	-10.2	-10.0*	-5.0*	-7.0*	-2.9
Japan	-3.2	7.8	0.6	-2.3*	0.7	-6.8	-0.5*	-3.7	-16.9	0.2	-5.5	-8.5	-3.2
EU/EEA countries	19	8	6	4	4	5	0	0	1	-1	0	-4	3
G20 countries	6	6	5	8	6	5	2	2	-3	0	-2	-3	3
All countries	12.6	6.6	5.4	4.9	4.9	4.2	1	0.6	-0.7	-0.7	-1	-3.2	2.9
OECD countries	15	6	5	3	3	2	0	1	-3	-1	0	-4	2

Note: * Indicates either that there was an increase or decrease in more than 95% of the uncertainty sets, or that there was complete historical data and so no multiple imputations were used.

The colour scheme is based on a two-point scale (minimum in light grey, maximum in blue and points in between coloured proportionally). Countries (and country groupings) are sorted from top to bottom from highest to lowest average resistance proportions (across antibiotic-bacterium combinations). Antibiotic-bacterium combinations are sorted from left to right from highest to lowest average resistance proportions (across countries).

VREFs: vancomycin-resistant *E. faecalis*; VREFm: vancomycin-resistant *E. faecium*; 3GCREC: third-generation cephalosporin-resistant *E. coli*; CRKP: carbapenem-resistant *K. pneumoniae*; 3GCRKP: third-generation cephalosporin-resistant *K. pneumoniae*; CRPA: carbapenem-resistant *P. aeruginosa*; MRSA: meticillin-resistant *S. aureus*; PRSP: penicillin-resistant *S. pneumoniae*; FRAB: fluoroquinolone-resistant *A. baumannii*; CRAB: carbapenem-resistant *A. baumannii*; FREC: fluoroquinolone-resistant *E. coli*; CREC: carbapenem-resistant *E. coli*.

Averages for different country groups are unweighted.

Source: OECD analyses of data from surveillance networks included in OneHealthTrust/IQVIA (2022[33]), *ResistanceMap – Antibiotic Use*, https://resistancemap.cddep.org/AntibioticUse.php.

The impact of the COVID-19 pandemic on antimicrobial resistance is still unclear

The COVID-19 pandemic and the actions taken by governments and populations in response to it are highly likely to have affected reporting on bacterial invasive isolates (mostly bloodstream infections) and observed resistance proportions in 2020. In the EU/EEA, for all bacterial species under surveillance by the European Antimicrobial Resistance Surveillance Network (EARS-Net), except for *S. pneumoniae*, the number of reported bacterial invasive isolates (mostly bloodstream infections) increased at EU/EEA level in 2020 compared to 2019, although this was not the case for every individual country in the region (OECD et al., 2022[35]). For *S. pneumoniae*, the number of reported invasive isolates decreased by 44%, from 15 608 in 2019 to 8 689 in 2020 (OECD et al., 2022[35]).

The COVID-19 pandemic has led to massive changes in human behaviour, which may have limited the spread of resistant organisms. The wide-ranging effects on human behaviour included drastically reduced mobility in 2020, likely substantially reducing opportunities to spread drug-resistant microorganisms and consequently reducing infections due to resistant pathogens (Murray, 2020[69]). This is illustrated by the sharp drop in the incidence of infections due to respiratory viruses, most notably influenza (flu) but also respiratory syncytial virus (Jones, 2020[70]). International tourist arrivals (overnight visitors) dropped 74% in 2020 compared to 2019, with around 300 million fewer arrivals in Asia and the Pacific alone and 500 million fewer international tourists in Europe alone (UNWTO, 2021[71]). At the national and regional levels, data from Google's COVID-19 Community Mobility Reports[10] suggest that populations radically reduced their movements (n.b. these data have important limitations and Google provides guidance on how to use and interpret the data). At the beginning of March 2021, mobility remained heavily constrained (Our World in Data, 2021[72]). During the pandemic, an estimated 40% of paid work by dependent employees in Europe was carried out at home, with more than a third of employees working exclusively from home (Eurofound, 2020[73]).

Undoubtedly at great cost, reductions in mobility and social contacts are likely to have reduced the spread of infectious diseases other than COVID-19. However, the pandemic has also affected the reporting of bacterial invasive isolates and changes in the reported number of bacterial invasive isolates in turn affect the resulting resistant proportions and make the observed changes in AMR between 2019 and 2020 difficult to interpret (OECD et al., 2022[35]). Robust surveillance systems will continue to be vital to monitor the situation and to assess the consequences and inform public health decisions (OECD et al., 2022[35]).

Average resistance proportions in the OECD are projected to drop slightly

Based on new historical data on resistance proportions and correlates of AMR (e.g. antimicrobial consumption in animals), it is now projected that between 2019 and 2035, resistance proportions, averaged across 12 priority antibiotic-bacterium combinations, will drop very slightly by on average 1 percentage point. Table 2.3 shows the percentage point changes in resistance proportions between 2019 and 2035, indicating an average reduction, across OECD countries and 12 antibiotic-bacterium combinations, of 1 percentage point. In OECD countries, resistance proportions averaged across 12 antibiotic-bacterium combinations are estimated to have increased from 18% (range across countries: 4.1-41.4%) in 2009 to 20% (range across countries: 5.7-46.5%) in 2019, and may drop to 19% (range across countries: 5.5-43.8%) by 2035 if current trends in resistance, and correlates of resistance, continue into the future and no other policy actions are taken beyond the ones currently in place. Similar reductions of around 1 percentage point for average resistance proportions are also projected for EU/EEA countries and G20 countries.

Across EU/EEA, G20 and OECD countries, resistance proportions averaged across 12 antibiotic-bacterium combinations are projected to increase in 18 countries, remain at their 2019 average levels in 1 country and decrease in 32 countries (these are averages; there might be increases or drops in these countries for different antibiotic-bacterium combinations, see Table 2.3). Peru is the only country where resistance proportions are projected to increase for all 12 antibiotic-bacterium combinations simultaneously – all other countries are projected to see both increases and reductions depending on the antibiotic-bacterium combination. Resistance proportions are projected to increase in 56% of country-antibiotic-bacterium combinations and are estimated to decrease in 39% of combinations.

In absolute terms, China, Luxembourg and Poland could see the largest percentage point increases, on average across 12 antibiotic-bacterium combinations, between nearly 3 and 6 percentage points higher in 2035 than in 2019. Conversely, the Czech Republic, Germany and Sweden could see the largest percentage point drops in average resistance proportions, projected to decrease around 4 to 5 percentage points. However, there is a very large uncertainty, as highlighted by the few estimates in Table 2.3 for which there were increases or decreases in more than 95% of the uncertainty sets (indicated by an asterisk). It remains very challenging to model future resistance proportions when so many data points are missing and when levels and trends differ so much across countries and antibiotic-bacterium combinations.

Table 2.3. Projected percentage point changes in resistance proportions for 12 priority antibiotic-bacterium combinations between 2019 and 2035

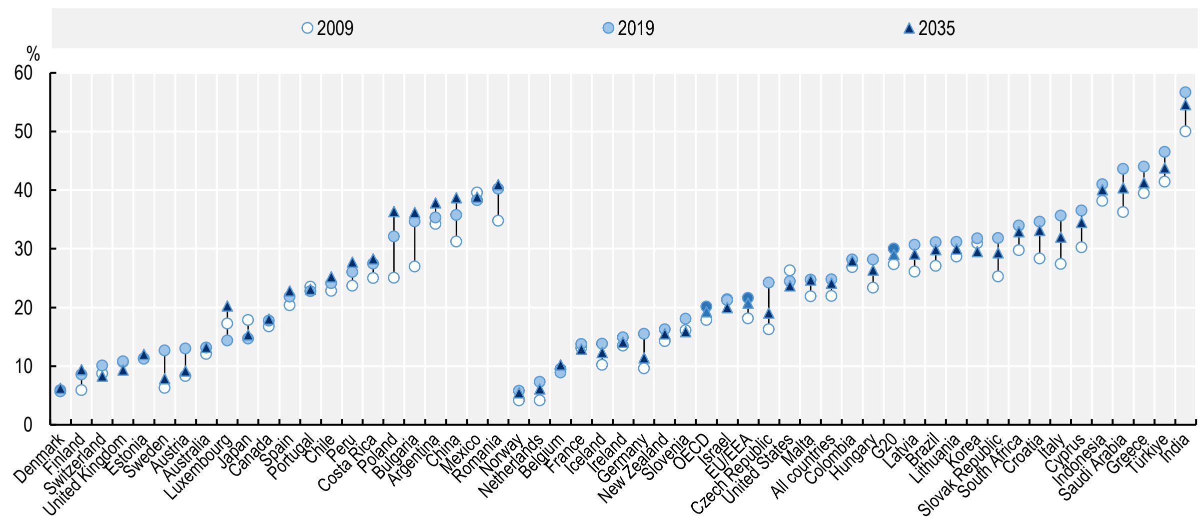
Country	FREC	CRPA	3GCREC	VREFs	PRSP	CRKP	CREC	3GCRKP	MRSA	VREFm	CRAB	FRAB	Average
Luxembourg	5	8.4	8.9	8.4*	-1	8	6.6	8.2	5.4	8	3.5	-0.1	5.8
Poland	10.4	7	6.1	6.3	3.8	8.5	7	3.6	7.7	2.9	-5.8	-6.3	4.3
China	-2.1	5.5	0.7	6.6	4.4	5.5	6	-0.2	6	3.1	-1.2	-2	2.7
Argentina	6.4	5	4.6	3.5	-1.4	2.1	3.1	0.2	2.1	1.7	3	-1.4	2.4
Peru	3.9	2.4	0.1	2.3	2.2	0.8	2.1	1.8	1.3	1.7	1.6	0.6	1.7
Bulgaria	4.4	5.5*	6.1	0.4	2.2	12.8	0.5*	0.1	1.7	-0.4	0.7	-15.9*	1.5
Belgium	0.9	-2.5	2	-0.1	4	-0.2	0	0.3	3.3*	1.9	4.3	1.4	1.3
Chile	3.7	2.2	2.6	0.5	0	0.5	0.5	1.9	0.5	1.2	1.2	-2.1	1.1
Spain	2.9	-2.1	2.0*	0	1.8	0	-1	1	2.8	1.5	-1.8	4.6	1
Costa Rica	3.1	1.7	2.2	1.5	0.7	0.3	0.9	1.4	1.3	1.5	-2.3	-1	0.9
Finland	1.7	0.2	0.4	0.2	2.1	0.3	0	0.5	0.5*	0.6*	2.7	0.3	0.8
Estonia	1.8	7.1	-1.3	0.1	1.6	0.6	0.2*	2.8	0.5	-0.3	-2.8	-1.2	0.8
Japan	1.6	3.3	-0.1	0.1	2	1.6	0.7	1.9	-4.4	-1.2	4.6	-1.5	0.7
Romania	3.1	0.9	4.4*	0.9	8.1	5.9	-0.7*	3.4	-3.5	-1.6	-6.6	-6.1	0.7
Denmark	2.2	2.3*	0.8	0.1	0.5	0.3	0	1.1	0.1	2.6	2.6*	-5.8	0.6
Canada	4	1.6	1.8	0.5	0.3	0.1	0.6	0.5	-1.6	3.1	-2.6	-2.8	0.5
Mexico	-0.3	2.2	0	0.7	1	-0.1	0.6	2.8	-0.4	0.3	0.6	-2.7	0.4
Portugal	0.9	2.4	0.9	0.9	-0.6	2.6	0.2	0.2	0.8	0.6	4.4	-9.2	0.3
Malta	-1.2	5.3	-0.6	3.9*	1.4	2.4	3.6	-1.6	-4.8	3.6	-6	-4.9	0.1
Australia	1.2	-0.5	0.2	-0.3	-0.4	1.2	0.2	0	-1.8	2.5	3.8	-6.2	0
Colombia	1.7	1	-1.8	0.6	0.4	-2	0.1	0.2	1.6	-1.1	-2.7	0.7	-0.1
Norway	2.0*	1.4	0.6*	0.7	0.2	0.1	0	0.3	0.5	0.2	-5.6	-5.4	-0.4
United States	0.8	0.5	2.6	-0.4	-3.4	-0.3	0.5	-0.4	-3.1	-1.4	-1.1	-2	-0.6
New Zealand	3.1	-0.9	3.1	-0.5	0	1.9	0.4	1.1	-4.1	0	-6.3	-6.4	-0.7
Ireland	2.3	3.3*	1	1.3	15.6*	0.3	0.4	-0.1	-3.3	-1.1	0.8	-30.8*	-0.8
France	3.5	0.8	2.5	0.9	4.7	0.6	0.9	-0.7	-1.4	1	-3.1	-20.1*	-0.9
South Africa	1.4	-1.7	-1.4	0.2	-0.8	-3.9	0.2	-2.3	4.9	-1.5	-4.8	-3	-1.1
Brazil	1	1	-1.8	0.1	-0.4	-0.4	-0.2	-1.6	-1.3	0	-6.8	-2.8	-1.1
Indonesia	-8.5	1.3	-8.1	1.6	-0.7	-0.2	0.8	-3.6	4.5	-0.8	0.5	-0.5	-1.1
Lithuania	5.0*	4.8*	-0.2	-3.4*	3.3*	0.6	0	-3.8	0.4	-1.3	-8.4	-11.4	-1.2
Netherlands	-2.0*	0.7	1.6	0	0.6	0.3	0	1	-0.3	0.2	1.6	-18.3*	-1.2
Israel	-0.1	-0.3	-1.2	-0.5	-0.8	-1.2	-0.4	-0.6	-3	0.9	-2.8	-4.9	-1.2
Iceland	2.4	0.3	2.4	0.3	-4.1	-0.6	-0.2	0	-4.6*	-0.9	-4.5	-6.6	-1.3
Croatia	4.3	2.1	1	-1.1*	-8.2*	8.6	0	-3.9	0.8	-2.3	-9.3	-9.1	-1.4
United Kingdom	0.7	0.7	0.2	0	0.4	-1.0*	0	-1.6	-2.5	1.3	-0.8	-15.7*	-1.5
Latvia	0.7	-8.3	1.4	-3.5	8.7	2.4	0.2	4.2	-1.9	-4.8	-11.3	-7	-1.6
Switzerland	1.8	-0.6	0.2	0.2	-0.3	1.9*	-3.8	1.4	0.6	0.7	1.7	-25.4*	-1.8
Hungary	-0.3	0.1	1.7	0	3.2	1	0	3.2	2.4*	-9.6	-0.9	-22.7*	-1.8
India	-2	0.4	-2.2	6.8	4.4	-3	-12.3	-6.2	-5.5	1.5	1	-6.8	-2
Cyprus	-1	4.5	11.1*	-2.1*	-0.5	2	1.1*	-3.5	0.7	-10.9	-14.3	-11.8	-2.1
Korea	2.9	2.6	-2	2.2	-9.3	3.5	2.5	7.9	-5.6	0	-22.5	-7.6	-2.1
Slovenia	2.9*	-1.9	2	0.5	-0.4	-0.1	0.6	3.1	1.8	-0.3	5.3	-39.7*	-2.2
Slovak Republic	5	0.9	3.8	0.1	7.5*	0.6	0	-2.8	1.5	-0.6	-15.5*	-30.6	-2.5
Greece	-0.7	-1.9	2.9	-0.1	1	0.8	-0.8*	3.8	-5.6	-17.1*	-7.7	-7.2	-2.7
Türkiye	-0.2	1.7	-5.8	3	-8.6	-7.8	1.8	-2.4	-2.3	4.8	-6.1	-11.1	-2.7
Saudi Arabia	-0.5	1.1	-7.9	2.6	1	-10.2	2.2	-9.7	-4.7	-2.4	-5.4	-6.7	-3.4
Italy	-2.1	1.8	-3.3	-0.3	-1.3	-8.9	-0.3	-4.2	-0.5	-1.5	-9.2	-14.6	-3.7
Austria	2.4*	0.5	1.5	0.1	-1.3	-1	0	-2.4	1.2	0.6	-1.5	-46.1*	-3.8

Country	FREC	CRPA	3GCREC	VREFs	PRSP	CRKP	CREC	3GCRKP	MRSA	VREFm	CRAB	FRAB	Average
Germany	3.1*	-18.1*	2	0	-1	-0.6*	0	0.2	1.3	0.2	1.4	-37.4*	-4.1
Sweden	0.7	-3.9*	1.3	0	-0.4	0.3	0	0.2	0.6	-0.2	-2.7	-53.8	-4.8
Czech Republic	0.2	-2.4	0	0.3*	-0.5	0.1	-0.6	-1.6	0.6	1.8	-9.9	-50.5*	-5.2
OECD countries	2	0	1	1	1	0	0	1	0	0	-2	-14	-1
EU/EEA countries	2	1	2	0	2	2	1	0	0	-1	-3	-16	-1
All countries	1.6	1	1	0.9	0.8	0.7	0.5	0.1	-0.2	-0.2	-2.9	-11.3	-0.7
G20 countries	1	1	-1	2	-1	-1	0	-1	-1	1	-3	-8	-1

Note:
* Indicates either that there was an increase or decrease in more than 95% of the uncertainty sets.
The colour scheme is based on a two-point scale (minimum in light grey, maximum in blue and points in between coloured proportionally). Countries (and country groupings) are sorted from top to bottom from highest to lowest average resistance proportions (across antibiotic-bacterium combinations). Antibiotic-bacterium combinations are sorted from left to right from highest to lowest average resistance proportions (across countries).
VREFs: vancomycin-resistant *E. faecalis*; VREFm: vancomycin-resistant *E. faecium*; 3GCREC: third-generation cephalosporin-resistant *E. coli*; CRKP: carbapenem-resistant *K. pneumoniae*; 3GCRKP: third-generation cephalosporin-resistant *K. pneumoniae*; CRPA: carbapenem-resistant *P. aeruginosa*; MRSA: methicillin-resistant *S. aureus*; PRSP: penicillin-resistant *S. pneumoniae*; FRAB: fluoroquinolone-resistant *A. baumannii*; CRAB: carbapenem-resistant *A. baumannii*; FREC: fluoroquinolone-resistant *E. coli*; CREC: carbapenem-resistant *E. coli*.
Averages for different country groups are unweighted.
Source: OECD analyses of data from surveillance networks included in OneHealthTrust/IQVIA (2022[33]), *ResistanceMap – Antibiotic Use*, https://resistancemap.cddep.org/AntibioticUse.php.

Figure 2.6 suggests that, in a minority of countries, resistance proportions, averaged across 12 antibiotic-bacterium combinations, are estimated to increase or decrease in both periods, 2009-19 and 2019-35. While the temporal variation across countries for average resistance proportions is small, Figure 2.6 illustrates the wide range in average resistance proportions across countries, broad differences that seem to remain over time. There is little evidence of any convergence in resistance proportions across countries. Countries with historically low average resistance proportions are likely to maintain these into 2035. Countries with historically high average resistance proportions are estimated to have experienced most of the growth in 2009-19, with average resistance proportions either flattening or dropping slightly by 2035.

Figure 2.6. Projected average proportion of infections caused by bacteria resistant to antimicrobial treatment for 12 antibiotic-bacterium combinations in 2009, 2019 and 2035



Note: For countries on the left of this graph, resistance proportions are higher in 2035, compared to 2019. For countries on the right, rates are be lower in 2035. Otherwise, countries are sorted left to right based on ascending resistance proportions in 2019. Averages for different country groups are unweighted.

Source: OECD analyses of data from surveillance networks included in OneHealthTrust/IQVIA (2022[33]), *ResistanceMap – Antibiotic Use*, https://resistancemap.cddep.org/AntibioticUse.php.

StatLink https://stat.link/8l5h7e

Despite a projected overall stabilisation of resistance proportions, averaged across 12 antibiotic-bacterium combinations, resistance proportions for certain countries and antibiotic-bacterium pairs are projected to remain dangerously high. In 2035, it is projected that in G20 countries around half of infections due to *A. baumannii* could be resistant to either fluoroquinolones or carbapenems (Table 2.4).

Table 2.4. Estimated resistance proportions for 12 priority antibiotic-bacterium combinations, 2035

Country	FRAB	CRAB	3GCRKP	FREC	CRPA	3GCREC	MRSA	VREFm	PRSP	CRKP	CREC	VREFs	Average
India	79.9	72	83.8	84	45.2	80.8	62.5	27.4	16.6	62	28.7	11.7	54.6
Türkiye	85.9	84.9	70.6	56.8	42.7	48.2	28.7	17.8	42.4	37.2	5.8	4	43.8
Greece	89.8	86.3	68.8	32.3	47.1	23.9	37.4	29.9	18	59.8	1.2	0.9	41.3
Romania	84.9	81.4	67.4	31.1	55.9	24.4	43.5	34.4	28.1	37.9	0.3	1.9	40.9
Saudi Arabia	70.9	76.6	62.3	49.5	34	50.1	44.3	27.1	24.3	35.8	5.2	4.6	40.4
Indonesia	77	53.5	72.4	63.5	35.2	62.9	44.5	26.2	18.9	16.8	5.8	3.8	40
Mexico	84.5	69.3	47.2	69.2	33.3	59	44.3	25.9	18.3	9.7	3.1	1.9	38.8
China	71.1	68.3	54.6	64.5	30.8	60.4	39.2	15.5	13	30.3	9	7.5	38.7
Argentina	74.7	72	56.2	37.4	33.5	22.6	44.1	58.7	23.6	21.1	4.1	5.7	37.8
Poland	83.7	66.2	61.6	46.4	34	23.1	22.7	46.9	18.8	16.5	7	9.3	36.3
Bulgaria	84.1	72.7	76.1	44.4	31.5	45.1	16.7	11.6	11.2	39.8	0.5	0.4	36.2
Cyprus	79.2	76.7	46.5	47	25.5	31.1	36.7	39.1	14	16	1.1	0.9	34.5
Croatia	84.9	84.7	50.1	34.3	34.1	17	25.8	23.7	18.8	23.6	0	0.9	33.2
South Africa	66.4	75.2	70.7	31.4	37.8	29.6	25.9	14	27.2	14.1	1.2	1.2	32.9
Italy	76.4	70.8	53.8	41.9	20.8	30.7	34.5	19.5	10.7	22.1	0.7	1.7	32
Lithuania	87.6	81.6	51.2	24	24.8	20.8	9.4	38.7	14.3	4.6	0	2.6	30

Country	FRAB	CRAB	3GCRKP	FREC	CRPA	3GCREC	MRSA	VREFm	PRSP	CRKP	CREC	VREFs	Average
Brazil	61.7	60.2	52.4	50	29.1	26.2	19.7	20.6	15.6	20.6	0.8	1	29.8
Korea	53.1	54.5	32.9	44.9	26.7	36	43.4	20.4	32.7	4.5	2.5	3.2	29.6
Slovak Republic	63.4	42.5	55.2	44	42.9	27.8	28.5	28.4	12.5	6.6	0	0.1	29.3
Latvia	80.3	73.7	41.2	28.7	36.7	20.4	6.1	35.2	18.7	3.4	0.2	4.5	29.1
Costa Rica	69.2	58.6	44.2	24.4	31	26.9	32.3	17	16.9	12.2	3.4	2.9	28.3
Colombia	67.5	56.5	43.6	24.5	29.3	28.6	32.4	19.8	16.1	12.5	2.6	2.3	28
Peru	64.5	50.6	40.5	27.5	26.5	29.1	28.7	27.9	16.6	12.4	3.8	4.7	27.7
Hungary	76.3	53.1	40.2	30.7	34.1	22.7	21.4	26.4	9.2	2	0	0	26.4
Chile	56.5	48.9	36.6	32.9	24.4	24	27	22.4	14.9	11.2	1.6	2	25.2
Malta	53.5	40.5	40.4	40.8	18.3	18.4	18.2	19.8	22.5	16.4	3.6	3.9	24.7
United States	47.3	24.8	15.5	26.4	16.3	13.8	40.7	67.1	19.3	7.7	1.7	3.9	23.7
Portugal	47.8	35.4	50.2	29.9	21.4	17.9	35.8	9.6	13.4	14.6	0.2	0.9	23.1
Spain	61.6	56.2	27	32.9	22.9	16	24.8	2.5	21.8	7	1	0	22.8
Luxembourg	40.7	33.6	34.2	28	18.4	20.9	11.4	11	20	9	7.6	8.4	20.3
Israel	48.1	33.9	26.9	24.4	17.1	16.9	20.2	28	14.2	7.7	0.9	1.6	20
Czech Republic	49.5	22.1	50.4	26.2	22.6	16	13.6	21.8	4.5	1.1	0.4	0.3	19
Canada	39.4	31	13	29.2	24.2	14.7	14	30.8	9.8	7	1.6	1.3	18
Slovenia	60.3	30.3	20.1	22.9	21.1	12	8.8	2.7	10.6	0.9	0.6	0.5	15.9
New Zealand	38.4	23	17.4	14.4	16.1	12.7	16.3	23.5	14.4	7.1	1.1	1.6	15.5
Japan	38	5.6	7.9	32.6	17.8	20.9	31.6	23.1	3	1.6	0.7	1.3	15.3
Ireland	14.2	3.8	17.9	24.3	12.3	15	11.7	36.9	29.6	1.3	0.4	1.3	14.1
Australia	17.1	6.8	10	20.2	10.3	13.2	16.2	47.7	13.8	2.2	0.2	0.5	13.2
France	21.9	6.9	30.3	18.5	19.8	11.5	10.6	2	29.7	1.6	0.9	0.9	12.9
Iceland	36.8	24	8.6	15.4	16	10.4	2.4	19.1	11.9	2.7	0.7	0.3	12.4
Estonia	40.9	24.5	15.8	21.8	17.1	10.7	3.5	3.7	5.6	0.6	0.2	0.1	12
Germany	22.6	4.4	13.2	22.1	20.9	14	8.3	26.2	5	0.4	0	0	11.4
Belgium	16.4	4.3	21.3	23.9	13.5	13	10.3	2.9	14	1.8	0	0.9	10.2
Finland	49.3	2.7	7.5	15.7	11.2	8.4	2.5	0.6	14.1	0.3	0	0.2	9.4
United Kingdom	14.3	3.2	13.4	19.7	8.7	13.2	7.5	23.3	5.4	1	0	2	9.3
Austria	27.9	7.5	10.6	21.4	16.5	10.5	6.2	3.6	4.7	1	0	0.1	9.2
Switzerland	22.6	6.7	8.4	19.8	12.4	10.2	3.6	2.7	5.7	1.9	5.2	0.2	8.3
Sweden	31.2	3.3	9.2	19.7	11.1	9.3	2.6	0.8	6.6	0.3	0	0	7.9
Denmark	12.2	2.6	9.1	14.2	6.3	8.8	2.1	13.6	5.5	0.3	0	0.1	6.2
Netherlands	16.7	2.6	11	19	7.7	8.6	1.7	1.2	4.6	0.3	0	0	6.1
Norway	9.6	3.8	9.3	15	11.4	6.6	1.5	1.2	6.2	0.1	0	0.7	5.5
G20 countries	56	47	42	42	27	34	31	27	18	16	4	3	29
ALL countries	54	41.9	36.8	32.6	24.7	23.8	22.1	21.6	15.4	12.3	2.3	2.2	24.1
EU/EEA countries	51	37	34	28	23	18	16	18	14	10	1	1	21
OECD countries	45	30	28	28	21	18	17	19	14	7	1	2	19

Note: The colour scheme is based on a two-point scale (minimum in light grey, maximum in blue and points in between coloured proportionally). Countries (and country groupings) are sorted from top to bottom from highest to lowest average resistance proportions (across antibiotic-bacterium combinations). Antibiotic-bacterium combinations are sorted from left to right from highest to lowest average resistance proportions (across countries). VREFs: vancomycin-resistant *E. faecalis*; VREFm: vancomycin-resistant *E. faecium*; 3GCREC: third-generation cephalosporin-resistant *E. coli*; CRKP: carbapenem-resistant *K. pneumoniae*; 3GCRKP: third-generation cephalosporin-resistant *K. pneumoniae*; CRPA: carbapenem-resistant *P. aeruginosa*; MRSA: meticillin-resistant *S. aureus*; PRSP: penicillin-resistant *S. pneumoniae*; FRAB: fluoroquinolone-resistant *A. baumannii*; CRAB: carbapenem-resistant *A. baumannii*; FREC: fluoroquinolone-resistant *E. coli*; CREC: carbapenem-resistant *E. coli*.
Averages for different country groups are unweighted.
Source: OECD analyses of data from surveillance networks included in OneHealthTrust/IQVIA (2022[33]), *ResistanceMap – Antibiotic Use*, https://resistancemap.cddep.org/AntibioticUse.php.

In the OECD, Greece and Türkiye are likely to continue to exhibit very significant average resistant proportions, with more than half of infections due to *K. pneumoniae* in Greece projected to be resistant to carbapenem and over half of infections due to *E. coli* estimated to be resistant to fluoroquinolones in Türkiye in 2035.

Box 2.2. Comparison of projections presented here and those published in 2018

Some of the estimates of resistance proportions, especially the averages, presented here are not strictly comparable to the estimates published in the OECD report *Stemming the Superbug Tide* (2018[3]), for two reasons. First, the new estimates presented in this report are for 12 antibiotic-bacterium combinations compared to 8 in 2018. Second, the reference years are slightly different: whereas 2005, 2015 and 2030 were used in *Stemming the Superbug Tide*, 2009, 2019 and 2035 are used in this report.

While this complicates comparisons of averages, it is possible to compare estimates for antibiotic-bacterium combinations in individual countries in specific years. This comparison shows that new estimates of resistance proportions are lower than estimates from 2018. The differences are largest for countries where data are missing the most, including Brazil, China, Costa Rica, Indonesia, Israel and Saudi Arabia. This is aligned with expectations that when new data became available, it would be the countries with the most missing data that would see the biggest changes. Oldenkamp et al. (2021[16]) recently explored the impact new surveillance data could have on predictions of resistance proportions, using an approach similar to the one used here. They found that predictions for countries like Brazil and Indonesia were volatile and more affected by uncertainty in the estimation procedures.

A key characteristic of the methodology employed here, and by Oldenkamp et al. (2021[16]), is that missing data are imputed based on existing surveillance data and relationships with covariates. When new data become available, it is likely that all estimates – even those for countries where no new data exist – will be revised in light of the new evidence. While a formal assessment of the key drivers behind these changes was not conducted, it is likely that new lower estimates are driven by at least four factors. One, there were more countries where resistance proportions, averaged across 12 antibiotic-bacterium combinations, exhibited a downward trend in the period 2009-19 than in the period 2005-15. Second, antibiotic consumption in humans in the EU/EEA (a region that accounts for more than half of the 51 countries included here and most of the existing data) has decreased between 2010 and 2019. Third, antimicrobial consumption in animals – included in the estimation procedures for the first time under a One Health approach – has shown a downward trend in the EU/EEA and the OECD in the last years. Fourth, recent trends in AMR in the EU/EEA between 2016 and 2020 show some reductions.

For all this, when interpreting the results presented here, it is crucial to consider the (often significant) uncertainty that underlies the estimates – especially for countries where data are sparser. It is also vital that countries continue to invest in comprehensive and standardised surveillance efforts so that efforts to fill data gaps lead to more accurate and robust estimates.

Source: OECD (2018[3]), *Stemming the Superbug Tide: Just A Few Dollars More*, https://doi.org/10.1787/9789264307599-en; Oldenkamp, R. et al. (2021[16]), “Filling the gaps in the global prevalence map of clinical antimicrobial resistance”, https://doi.org/10.1073/PNAS.2013515118.

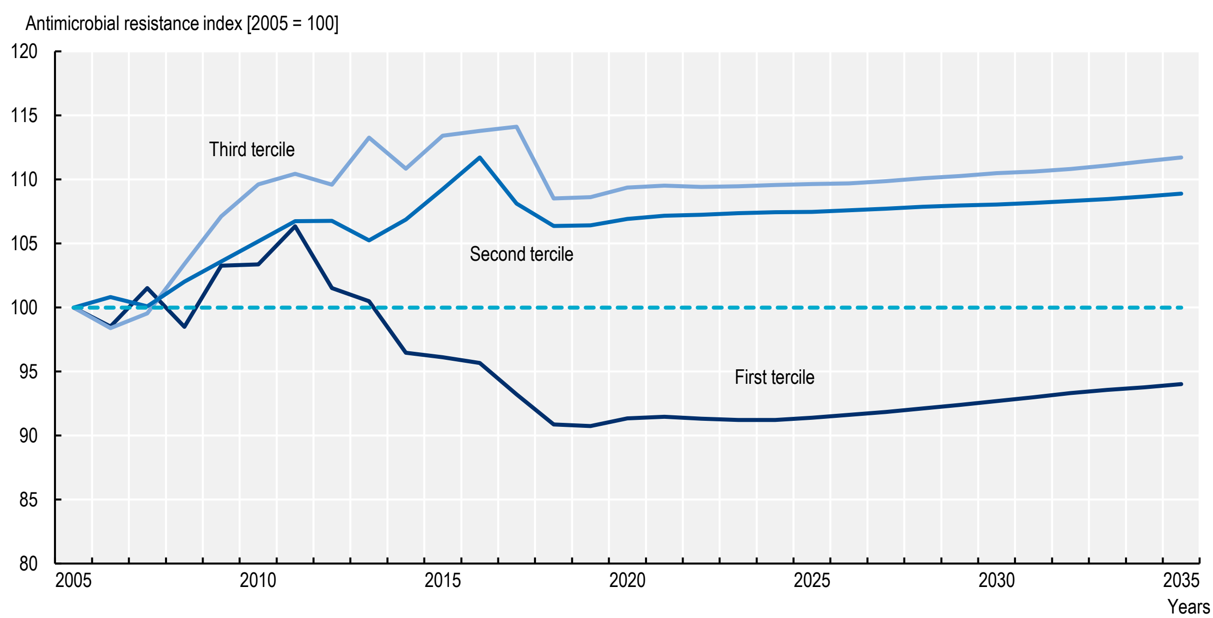
Resistance proportions are forecasted to remain high compared to 2005

There is no clear projected reduction in the broad range between the highest average resistance proportions and the lowest average resistance proportions in OECD countries (Figure 2.7). Between 2005 and around 2011, in countries at different levels of resistance, averaged across 12 antibiotic-bacterium combinations, AMR evolved similarly, with resistance proportions growing compared to the 2005 baseline. However, from around 2011, in countries in the bottom tercile of resistance proportions (based on 2005 levels), resistance proportion started to decrease, while continuing their upward trends in countries in the second and third terciles. While from 2017, resistance proportions in countries in the bottom tercile have trended significantly upward, there is still a significant gap between resistance proportions in the top tercile and the bottom tercile.

Countries in the top two terciles face significant challenges. Not only are they starting in 2005 with higher resistance proportions than in countries in the bottom tercile but resistance proportions have increased more since 2005 compared to countries in the bottom tercile. Moreover, the projection is that the gaps between countries in the bottom and top terciles will slightly widen in coming years. The range in average resistance proportions across countries is projected to go from 5.7-46.5% in 2019 to 5.5-43.8% by 2035, barely changing. This indicates that countries on the higher end of the range need to do more to reverse current trends or they will continue to face persistently high resistance.

Figure 2.7. In OECD, resistance proportions estimated to remain persistently higher than in 2005

Countries are grouped into terciles based on average resistance proportions for 2005 and resistance proportions are then normalised to average antimicrobial resistance in 2005 (equal to 100) for each tercile



Note: Countries were split into terciles based on 2005 resistance proportions, averaged across 12 antibiotic-bacterium combinations. Data were normalised to average antimicrobial resistance in 2005 (equal to 100) for each tercile (e.g. a value of 112 for resistance in second tercile countries in 2017 means that resistance is 12% higher than it was in 2005 in those countries). Averages for different country groups are unweighted. Historical data go from 2005 to 2020 and forecasts start in 2021.
Source: OECD analyses of data from surveillance networks included in OneHealthTrust/IQVIA (2022[33]), *ResistanceMap – Antibiotic Use*, https://resistancemap.cddep.org/AntibioticUse.php.

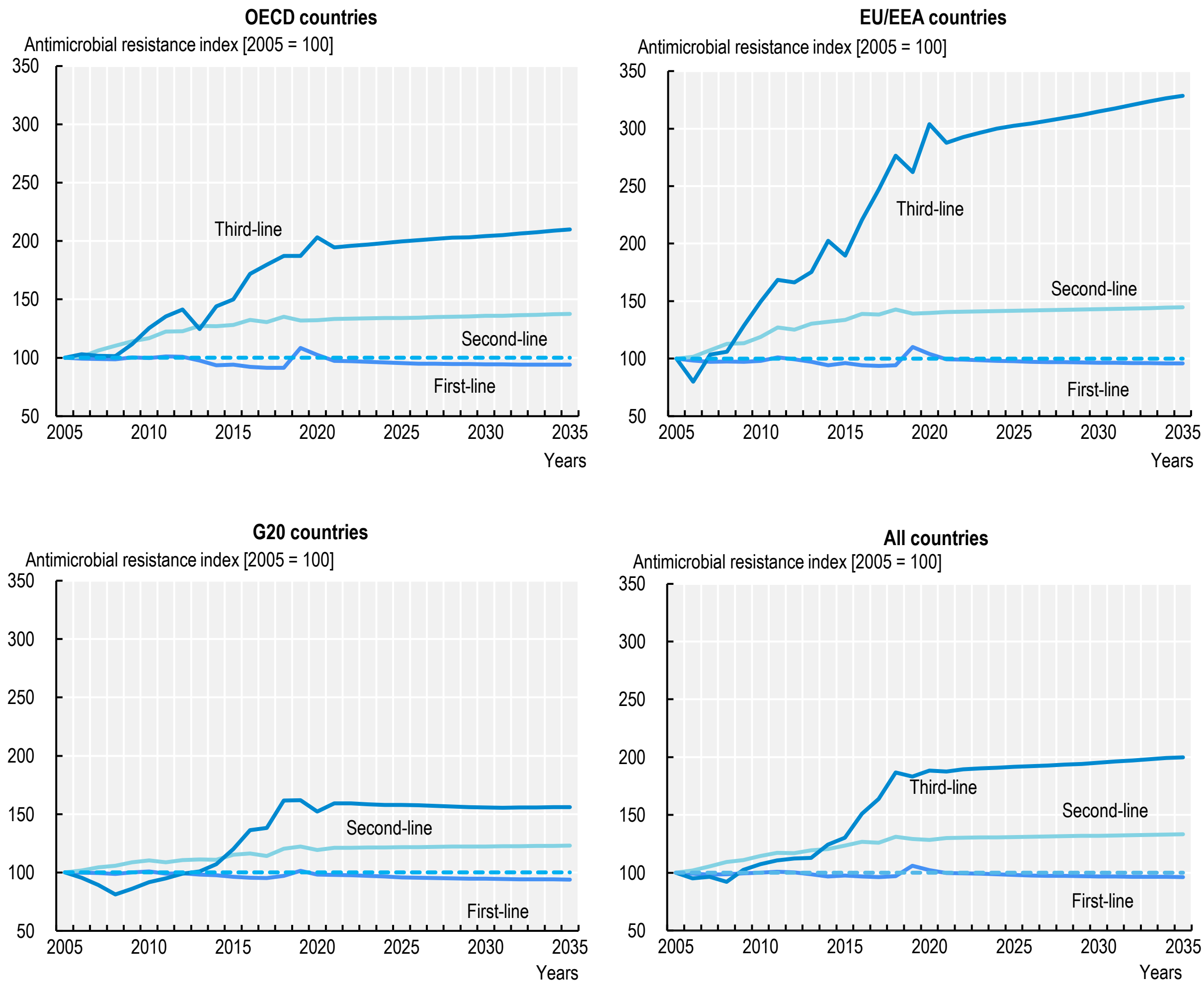
StatLink https://stat.link/1kj0xf

Concerning trends in resistance to third-line antimicrobials and multidrug resistance

Of added concern are also trends in resistance to first-, second- and third-line antimicrobials which indicate that, from 2005, relative growth rates for resistance to second- and third-line antibiotics are higher than for resistance to first-line treatments (Figure 2.8). Resistance to third-line antimicrobials specifically has increased markedly between 2005 and 2019 in EU/EEA, G20 and OECD countries, albeit from still mostly low levels (Table 2.1) which should remain relatively low (Table 2.4). However, resistance to carbapenems, a third-line treatment, in infections due to *K. pneumoniae* is very high in Greece and quite high in Bulgaria, Romania and Türkiye. Furthermore, while the overall consumption of antimicrobials in humans is likely to decrease or stagnate in the future, the consumption of carbapenems is projected to increase. The more these treatments are used, the more likely it is that resistance develops. As resistance develops, and in absence of new antibiotics, the only options left to treat infections with resistant bacteria will be older antimicrobial agents, including those with potentially lower efficacy, such as polymyxins (e.g. colistin) or combination therapy.

Resistance among difficult-to-treat microorganisms *P. aeruginosa* is also concerning. These bacteria are intrinsically resistant to several antimicrobial agents and remain a major cause of healthcare-associated infections (ECDC, 2020[74]; CDC, 2019[75]). Resistance proportions for carbapenem-resistant *P. aeruginosa* have actually decreased on average in the EU/EEA and the United States in the recent past, resistance proportions are projected to increase slightly up to 2035 (Table 2.3). Already in 2019, on average across OECD countries, one in five infections due to *P. aeruginosa* were already resistant to carbapenems. Resistance proportions in Greece, Hungary and the Slovak Republic were particularly high. With consumption of carbapenems projected to increase up to 2035, certainly, it remains crucial to balance access to antimicrobial therapies with prudent and appropriate use (stewardship). Interventions for infection prevention and control, especially in healthcare settings, are also essential to prevent further emergence and spread of resistance. Finally, multidrug resistance is already high in certain pathogens. According to the latest European data (EFSA/ECDC, 2020[68]), almost a third of *Salmonella* spp. isolates from humans were multidrug resistant in 2018 (OECD et al., 2022[35]).

Figure 2.8. Trends in antimicrobial resistance in selected regions and country groups among priority antibiotic-bacterium combinations, by line of antimicrobial treatment



Note: Data were normalised to average antimicrobial resistance in 2005 (equal to 100) for each treatment line (e.g. a value of 150 for resistance to second-line treatments in 2015 in G20 countries means that resistance to second-line treatments is 50% higher than it was in 2005 in G20 countries). Resistance to first-line treatments is defined as the average of the proportions of penicillin-resistant *S. pneumoniae*, MRSA, fluoroquinolone-resistant *A. baumannii*, and carbapenem-resistant *A. baumannii*. Resistance to second-line treatments is the average of the proportions of *E. coli* and *K. pneumoniae* resistant to third-generation cephalosporins, *E. coli* resistant to fluoroquinolones, vancomycin-resistant *E. faecalis*, vancomycin-resistant *E. faecium*, and carbapenem-resistant *P. aeruginosa*. Resistance to third-line treatments is defined as the average of the proportions of *K. pneumoniae* resistant to carbapenems and carbapenem-resistant *E. coli*. Averages for different country groups are unweighted. Historical data go from 2005 to 2020, and forecasts start in 2021.
Source: OECD analyses of data from surveillance networks included in OneHealthTrust/IQVIA (2022[33]), *ResistanceMap – Antibiotic Use*, https://resistancemap.cddep.org/AntibioticUse.php.

StatLink https://stat.link/cyqbpn

Conclusion

Over the last two decades, on average across OECD countries, antimicrobial consumption in humans increased only slightly and, in the last couple of years, the trend has been downward. While the levels and trends across individual countries were very heterogeneous, recent data seem to suggest that antimicrobial stewardship may be leading to real change. If total antibiotic consumption continues to evolve along the same lines as in the period 2000-15, then it is estimated that consumption will decrease between 2015 and 2035 by 3% in the OECD as a whole. Also in the food animal sector, antimicrobial is projected to decrease, following a pattern of reductions in the last decade in the EU/EEA and OECD. Despite these positive projections, consumption of highest priority and third-line antibiotics is growing. In 2015, there were 14 OECD countries, along with Brazil, China and India, that did not meet the WHO target for Access antibiotics to make up at least 60% of total national consumption. Vaccination targets for seasonal influenza among older populations, which could help reduce the need for antimicrobials, are also widely missed.

Alongside downward trends in total antimicrobial consumption in humans and animals, resistance proportions are projected to drop slightly by 2035, on average across 12 priority antibiotic-bacterium combinations, if current trends in resistance, and correlates of resistance, continue into the future and no other policy actions are taken beyond the ones currently in place. However, regional averages mask the ten-fold difference in average resistance proportions across OECD countries, with more than half of infections due to *K. pneumoniae* in Greece projected to be resistant to carbapenems and over half of infections due to *E. coli* estimated to be resistant to fluoroquinolones in Türkiye in 2035. What is worse, there is no evidence of a convergence in resistance proportions across countries; in fact, it is projected that the range between the countries with the most resistance and those with less resistance will slightly widen in 2035. This indicates that countries on the higher end of the range need to do more to reverse current trends, or they will continue to face persistently high resistance.

While modelling has been increasingly used to make up for gaps in data collection and while it can be useful when data are unavailable or are difficult to compare without manipulation, modelling is not a substitute for comprehensive high-quality surveillance and should not detract from efforts to expand and improve surveillance networks. Furthermore, it is intrinsically difficult to predict a new resistance mechanism using models. Despite recent progress in surveillance, there are still gaps in the collection and reporting of comprehensive, internationally comparable, standardised data on antimicrobial consumption and resistance. Without these data, there can be no accurate understanding of the AMR challenge, its consequences, its evolution and whether actions to tackle the challenge are effective. Efforts to standardise and harmonise data collection from a One Health approach have been especially slow.

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Notes

[1]See *List of Enrolled Countries* link in https://www.who.int/initiatives/glass/country-participation (accessed March 2023).

[2] See https://www.ecdc.europa.eu/en/about-us/networks/disease-networks-and-laboratory-networks/ears-net-data (accessed March 2023).

[3] Ibid.

[4] Not all sales of antimicrobials lead to consumption, however data on consumption are difficult to obtain, if not impossible in the community. As such, sales are used throughout this chapter as an imperfect yet pragmatic proxy for consumption. The IQVIA MIDAS database estimates antibiotic consumption from the volume of antibiotics sold in retail and hospital pharmacies based on national sample surveys done by pharmaceutical sales distribution channels (i.e. from manufacturer to wholesaler to retailer).

[5] DDD is a standard measure for drugs, calculated as the assumed average maintenance dose per day for a drug used for its main indication in adults (WHO, 2003[77]). The unit used throughout this chapter is DDD per 1 000 inhabitants per day.

[6] Broad-spectrum antibiotics: broad-spectrum penicillins (ATC groups J01CR, J01CD), broad-spectrum cephalosporins (J01DC, J01DD), macrolides (J01 FA) except erythromycin (J01FA01) and fluoroquinolones (J01MA); narrow-spectrum antibiotics: narrow-spectrum penicillins (J01CA, J01CE, J01CF), narrow-spectrum cephalosporins (J01DB) and erythromycin (J01FA). Consumption expressed in DDD per 1 000 inhabitants per day.

[7] Proportion (%) of glycopeptides, third- and fourth-generation cephalosporins, monobactams, carbapenems, fluoroquinolones, polymyxins, piperacillin and enzyme inhibitors, linezolid, tedizolid and daptomycin (DDD per 1 000 inhabitants per day) out of total hospital consumption of antibiotics for systemic use.

[8] Canada's National Aquaculture Public Reporting Data provide a comprehensive dataset containing a list of the type and quantities of drug and pesticide products used at aquaculture facilities to combat pests and microbial pathogens (Government of Canada, 2022[76]).

[9] NARMS Now: Human Data, an interactive tool from CDC, can be accessed from https://wwwn.cdc.gov/NARMSNow.

[10] Reports can be found at http://www.google.com/covid19/mobility/ (last accessed June 2022).

3 Health and economic burden of antimicrobial resistance

This chapter provides an overview of the burden of resistant infections on population health and the economy. The results presented in the chapter are generated using the OECD Strategic Public Health Planning for Antimicrobial Resistance (SPHeP-AMR) model based on data gathered for 34 countries, including 29 European Union (EU)/European Economic Area (EEA) countries as well as Japan, Switzerland, Türkiye, the United Kingdom and the United States. The burden of AMR on population health is assessed through measures of mortality, life expectancy and morbidity. The impact on the economy is examined through the use of healthcare resources, health expenditure, participation in the labour force and workforce productivity.

Key findings

AMR continues to pose great risks to population health in OECD and EU/EEA countries

- Nearly 4.3 million resistant infections occur each year in the 34 OECD countries and EU/EEA countries included in the analysis.
- While around 35% of resistant infections are acquired in healthcare settings each year across all countries included in the OECD analysis, these infections account for about 62% to 73% of AMR-related deaths.
- Around three-quarters of all deaths that occur due to AMR each year are caused by 3 pathogens – *Escherichia coli (E. coli), Klebsiella pneumoniae (K. pneumoniae)* and *Staphylococcus aureus (S. aureus)* – across the 34 countries included in the analysis.
- A geographic gradient persists in the mortality burden due to AMR. Generally, countries in southern Europe such as Italy, Malta and Portugal are estimated to have the greatest mortality rates each year due to AMR by 2050 whereas the Netherlands and Norway are expected to face the smallest mortality burden. Across non-EU/EEA member OECD countries, Türkiye is estimated to face the highest mortality rate attributable to resistant infections.
- Complete elimination of AMR would produce a gain of, on average, about 133 life years (LYs) per 100 000 persons per year up to 2050 across the 34 countries included in the analysis. This figure stands at around 40 LYs gained per 100 000 persons if resistant infections were to be replaced by susceptible infections. Under both scenarios, the greatest gains per capita in LYs are estimated to be experienced in Italy and Malta across EU/EEA countries and in Türkiye across non-EU/EEA member OECD countries. If resistant infections are not eliminated, the reduction in life expectancy due to AMR can be around one-third of the reduction in life expectancy due to COVID-19 between 2019-20.
- Impact on quality of life, as measured in gains in disability-adjusted life-years (DALYs) is estimated to be around 18% greater than the estimated gains in LYs if AMR was entirely eliminated and around the same magnitude if resistant infections were replaced by susceptible infections.

Infections caused by resistant organisms are estimated to have deleterious effects on the budget of health systems across the OECD and EU/EEA countries included in the analysis

- AMR will put substantial pressure on hospital resources that were already stretched throughout the COVID-19 pandemic. Using the elimination scenario, an additional 32.5 million extra days are estimated to be spent in hospitals to treat resistant infections each year up to 2050 across the 34 countries included in the analysis. This figure stands at around 6.9 million extra hospital days using the replacement scenario. This would be equivalent to using the entire acute bed capacity in Spain in 2020 for nearly one year under the elimination scenario and around two months under the replacement scenario.
- If resistance proportions continue to follow the expected growth rates, the OECD and EU/EEA countries included in the analysis are estimated to spend around USD 28.9 billion each year up to 2050 adjusting for purchasing power parity (PPP) for treating resistant infections using the elimination scenario, which corresponds to USD PPP 25.6 per capita. Using the replacement scenario, the annual healthcare spending on AMR is estimated to reach around USD PPP 5.9 billion up to 2050, corresponding to about USD PPP 5.2 per capita.

- The economic burden of healthcare expenditures attributable to resistant infections is marked by important differences across countries. Using both scenarios, the greatest amount of financial resources per capita each year up to 2050 are estimated to be spent by Italy and Luxembourg across the EU/EEA countries and by Switzerland and the United States across non-EU/EEA member OECD countries.
- The cost of inaction to tackle AMR in the next three decades will exceed treatment costs due to COVID-19 in 2020. In 17 countries for which data are available, the average annual health expenditure incurred each year due to AMR is about 19% of the total health expenditure due to treating COVID-19 patients in 2020 using the elimination scenario and 4% using the replacement scenario. This means that the cost incurred around every five years for treating patients with resistant infections will be equivalent to the treatment costs due to COVID-19 in 2020 using the elimination scenario.

Resistant infections have substantial consequences for workforce participation and productivity and the overall macroeconomic performance

- Resistant infections are associated with notable declines in participation in the labour force and reductions in productivity, estimated to exceed 734 000 full-time workers annually up to 2050 across the 34 countries included in the analysis.
- Across the 34 countries included in the analysis, the total annual losses in the labour market output attributable to AMR averages around USD PPP 36.9 billion, corresponding to USD PPP 32.7 per capita using the elimination scenario. This corresponds to roughly one-fifth of the gross domestic product (GDP) in Portugal in 2020. Annual losses in labour market output are estimated to average around USD PPP 6.6 billion each year up to 2050 using the replacement scenario, corresponding to USD PPP 5.9 per capita. These losses are driven primarily by the declines in employment as well as reductions in workforce productivity particularly due to considerable increases in absenteeism from work.

The fight against antimicrobial resistance is far from over

It is widely recognized that AMR remains one of the leading challenges to human health, jeopardising the effectiveness of many medical and public health advances made in the 20th century. Resistance to readily available, affordable treatments often means that providers must treat such infections with medicines that are more costly, less effective, unavailable or unaffordable in many settings (WHO, 2015[1]).

Results from Chapter 2 suggest that between 2019 and 2035, the average resistance proportions in OECD across 12 priority antibiotic-bacterium combinations are projected to remain largely stable. This new round of analyses revises a previous projection concluding that, between 2015 and 2030, there would have been a 1 percentage point increase in the average resistance proportions, assuming that no new policy actions are implemented beyond those already in place (OECD, 2018[2]). Policies put in place since the previous OECD analysis may have contributed to curbing the growth rate of resistance proportions (see Chapter 4). In recent years, the recognition of AMR as a global health priority led to the proliferation of various policy initiatives with many OECD countries developing their national action plans to tackle AMR in accordance with their own priorities and rolling out a wide range of multi-sectoral programmes with aims ranging from optimising the use of antimicrobials in human and animal health, improving infection prevention and control practices to increasing AMR awareness and understanding in the general public.

Despite some progress, the OECD analysis revealed alarming differences in the resistance proportions across countries, with a tenfold difference between countries with the highest and lowest estimated proportion of resistant infections (see Chapter 2). The results also pointed to worrisome variations in resistance proportions across antibiotic-bacterium combinations, across countries within antibiotic-bacterium combinations as well as antibiotic-bacterium combinations within countries. Exacerbating these challenges are the uncertainties surrounding the COVID-19 pandemic and its impact on AMR. As new data and analyses continue to emerge, it is crucial to provide accurate estimates of the health and economic burden of AMR to inform the design and implementation of policies and regulations to limit its consequences.

The analyses presented in this chapter builds on the previous OECD analysis on AMR (OECD, 2018[2]), using the most recent data on the incidence of infections and the prevalence of AMR provided by national governmental agencies or by intergovernmental organisations such as the European Centre for Disease Prevention and Control (ECDC). Data provided to the OECD are collected by national surveillance systems and generally reflect the national official statistics. This approach has many advantages. For example, the data used in the OECD analysis are consistent with information presented by countries in their own national reports and evaluations produced by the ECDC. The data obtained from the ECDC are gathered from laboratories and hospitals in countries using procedures that aim to harmonise data collection and management methodologies across countries (ECDC, 2022[3]).

The results presented in this chapter should be considered as conservative. While many OECD countries and EU/EEA countries made efforts in recent years to strengthen AMR surveillance, detection and reporting capacity, notable cross-country differences persist (see Chapter 4). It is important to note that these differences can mean that countries with more accurate reporting systems may show a higher AMR burden because they face a lower risk of under-reporting. Considering this, OECD estimates, both in terms of the overall AMR burden and cross-country comparisons, may differ from estimates generated by other analyses using different data sources. For example, one recent academic analysis that combined data from various sources (e.g. data that are not publicly available, literature reviews and other sources) suggested a significantly higher incidence of infections and the order of countries in terms of their AMR burden differed from those presented in this chapter (Mestrovic et al., 2022[4]).

The chapter starts by providing a brief overview of the current evidence describing the burden of AMR from a One Health perspective and it highlights major knowledge gaps in the current literature. Next, it describes the OECD Strategic Public Health Planning for AMR (SPHeP-AMR) model and presents results across four main areas: i) human population health; ii) healthcare resources and expenditure; iii) labour markets and workforce productivity; and iv) national GDP and fiscal pressure. Next, the chapter discusses how estimates from the OECD compare against other major modelling-based analyses. The final section summarises key takeaways and discusses their policy implications.

In line with the One Health approach, a growing body of evidence emerging from multiple sectors sheds light on the health and economic burden of AMR

Estimating the AMR burden requires acknowledging and measuring the impacts of relationships between human, animal and environmental sectors with respect to AMR emergence and spread. Increasingly understood to be a multi-sectoral problem with resistant organisms evolving and spreading through a complex ecosystem of shared human, animal and environmental habitats, recommended approaches to estimating the burden of AMR have shifted towards a One Health perspective (Hernando-Amado et al., 2019[5]; Thakur and Gray, 2019[6]; Prestinaci, Pezzotti and Pantosti, 2015[7]). This perspective recognises the interconnectedness and emphasises unified efforts across human, animal and environmental sectors to combat the spread of resistant bacteria and resistance determinants across borders (FAO and WHO, 2021[8]). One positive fact is that the literature that examines the health and economic burden of resistant infections has grown since previous OECD analysis. However, most of these studies focused on human health, estimating the AMR burden from the patient, healthcare system or economic perspectives. However, there remains a dearth of evidence that examines the complex relationships between human, animal and plant health, as well as the role of the environment in the emergence and spread of AMR.

In the human health sector, several studies emerged since the 2018 OECD analysis that provided estimates on the health and economic burden of AMR across the globe and among OECD and EU/EEA countries. One study attempted to estimate the global burden of AMR for 23 pathogens and 88 pathogen-drug combinations across 204 countries and territories in 2019 (Murray et al., 2022[9]). By gathering data from systematic literature reviews, hospital systems, surveillance systems and other sources, this study found that in a scenario that assumes susceptible infections would replace resistant infections, an estimated 1.27 million (95% uncertainty interval [UI] 0.911-1.71) deaths would be attributable to AMR. In an alternative scenario in which resistant infections are eliminated entirely, about 4.95 million (95% UI 3.62-6.57) deaths would be associated with resistant infections. The study pointed to substantial cross-country variation in deaths due to AMR. This study also concluded that 6 pathogens, combined, accounted for nearly three-quarters of deaths attributable to bacterial AMR, including *E. coli*, *S. aureus*, *K. pneumoniae*, *Streptococcus pneumoniae* (*S. pneumoniae*), *Acinetobacter baumannii* (*A. baumannii*) and *Pseudomonas aeruginosa* (*P. aeruginosa*).

Several studies with a focus on the EU/EEA countries also emerged. In 2019, one population-level modelling analysis estimated the incidence of infections with 16 antibiotic-bacterium combinations across the EU/EEA countries, using data gathered from the European Antimicrobial Resistance Surveillance Network (EARS-Net) in 2015 (Cassini et al., 2019[10]). This study found that the estimated number of resistant infections reached 671 689 (95% UI 583 148-763 966) in 2015. These infections are estimated to lead to around 33 110 (95% UI 28 480-38 430) deaths and around 874 541 (95% UI 768 837-989 068) DALYs. Similar to earlier OECD work, this study also found that the highest burden was among children under the age of 1 and the elderly population aged 65 and more. The highest AMR burden was estimated to be in Greece and Italy both in terms of deaths and DALYs attributable to resistant infections.

Subsequently, the European Antibiotic Resistance Collaborators estimated deaths and DALYs attributable to and associated with AMR in 2019 (Mestrovic et al., 2022[4]). This study replicated the modelling framework used in the 2019 global burden of AMR study (Murray et al., 2022[9]) and provided estimates for two separate counterfactual scenarios. In a scenario where resistant infections are replaced with susceptible ones, the number of deaths attributable to resist infections was estimated to reach around 133 000 (95% UI 90 100-188 000). In an alternative scenario, where resistant infections would be eliminated entirely, about 541 000 deaths (95% UI 370 000-763 000) were estimated to be associated with resistant infections. This study also concluded that around 84% of deaths were due to seven bacteria including *E. coli*, *S. aureus*, *K. pneumoniae*, *P. aeruginosa*, *Enterococcus faecium* (*E. faecium*), *S. pneumoniae* and *A. baumannii*.

Most recently, the ECDC provided new estimates for infections with 12 bacterium-antibiotic resistance combinations in the EU/EEA countries between 2016 and 2020 (ECDC, 2022[11]). This analysis found that the number of resistance infections ranged from around 685 433 (95% UI 589 451-792 873) in 2016 to 865 767 (95% UI 742 802-1 003 591) in 2019. Coupled with this trend were deaths due to resistant infections ranging from 30 730 (95% UI 26 935-34 836) in 2016 to 38 710 (95% UI 34 053-43 748) in 2019. The ECDC analysis highlighted that there were slight declines in the number of infections, attributable deaths and DALYs between 2019 and 2020, though this study also noted that the observed changes in health outcomes may be explained partly by the changes in surveillance practices and the provision of healthcare services in part driven by the COVID-19 pandemic. Moreover, some of the declines in the observed trends between 2019 and 2020 may be attributable to the measures put in place to curb the COVID-19 pandemic, including infection prevention and control (IPC) measures, and changes in the mix of patients treated in hospitals throughout the outbreak. Much like earlier studies, the ECDC analysis also showed that the age-specific burden was the greatest in infants and older adults. The overall burden of infections was estimated to be the highest in Greece, Italy and Romania after adjusting for differences in population size.

In the United States, the Centers for Disease Control and Prevention (CDC) have been regularly publishing technical reports that assess the impact of AMR in the country. In 2013, one CDC analysis quantified that the overall cost of AMR to the US economy was estimated to be around USD 20 billion in direct healthcare costs and an additional USD 35 billion in additional costs due to loss of productivity (CDC, 2013[12]). Following this analysis, one 2019 CDC analysis focused on 18 pathogens and found that around 2.8 million resistant infections occurred annually in the United States and the number of deaths due to AMR exceeded 35 000 each year (CDC, 2019[13]). This analysis also showed that deaths due to AMR declined by 18% between 2012 and 2017, with the size of this reduction reaching around 28% for deaths occurring in hospital settings. In 2022, the CDC published a special report that estimated the impact of COVID-19 on AMR (CDC, 2022[14]). Despite a number of challenges that may have hindered the precision of estimates, the CDC analysis found a 15% increase in the number of resistant infections between 2019 and 2020, with particularly alarming rising trends in infections due to carbapenem-resistant *Acinetobacter* (78%), antifungal-resistant *Candidate auris* (60%) and carbapenem-resistant *Enterobacterales* (35%). This analysis also noted that the COVID-19 pandemic led to a rise in antibiotic use and challenges in adhering to IPC guidelines. Combined, these factors led to an increase in healthcare-acquired infections (HAIs) and resistant infections in hospitals across the United States (CDC, 2022[14]).

In Canada, the Council of Canadian Academies (CCA) looked at the impact of AMR on population health and the economy (CCA, 2019[15]). This work estimated that AMR was associated with a reduction in labour productivity amounting to CAD 2 billion in 2018, with pronounced effects across industries including hospitality, transportation and education, as well as agriculture. Further, this study concluded that AMR was associated with longer hospital stays, prolonged courses of treatment and a rise in other expenses to the healthcare system. Combined, these costs amounted to about CAD 1.4 billion in 2018. This report also estimated that if resistance to first-line antimicrobials stayed constant at around 26% or rose to 40% by 2050, the cost of AMR to the Canadian economy would range between CAD 13 billion to CAD 21 billion every year and the annual cost to the Canadian health system would range from CAD 6 billion to CAD 8 billion respectively (CCA, 2019[15]).

In the animal sector, the emerging evidence suggests that the use of veterinary antimicrobials imposes significant health and economic costs on society. As discussed in more detail in Chapters 2 and 5, several studies showed that restrictions on antimicrobial use in animals have been associated with decreases in resistant bacteria in humans (Innes et al., 2019[16]; Scott et al., 2018[17]; Tang et al., 2017[18]). New evidence has also been emerging to provide estimates of how much AMR in animals contributes to AMR in humans. For instance, one recent analysis carried out jointly by the ECDC, European Food Safety Authority and European Medicines Agency explored the potential associations between antibiotic consumption and AMR in humans and food-producing animals, using data from various surveillance and monitoring networks (ECDC/EFSA/EMA, 2021[19]). Results from this work suggested, for instance, the consumption of fluoroquinolones and other quinolones in food-producing animals like pigs and veal indirectly contributed to resistance to fluoroquinolones in invasive *E. coli* from humans. Other studies suggested, however, that reducing the consumption of veterinary antimicrobials alone is unlikely to be sufficient to limit the burden of AMR in humans (van Bunnik and Woolhouse, 2017[20]; Booton et al., 2021[21]).

With respect to the environmental sector, resistant pathogens that contaminate natural ecosystems have been suggested to have an impact on human health. Such pathogens are primarily introduced to the environment by the release of human or animal waste (Hernando-Amado et al., 2019[5]; Karkman, Pärnänen and Larsson, 2019[22]). Research has identified contaminated drinking water to be an important vehicle of spread from the environment to humans (Hernando-Amado et al., 2019[5]; Yang et al., 2017[23]). Because of the role of waterways and water systems in the transfer of resistant pathogens from the environment to humans, efforts have focused on different types of wastewater treatment programmes to reduce the number of pathogens in water systems (Rodríguez-Chueca et al., 2019[24]; Jojoa-Sierra et al., 2017[25]; Paulus et al., 2019[26]). However, their downstream effects on human health and the burden of AMR remain largely unknown.

The OECD SPHeP-AMR model

The OECD SPHeP-AMR model is a microsimulation model that simulates the emergence and spread of AMR by replicating transmission dynamics in the health sector and the community in 34 countries using a One Health framework (Box 3.1). Broadly, the OECD model aims to:

- Build a business-as-usual model to quantify the health and economic impact of AMR.
- Forecast these impacts in the long term and generate a cost-effectiveness model that evaluates the potential impact of AMR-relevant interventions by comparing the effectiveness of scaling up these interventions against the business-as-usual scenario.

The remainder of this chapter focuses on the first objective whereas methodologies and results related to the second objective are presented in Chapter 6.

Box 3.1. The OECD SPHeP-AMR model

In line with the One Health approach, the OECD model includes an expanded list of priority antibiotic-bacterium pairs, covering infections with significant environmental and zoonotic reservoirs (Table 3.1). The selection of infective agents reflects expert advice based on the disease burden, policy priorities and data availability in the 34 countries included in the analysis. Some infections considered in the model can be both hospital- and community-acquired and they can be resistant to multiple antibiotics.

Table 3.1. Pathogens included in the model

Pathogens	Strain characteristics	Setting	
		Healthcare	Community
Acinetobacter spp.	*Acinetobacter* spp. excluding isolates with resistance to carbapenem and/or fluoroquinolones	x	
	Acinetobacter spp. with resistance to carbapenem	x	
	Acinetobacter spp. with multidrug resistance (i.e. three or more of piperacillin ± tazobactam, fluoroquinolones, ceftazidime and aminoglycosides) excluding carbapenem	x	
Campylobacter jejuni (*C. jejuni*) & *Campylobacter coli* (*C. coli*)	*C. jejuni* and *C. coli* excluding isolates with resistance to fluoroquinolones and macrolides		x
	C. jejuni and *C. coli* with resistance to fluoroquinolones		x
	C. jejuni and *C. coli* with resistance to macrolides		x
Enterococcus faecalis (*E. faecalis*) & *Enterococcus faecium* (*E. faecium*)	*E. faecalis* and *E. faecium* excluding vancomycin-resistant isolates	x	
	E. faecalis and *E. faecium* resistant to Vancomycin	x	
Escherichia coli (*E. coli*)	*E. coli* excluding isolates with resistance to third-generation cephalosporins and/or carbapenems	*x*	*x*
	E. coli. with resistance to carbapenem	*x*	*x*
	E. coli with resistance to third-generation cephalosporins excluding carbapenem	*x*	*x*
Klebsiella pneumoniae (*K. pneumoniae*)	*K. pneumoniae* excluding isolates with resistance to third-generation cephalosporins and/or carbapenems	x	x
	K. pneumoniae with resistance to third-generation cephalosporins excluding carbapenem	x	x
	K. pneumoniae with carbapenem resistance	x	
Mycobacterium tuberculosis (*M. tuberculosis*)	*M. tuberculosis* excluding isolates with multidrug resistance (i.e. at least isoniazid and rifampin) and extensive drug resistance (i.e. isoniazid, rifampin, plus any fluoroquinolone and at least one of three injectable second-line drugs: amikacin, kanamycin or capreomycin)		x
	M. tuberculosis with multidrug resistance (i.e. at least isoniazid and rifampin) excluding extensive drug resistance		x
	M. tuberculosis with extensive drug resistance (i.e. isoniazid, rifampin, plus any fluoroquinolone and at least one of three injectable second-line drugs: amikacin, kanamycin or capreomycin)		x
Pseudomonas aeruginosa (*P. aeruginosa*)	*P. aeruginosa* excluding isolates with carbapenem resistance and/or resistance to three or more of piperacillin ± tazobactam, fluoroquinolones, ceftazidime and aminoglycosides	x	
	P. aeruginosa with carbapenem resistance	x	
	P. aeruginosa with multidrug resistance (i.e. three or more of piperacillin ± tazobactam, fluoroquinolones, ceftazidime and aminoglycosides) excluding carbapenem	x	
Salmonella spp.	*Salmonella spp.* excluding isolates with resistance to fluoroquinolones, cephalosporins and resistance to three or more of ampicillin, chloramphenicol, streptomycin, sulphonamides and/or tetracycline		x
	Salmonella spp. with resistance to fluoroquinolones		x
	Salmonella spp. with multidrug resistance (i.e. three or more of ampicillin, chloramphenicol, streptomycin, sulphonamides and/or tetracycline, and/or cephalosporins) excluding fluoroquinolones		x
Staphylococcus aureus (*S. aureus*)	*S. aureus* excluding methicillin-resistant *Staphylococcus aureus* (MRSA) isolates	x	x
	Methicillin-resistant *S. aureus* (MRSA)	x	x
Streptococcus pneumoniae (*S. pneumoniae*)	*S. pneumoniae* excluding isolates with single penicillin resistance and combined resistance to penicillins and macrolides		x
	Penicillin-resistant *S. pneumoniae* excluding macrolide-resistant isolates		x
	S. pneumoniae with combined penicillin and macrolide resistance		x

Individual models were run separately for 34 countries: 29 EU/EEA countries and Japan, Switzerland, Türkiye, the United Kingdom and the United States. For each country, the OECD SPHeP-AMR model was initialised using country-aggregated data collated across multiple datasets available in the public domain and national datasets:

- **Demographic characteristics of populations**: The SPHeP-AMR model simulates dynamic populations based on historical and projected birth, migration and mortality rates available by sex and age. Data informing the composition of these populations for each country examined in the model were obtained from the Human Mortality Database maintained by researchers in Germany and the United States with the support of collaborators from around the world.
- **Infection epidemiology for each antibiotic-bacterium pair**: The ECDC provided epidemiological data on the antibiotic-bacterium pairs analysed in 29 EU/EEA countries (ECDC, 2022[11]). Data for Japan, Switzerland and the United States was provided by local experts contacted via national delegates to the OECD Expert Group on the Economics of Public Health. Data for Türkiye were provided by the World Health Organization (WHO) Regional Office for Europe.
- **Hospital resource use**: Statistics on the use of hospital resources and related expenditure were sourced from OECD.Stat and other international datasets such as Eurostat. The likelihood of hospitalisation by age and gender was derived from an OECD analysis.
- **Labour market and productivity indicators**: Data on employment and related labour market features were obtained from Eurostat and the International Labour Organization (ILO) databases. Data informing measures of absenteeism and presenteeism to compute changes in labour productivity were obtained based on a review of the published academic literature.

Analyses were conducted from a societal perspective, considering direct and indirect healthcare costs as well as costs arising from losses in labour productivity among infected individuals.

Health impacts capture mortality and morbidity due to infections caused by resistant organisms and are measured through the number of deaths due to AMR, losses in life expectancy (LE) and healthy life expectancy (HALE), LYs and DALYs lost due to AMR. Economic impacts quantify the number of additional days spent in hospital, attributable health expenditure, employment rate, rate of absenteeism and presenteeism, and GDP.

Little evidence exists to assess the extent to which resistant infections could be eliminated or replaced by infections that are susceptible to antibiotics. Recognising this, and after extensive expert consultation, the OECD SPHeP-AMR model makes use of two scenarios to assess the health and economic impact of AMR:

- In a first scenario, the replacement scenario, the total incidence of infections (i.e. incidence of susceptible infections and incidence of resistant infections) is maintained constant, while the prevalence of resistant infections is set to zero. In practice, this means that all resistant infections are completely replaced by susceptible infections. This scenario assumes that bacteria can no longer develop resistance and people that were infected by resistant bacteria continue being infected by bacteria that are susceptible to antibiotics. Outputs from this scenario are more conservative because susceptible bacteria increase the risk of complications and deaths but less than resistant bacteria.
- In a second scenario, the elimination scenario, the incidence of susceptible infections is maintained constant while the incidence of resistant infections is set to zero which results in a complete elimination of all resistant infections. This scenario uses the classical burden of disease approach and assumes that antibiotic-resistant bacteria no longer exist. In practical terms, the scenario evaluates how assessed outcomes change resulting from a fictitious elimination of the risk factor and, consequently, of all its consequences.

The elimination scenario can be considered as an optimistic option whereas the replacement scenario is a pessimistic alternative. The results generated using these two scenarios are significantly different from one another due to the lower but still significant burden caused by susceptible infections. Both scenarios are considered plausible given the lack of any concluding evidence in the literature on which scenario is more likely to occur in case of elimination of AMR. By adopting a multiple-scenario modelling approach, the OECD analysis aims to improve the usefulness of results for identifying policy options and interventions that offer the most cost-effective means to tackling AMR. The elimination scenario might be more useful to policy makers when evaluating the impact of interventions that would prevent resistant infections from emerging in the first place, such as improving vaccination coverage, and IPC measures like improving hand hygiene and enhancing environmental hygiene. Whereas the replacement scenario may be more useful when evaluating the effectiveness of interventions whose scale-up might result in a swap of susceptible and resistant bacteria rather than the elimination of resistant bacteria. These interventions may include antimicrobial stewardship programmes in healthcare settings, financial incentives that promote the prudent use of antimicrobials, provider training and education and others.

Propagating uncertainty

The simulation uncertainty is calculated on independent runs of 20 random subsamples for both business-as-usual and the two counterfactuals (i.e. elimination scenario and replacement scenario).

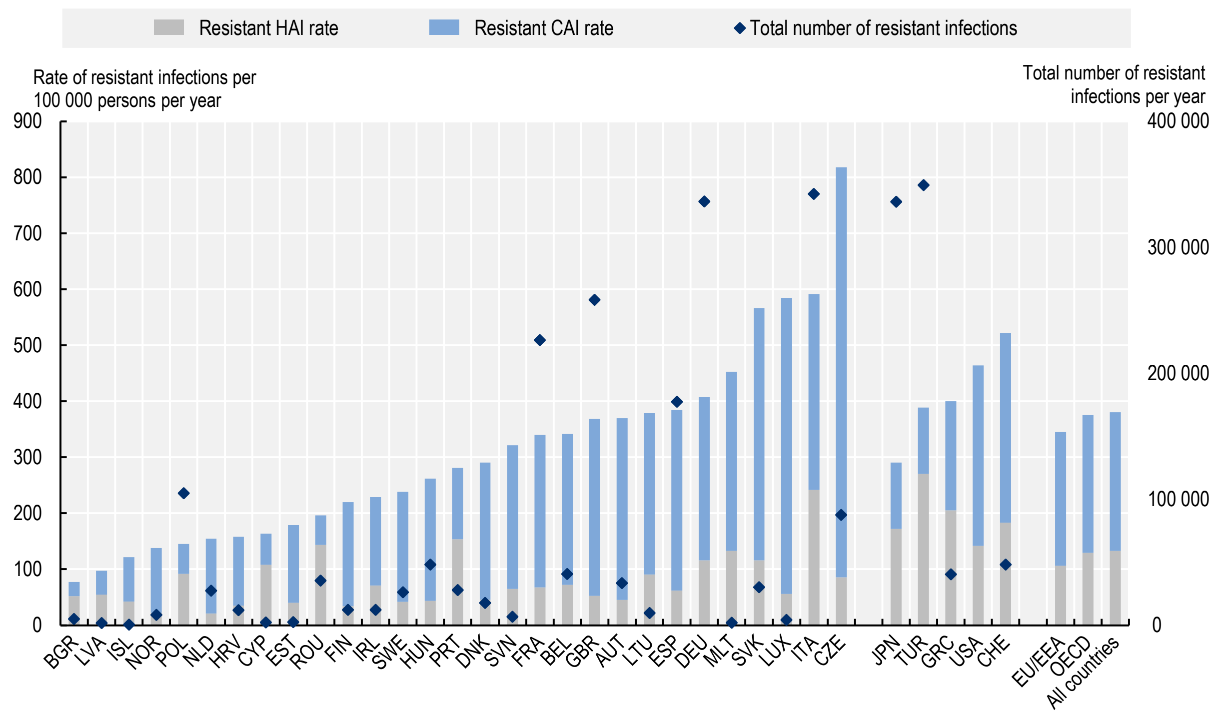
Note: More information on the key model assumptions and model structure are available at http://oecdpublichealthexplorer.org/amr-doc/.

The burgeoning burden of AMR on population health

Nearly 4.3 million resistant infections occur each year across OECD countries and EU/EEA countries

Resistant infections present a considerable threat to population health. Nearly 4.3 million infections are estimated to occur each year in the 34 countries included in the OECD analysis due to bacteria that are resistant to antimicrobial treatment (Figure 3.1). Almost 1.7 million of these infections occur across the EU/EEA countries. These aggregate figures, however, mask important cross-country differences. Across the EU/EEA countries, the Czech Republic appears to have the highest estimated burden of resistant infections as measured by resistant infection rates, followed by Italy and Luxembourg. Across non-EU/EEA member OECD countries, Switzerland is estimated to have the greatest annual rate of resistant infections, whereas Japan has the lowest annual rate of resistant infections averaging at nearly 291 per 100 000 persons. However, as discussed earlier, these cross-country differences in the burden of resistant infectious should be interpreted with care, considering that countries with stronger AMR surveillance systems risk a greater likelihood of a lower under-reporting of their true burden.

Figure 3.1. The number of resistant infections reaches nearly 4.3 million each year across the 34 countries included in the OECD analysis



Note: Results for Greece are presented on the right-hand side of the panel because data for *S. pneumoniae* are not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right-hand sides of the panel due to the methodological differences in data collection and data extraction practices. In the USA, the total number of resistant infections is estimated to exceed 1.6 million per year.

CAI: Community-acquired infection; HAI: Hospital-acquired infection.

Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/90m5cd

On average, around two in three resistant infections are acquired in the community (Figure 3.1). The OECD analysis suggests that, on average, around 65% of all resistant infections that occur each year are estimated to be acquired in community settings across all 34 countries whereas the remainder of these infections are acquired in healthcare settings. The share of community-acquired resistant infections appears to be slightly higher across the EU/EEA countries. On average, around 69% of resistant infections are estimated to be acquired in community settings across the EU/EEA countries.

Importantly, the share of resistant infections that occur in healthcare settings varies greatly across countries. Around seven out of every ten resistant infections in Bulgaria and Romania are estimated to occur in healthcare settings whereas, in the Czech Republic and Luxembourg, only around 10% of infections are estimated to be acquired in healthcare settings. In Türkiye, around 70% of resistant infections are estimated to occur in healthcare settings, (the highest across non-EU/EEA member OECD countries) whereas the United States has the lowest share of resistant infections occurring in healthcare settings. Understanding these cross-country differences in terms of the setting in which resistant infections occur is crucial to inform the selection of interventions that are best fit to support the OECD countries and EU/EEA countries in their continued efforts to tackle AMR in accordance with their unique country context.

Resistant infections claim the lives of tens of thousands of citizens in OECD and EU/EEA countries every year

Every year, tens of thousands of lives are lost due to resistant infections across the 34 EU/EEA and OECD countries included in the analysis (Figure 3.2). Using the elimination scenario, resistant infections are estimated to claim the lives of around 79 000 people, on average, each year up to 2050 across all of the countries included in the analysis. Of these deaths, nearly 22 000 are estimated to occur in the EU/EEA countries. The estimated death toll due to resistant infections is lower using the replacement scenario whereby the number of deaths due to resistant infections exceeds 24 000 every year up to 2050 across the 34 countries included in the analysis, with around 6 000 of these deaths occurring across the EU/EEA countries.

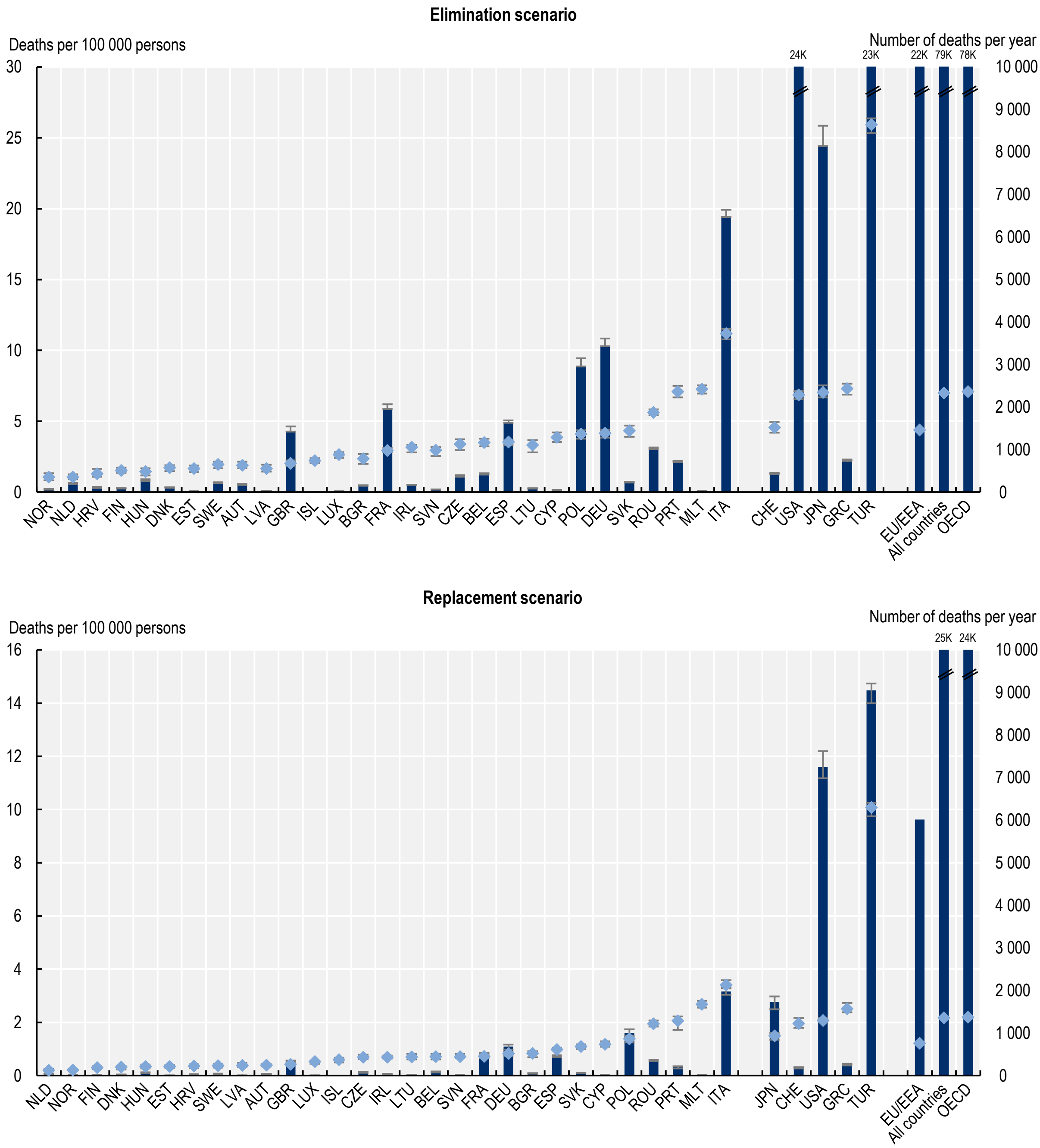
The mortality rate due to resistant infections varies substantially across countries, with countries in southern Europe facing a greater AMR burden. Similar to the previous OECD analysis (2018[2]), the new OECD analysis suggests an important geographic gradient in the mortality burden of AMR. Across the EU/EEA countries, Italy and Portugal are generally estimated to have the highest annual mortality burden due to AMR – both in terms of mortality rate and the total number of deaths due to AMR – using both modelling scenarios. For instance, in Italy, the annual mortality rate due to resistant infections is estimated to average nearly 11 deaths per 100 000 inhabitants under the elimination scenario and around 3.4 deaths per 100 000 inhabitants using the replacement scenario. Across non-EU/EEA member OECD countries, Türkiye is estimated to have the highest mortality rate attributable to resistant infections using both modelling scenarios.

Cross-country variation in the mortality estimates should be interpreted with caution. Several factors help explain the differences in estimated mortality rates across countries. First, certain countries have made laudable efforts in recent years to improve AMR surveillance, detection and reporting. As discussed earlier, it is expected that countries that have been investing in strengthening their AMR surveillance systems are able to track the incidence of infections at a higher rate than some of the other countries included in the analysis. For example, Switzerland's AMR monitoring system encompasses humans, animals, agriculture and the environment. In human health, the Swiss Sentinel Surveillance Network enables the collection of epidemiological data and the use of antibiotics (Bell and Nuzzo, 2021[27]). Similarly, Türkiye has prioritised the strengthening of disease surveillance capacity and healthcare data quality in its large-scale healthcare reforms since 2003 (WHO, 2022[28]). In terms of AMR surveillance, Türkiye established a national antimicrobial resistance surveillance system that collects data on antimicrobial resistance, antibiotic consumption and HAIs and reports data to the Central Asian and European Surveillance of Antimicrobial Resistance network, which uses the same methodology as the EARS-Net (Bell and Jennifer, 2022[29]). Another important factor that influences the cross-country differences in the mortality rates relates to the relative burden of resistant infections. As shown in Chapter 2, in 2019, resistance proportions in Türkiye were estimated to reach 46.5% and they are projected to remain the highest among OECD countries by 2035. Finally, population ageing in the next decade is expected to exacerbate the mortality burden due to AMR because the elderly population faces an elevated risk of death caused by resistant infections.

Across the 34 countries included in the analysis, the estimated number of yearly deaths due to AMR is comparable to the number of lives lost due to tuberculosis (TB), influenza and human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) in 2020 or the nearest year for which information is available. The total number of deaths due to AMR that occur annually in the 34 countries included in the analysis is estimated to be around 2.4 times that of deaths due to TB, influenza and HIV/AIDS in these countries under the elimination scenario and 0.7 times under the replacement scenario. Across the EU/EEA countries, the total number of AMR-related deaths that occur each year is estimated to be 1.5 and 0.4 times that of the number of deaths attributable to TB, influenza and HIV/AIDS using the elimination and replacement scenarios respectively.

Figure 3.2. Annual mortality attributable to resistant infections varies greatly across countries

Annual total number of deaths and mortality rate due to AMR up to 2050



Note: Results for Greece are presented in the right-hand side of the panel because data for *S. pneumoniae* are not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right-hand sides of the panel due to the methodological differences in data collection and data extraction practices.
Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/iam2qc

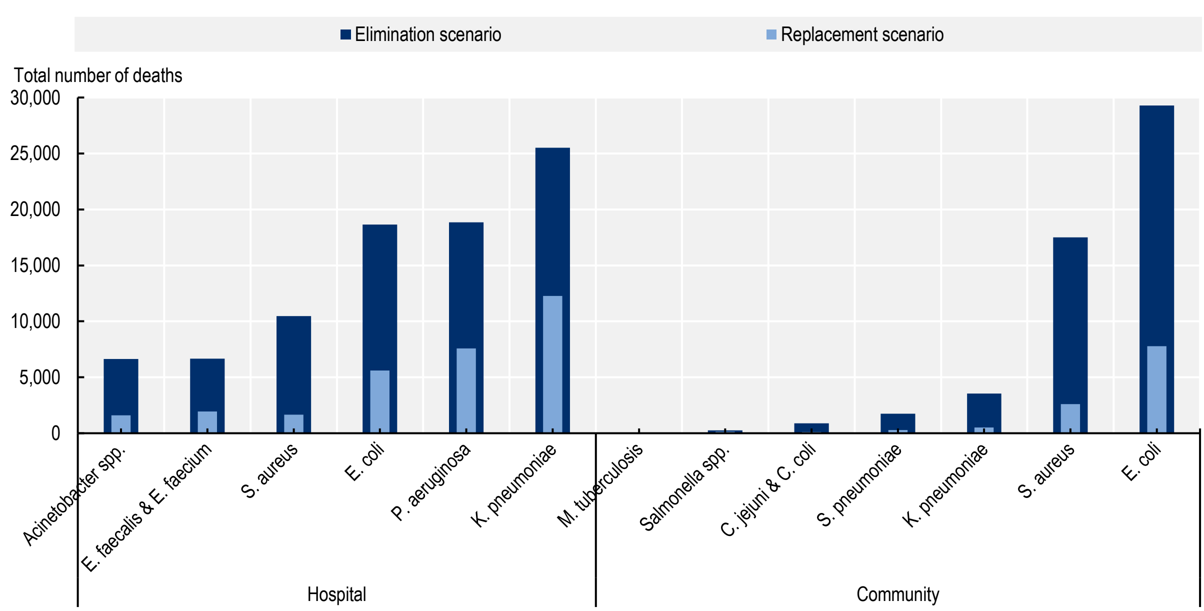
Three pathogens – E. coli, K. pneumoniae and S. aureus – are responsible for around three out of four deaths that occur each year due to resistant infections

Every year, nearly three in four deaths attributable to resistant infections are caused by *E. coli*, *K. pneumoniae* and *S. aureus* across all countries included in the analysis (Figure 3.3). *E. coli*, *K. pneumoniae* and *S. aureus* account for 75% of deaths due to resistant infections using the elimination scenario and 72% using the replacement scenario. In both scenarios, deaths due to *E. coli* represent about one-third of all deaths due to resistant infections. In both scenarios, *K. pneumoniae* follows *E. coli* as the second leading pathogen that causes mortality, accounting for about 21% and 30% of all deaths due to resistant infections in the elimination and replacement scenarios respectively. In contrast, *Salmonella* spp., *C. jejuni* and *C. coli* represent a very small share of the mortality burden due to resistant infections across the 34 countries included in the analysis.

The burden of *M. tuberculosis* is also low across countries included in the analysis. While infections by these agents are well controlled in OECD countries, they remain top public health challenges elsewhere. For example, in 2019, diarrheal diseases were estimated to cause more than 1.5 million deaths worldwide. Diarrheal diseases were ranked as the third most common cause of death among children under five years of age, claiming more than half a million lives among children in this age group worldwide (Vos et al., 2020[30]). Similarly, it is estimated that, globally, tuberculosis killed 1.6 million people in 2021, with a significant part of these deaths attributable to resistant tuberculosis (WHO, 2022[31]). About two-thirds of cases of resistant tuberculosis worldwide can be found in seven countries: China, India, Indonesia, Pakistan, the Philippines, the Russian Federation and South Africa (WHO, 2022[31]).

Figure 3.3. Around three in four deaths attributable to resistant infections occur annually due *to E. coli, K. pneumoniae* and *S. aureus*

Annual total number of deaths due to AMR up to 2050, by pathogen



Source: OECD analysis based on the OECD SPHeP-AMR model.

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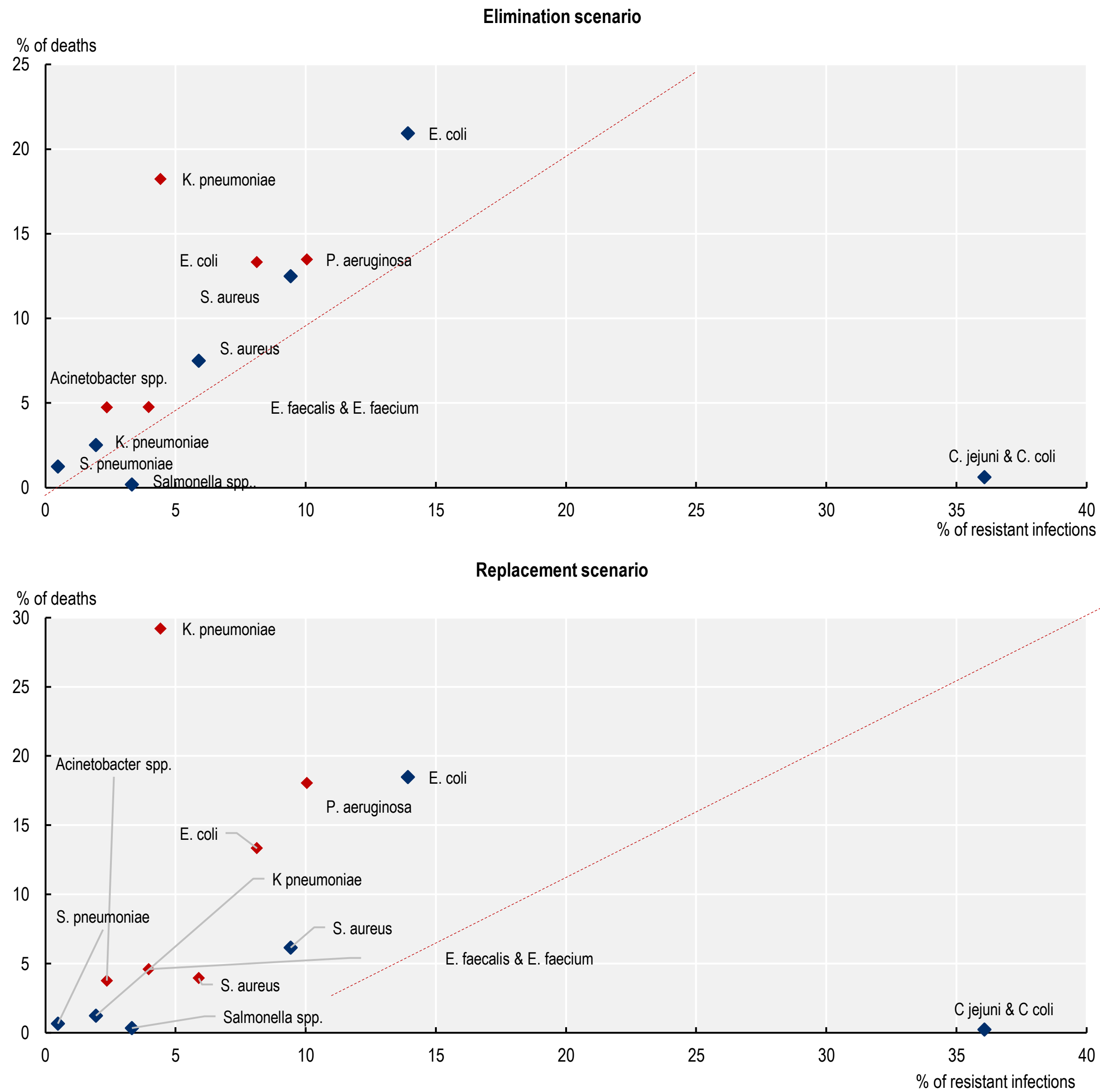
HAIs are linked with the majority of annual deaths due to AMR

The OECD analysis further demonstrates that resistant HAIs account for the majority of annual mortality due to resistant infections across the 34 countries included in the analysis (Figure 3.3). Using the elimination scenario, infections acquired in hospital settings are estimated to represent around 62% of mortality due to resistant infections whereas under the replacement scenario, this figure reaches around 73%. This finding should be interpreted with care. In general, a greater proportion of infections acquired in healthcare settings are reported compared to those acquired in the community. This challenge data reporting is likely to influence the precision of the estimates.

In particular, *K. pneumoniae, P. aeruginosa* and *E. coli* acquired in healthcare settings pose a substantially greater risk of death compared to main community-acquired infections (Figure 3.4). For instance, *K. pneumoniae* acquired in healthcare settings is estimated to cause around only around 4% of all resistant infections each year and is estimated to account for 18-29% of AMR-related deaths in the elimination and replacement scenarios respectively. Similarly, *E. coli* and *P. aeruginosa* combined account for less than one-fifth of infections but represent 27-31% of deaths (in elimination and replacement scenarios respectively). Conversely, *C. jejuni* and *C. coli* occurring in community settings are estimated to cause more than 36% of all resistant infections (corresponding to more than 1.5 million infections) every year but account for less than 1% of all AMR-related annual deaths. Combined, these findings underline the importance of IPC measures to reduce the burden of HAIs.

Figure 3.4. *K. pneumoniae, E. coli* and *P. aeruginosa* in healthcare settings account for less than a quarter of all resistant infections but represent nearly 45-60% of deaths due to AMR



Notes: The colour red denotes HAIs and dark blue denotes CAIs.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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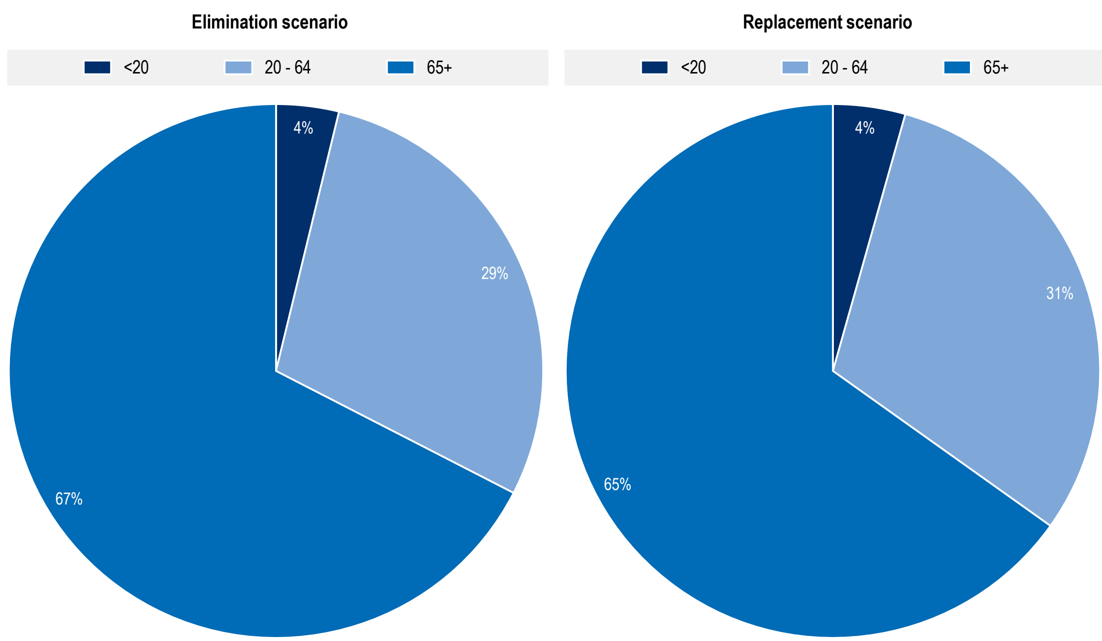
The elderly population face the greatest risk of death due to resistant infections

Deaths due to AMR are concentrated among the elderly populations across the 34 countries included in the analysis (Figure 3.5). The OECD analysis suggests that around 65-67% of annual deaths due to AMR occur among people above 65 years of age in the replacement and elimination scenarios respectively. Working-age population between 20 and 64 years of age also face mortality risks due to AMR, with approximately 29-30% of deaths occurring across people in this age group. About 4% of deaths due to AMR occur among people under 20 years of age. Findings from the analysis on the burden of AMR by age group are in line with several earlier analyses. For example, a 2022 study by the European Antimicrobial

Resistance Collaborators provided age-specific mortality rates in 2019 for each country in the WHO European region (Mestrovic et al., 2022[4]). Similar to the OECD analysis, this study also found that the majority of deaths due to AMR occurred in older age groups, with people above the age of 60 facing a greater risk of mortality compared to people below 60 years of age.

Figure 3.5. Annual number of deaths due to AMR by age groups, per year, up to 2050



Source: OECD analysis based on the OECD SPHeP-AMR model.

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The elevated risk of mortality due to resistant infections among the elderly is driven by several factors. Previous studies showed that immune response declines with age. Older adults do not respond to pathogens as efficiently as younger individuals even if they were exposed to the same pathogen before (Montecino-Rodriguez, Berent-Maoz and Dorshkind, 2013[32]; Keilich, Bartley and Haynes, 2019[33]). Coupled with weakened immune response, co-morbidities commonly observed among the older populations are linked to increased risk of infection (e.g. pulmonary diseases are associated with increased risk of pneumonia) while the presence of foreign materials (e.g. pacemakers, prostheses, etc.) can make them more vulnerable to medical device-associated infections (Beckett, Harbarth and Huttner, 2015[34]). It has been shown that diagnostic uncertainty is another pressing challenge for elderly patients. Previous studies demonstrated that the sensitivity of certain diagnostic procedures was lower for older adults than for younger individuals (Gavazzi and Krause, 2002[35]). Moreover, many infections have different clinical presentations among elderly adults compared to younger individuals (Beckett, Harbarth and Huttner, 2015[34]).

Preventing deaths due to AMR can translate into gains in life expectancy and healthy life expectancy in the next three decades

AMR is linked with reductions in life expectancy at birth (Figure 3.6). Using the elimination scenario, on average, life expectancy across the 34 OECD and EU/EEA countries included in the analysis is estimated to be 2.6 months lower due to AMR. Across the EU/EEA countries, the loss in life expectancy due to AMR is estimated to average around 1.6 months over the course of the projection period. Using the replacement scenario, life expectancy is 0.8 months lower due to AMR across the 34 countries included in the analysis and 0.4 months lower across the EU/EEA countries over the next 3 decades. Under both scenarios, Italy and Portugal are estimated to risk the greatest reductions in life expectancy across the EU/EEA countries. In contrast, the Netherlands and Norway are estimated to risk the smallest declines. Among non-EU/EEA member OECD countries, the largest predicted declines in life expectancy are estimated to be experienced by Türkiye.

These estimated losses in life expectancy due to AMR are not negligible, especially when compared to declines in life expectancy due to COVID-19. Partly driven by the adverse shock of the COVID-19 pandemic, life expectancy at birth declined by 7.5 months across the 34 countries included in the analysis and by 8 months across the EU/EEA countries between 2019 and 2020. This can potentially mean that, under the elimination scenario, loss of life due to AMR can reach as high as almost 35% of the reduction in life expectancy due to COVID-19 across 34 countries included in the analysis and about 20% of potential losses across the EU/EEA countries. As expected, the potential losses in life expectancy due to AMR compared to the COVID-19 pandemic is relatively modest using the replacement scenario, with these losses averaging around 11% for the 34 countries included in the analysis and around 6% for the EU/EEA countries.

AMR also lowers healthy life expectancy (HALE) – a key measure of population health that quantifies the average number of years each person is expected to live in full health by considering the number of years lived in less than full health due to disease or/and injury (Figure 3.6). Based on the elimination scenario, on average, AMR is estimated to lower HALE by 2.84 months by 2050 across the 34 countries included in the OECD analysis and by 1.7 months across the EU/EEA countries. Using the replacement scenario, AMR lowers HALE by 0.8 months across the 34 OECD and EU/EEA countries included in the analysis and 0.4 months lower across the EU/EEA countries over the next 3 decades. Across the EU/EEA countries, the greatest declines in HALE are expected to be observed in Italy and Portugal. Among non-EU/EEA member OECD countries, Türkiye is expected to experience the largest predicted reductions in HALE.

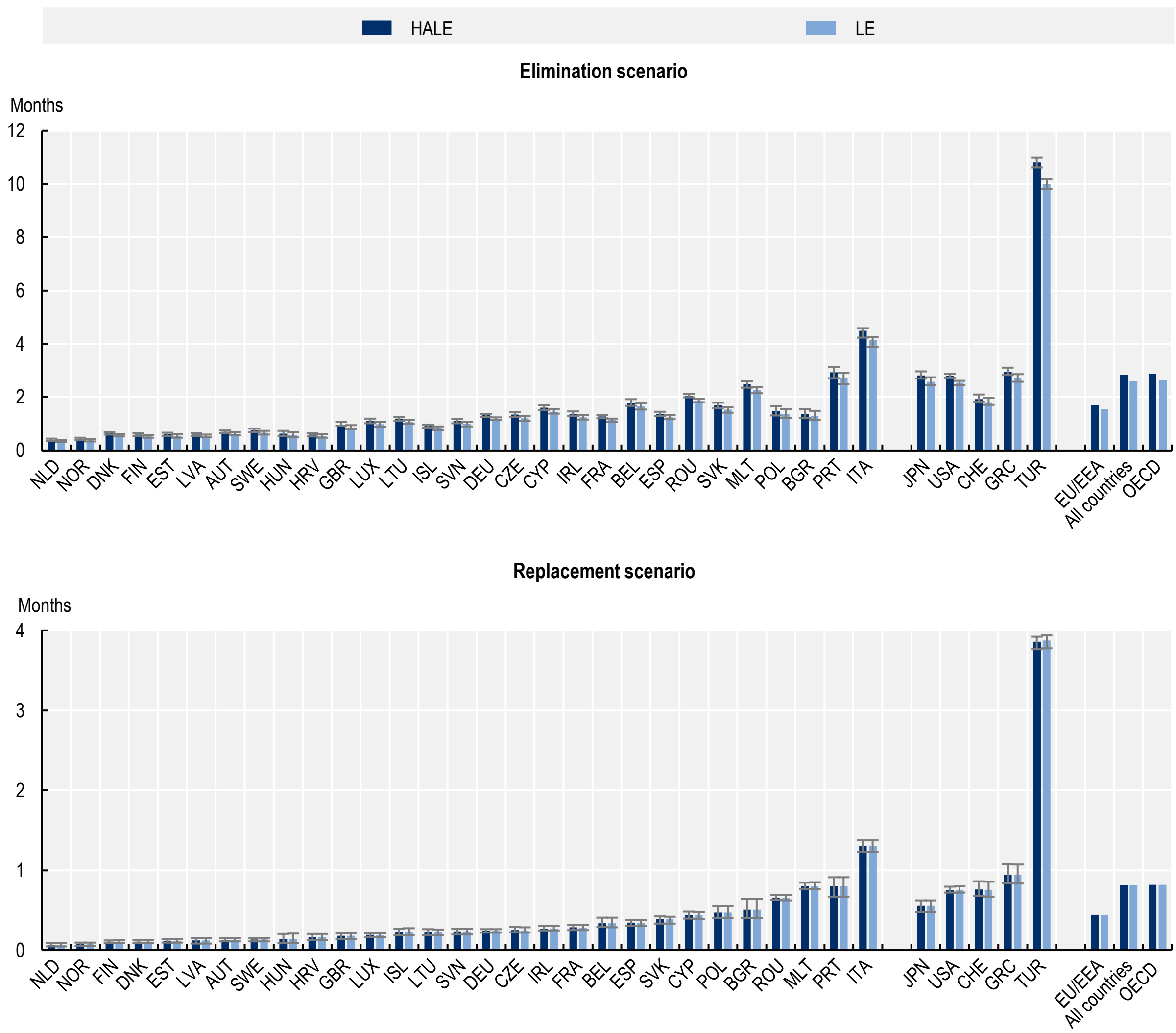
AMR is associated with reductions in years of life and the quality of life

Under the elimination scenario, a total of 1.5 million LYs are estimated to be lost due to AMR every year up to 2050 across the 34 countries included in the analysis, corresponding to around 133 LYs per 100 000 persons (Figure 3.7). Using the replacement scenario, about 454 000 LYs are estimated to be lost due to AMR annually up to 2050 across all 34 countries included in the analysis, corresponding to about 40 LYs per 100 000 persons. Using both scenarios, the deleterious impact of AMR on mortality is estimated to be lower across EU/EEA countries than the mortality estimates for all countries included in the analysis.

Resistant infections have important implications for quality of life as measured by the number of years lived with disability. Using the elimination scenario, across the 34 countries included in the analysis, on average, 1.8 million DALYs are estimated to be lost due to AMR every year up by 2050, corresponding to around 157 DALYs per 100 000 persons (Figure 3.7). Using the replacement scenario, all countries included in the analysis lose, on average, around 455 000 DALYs in total annually due to AMR, corresponding to around 40 DALYs per 100 000 persons.

Figure 3.6. AMR lowers life expectancy and healthy life expectancy

Total reduction in LE and HALE at birth due to AMR up to 2050



Note: Results for Greece are presented on the right-hand side of the panel because data for *S. pneumoniae* are not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right-hand sides of the panel due to the methodological differences in data collection and data extraction practices.
HALE: Healthy life expectancy; LE: Life expectancy.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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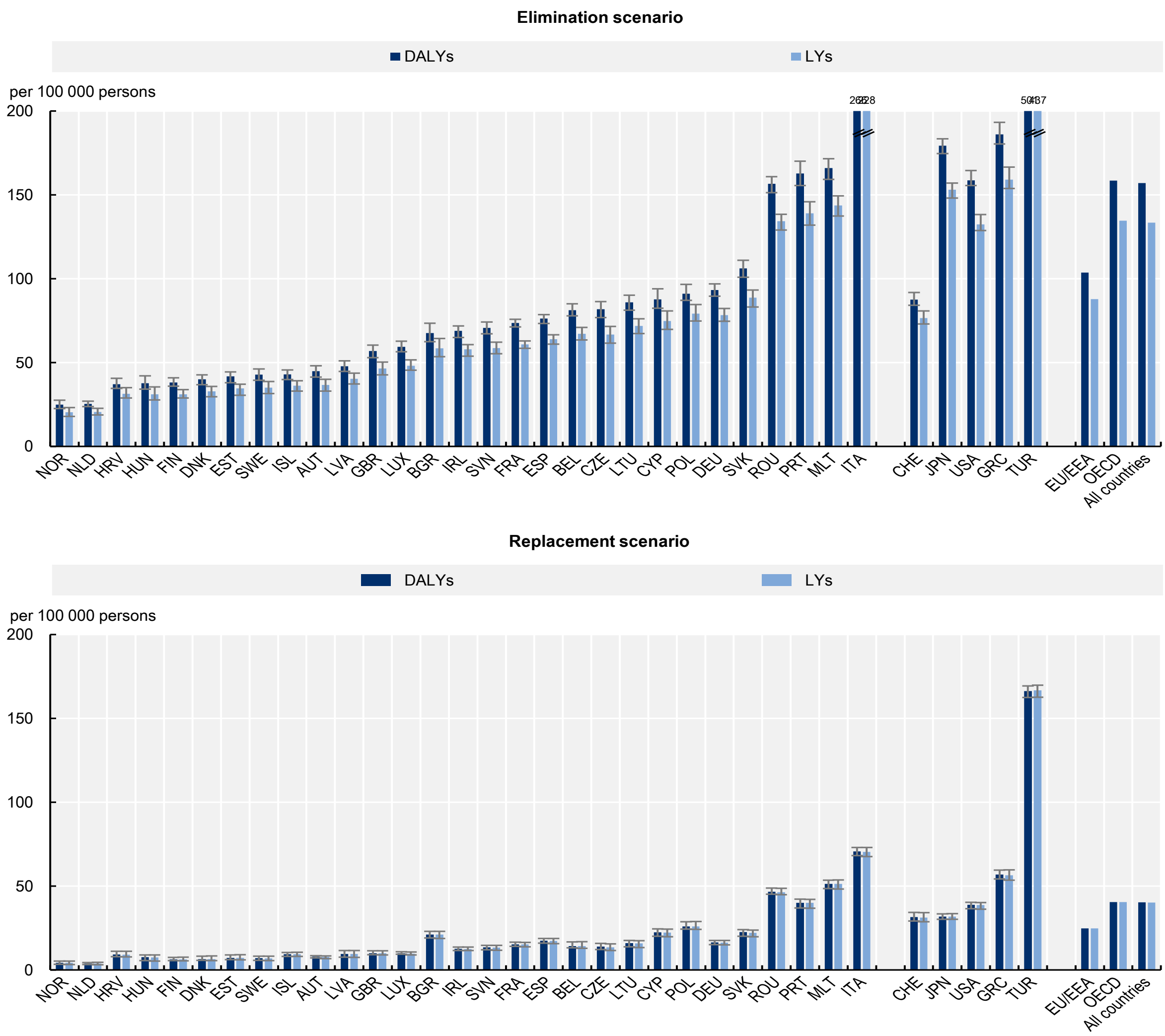
Figure 3.7. AMR is associated with years of life lost and disability-adjusted life years each year up to 2050 across the 34 countries included in the OECD analysis

Average annual number of DALYS and LYs lost due to AMR up to 2050



Note: Results for Greece are presented on the right-hand side of the panel because data for *S. pneumoniae* are not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right-hand sides of the panel due to the methodological differences in data collection and data extraction practices.
DALY: Disability-adjusted life-years; LYs = Life years.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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Impacts of AMR on healthcare resources and expenditure

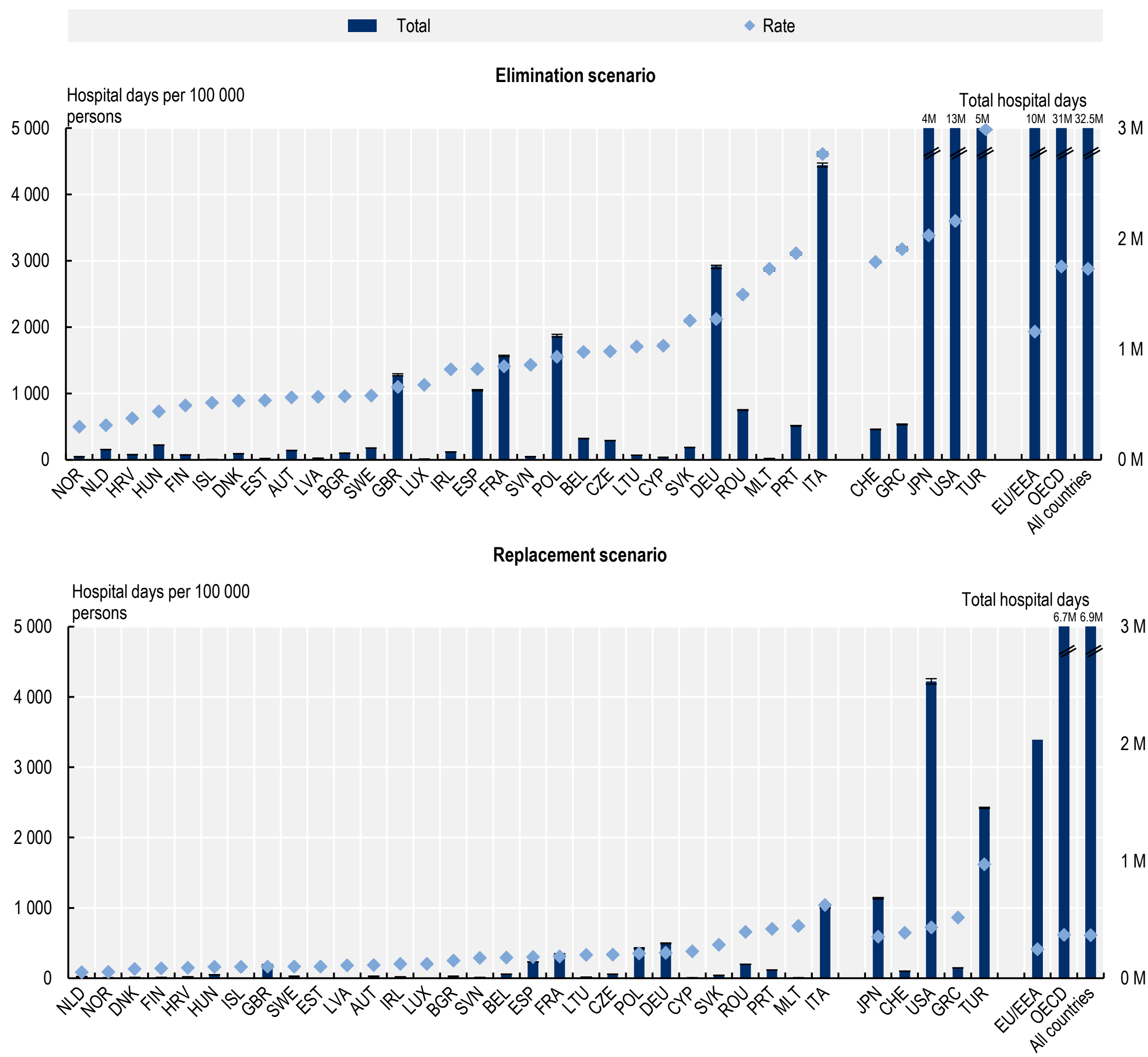
Treating infections caused by resistant organisms translates into increased pressure on the use of hospital resources

Patients developing resistant infections typically require more intensive healthcare and are more likely to develop complications and spend a longer hospital stay if they require hospital care. The OECD analysis shows that resistant infections are estimated to result in nearly 32.5 million extra days spent in hospitals every year up to 2050 under the elimination scenario and 6.9 million extra days under the replacement scenario across the 34 countries included in the analysis (Figure 3.8). Across the EU/EEA countries, this figure stands at more than 9.5 million extra hospital days under the elimination scenario and about 2 million extra hospital days under the replacement scenario. These estimates suggest that extra days spent in hospitals annually for treating complications due to AMR across all 34 countries included in the analysis would be equivalent to using the entire acute bed capacity in Spain in 2020 for nearly 1 year under the elimination scenario and around 2 months under the replacement scenario.

Moreover, there are important cross-country differences in the estimates of use of hospital resources for treating resistant infections. Across the EU/EEA countries, Italy is expected to face the greatest pressure on its hospital resources in both modelling scenarios, as measured by the annual rate of hospital days per 100 000 persons up to 2050. On average, in Italy, about 4 608 additional days are estimated to be spent in hospitals per 100 000 persons annually for treating complications due to AMR up to 2050 using the elimination scenario and almost 1 040 additional days per 100 000 persons using the replacement scenario. Across non-EU/EEA member OECD countries, Türkiye is estimated to risk the highest annual rate of extra days spent in hospital due to AMR: by 2050, in Türkiye, the number of additional days spent in hospital each year is estimated to average around 6 018 days per 100 000 persons using the elimination scenario and 1 618 days per 100 000 persons under the replacement scenario. Variation in the incidence of infections across countries is the primary driver of these differences in varying levels of pressure caused by AMR on hospital resources, though other factors like variation in clinical practices in treating patients with resistant infections also play a role.

Figure 3.8. AMR puts additional pressure on hospital resources that were already overstretched over the course of the COVID-19 pandemic

Annual total number of extra days spent in hospital due to AMR up to 2050



Note: Results for Greece are presented on the right-hand side of the panel because data for *S. pneumoniae* are not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right-hand sides of the panel due to the methodological differences in data collection and data extraction practices.
M: Millions.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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Health care budgets in OECD and EU/EEA countries will face a substantial burden

Infections caused by antimicrobial-resistant pathogens are considerably more costly to treat compared to susceptible infections. Typically, treating complications caused by resistant infections necessitate a greater reliance on more intensive medical procedures, requires additional investigations such as advanced laboratory tests and prolonged stays in hospital. Health providers may need to rely on more expensive and aggressive therapies involving the use of second-line treatment or various combinations of antimicrobials to treat resistant infections.

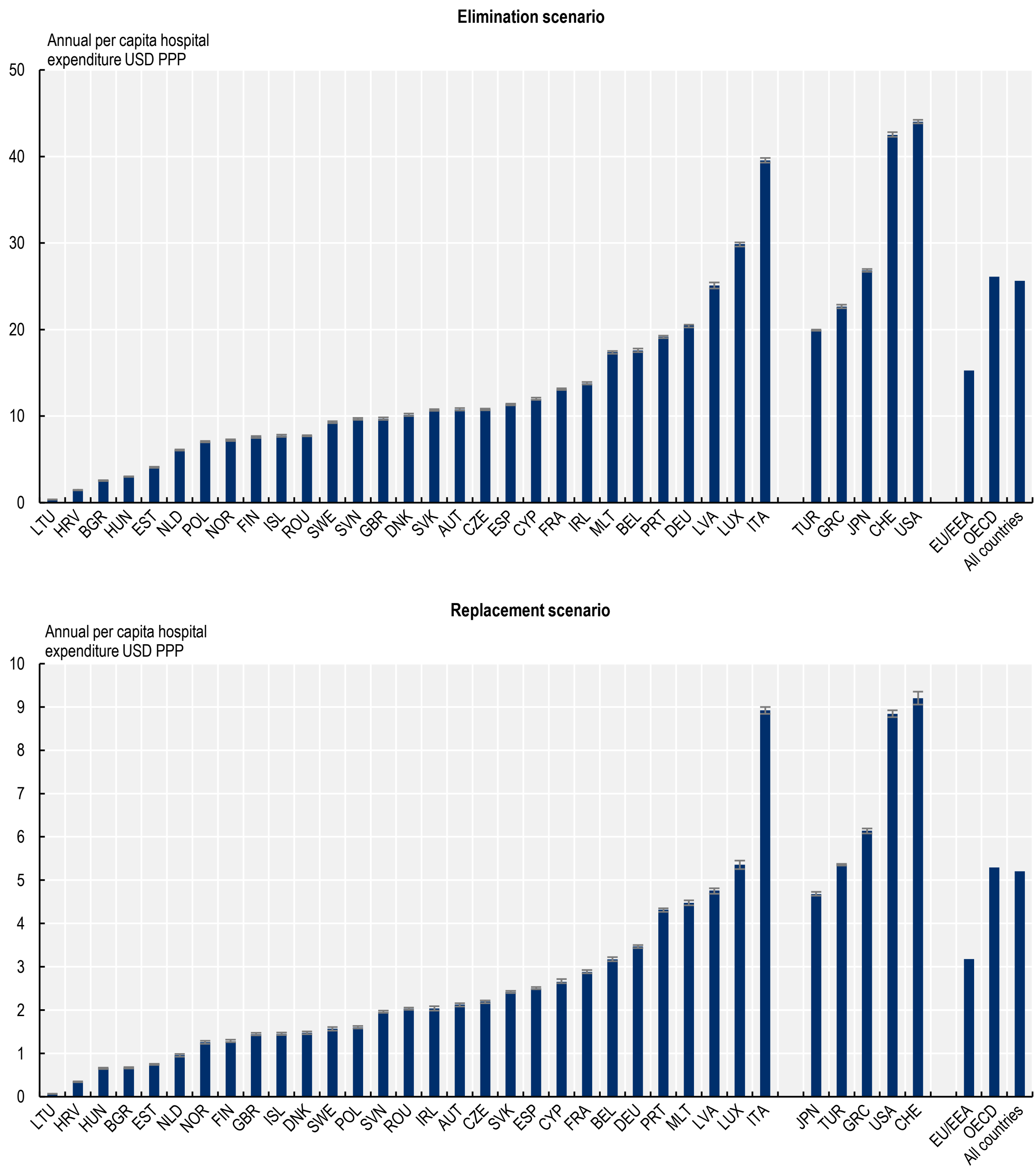
Under the elimination scenario, the annual cost of treating complications caused by resistant infections is estimated to average more than USD 28.9 billion up to 2050 adjusting for PPP across all the countries included in the analysis, corresponding to nearly USD PPP 26 per capita (Figure 3.9). Across the EU/EEA countries, the cost of AMR to the health systems is estimated to reach around USD PPP 7.5 billion every year up to 2050 (see Annex 3.A for total hospital expenditure by country). This figure corresponds to around USD PPP 15.3 per capita. Using the replacement scenario, the annual cost of AMR is estimated to average around USD PPP 5.9 billion each year by 2050 across the 34 countries included in the analysis, corresponding to around USD PPP 5.2 per capita. Across the EU/EEA countries, the total spending on AMR averages around USD PPP 1.6 billion annually up to 2050, which is about USD PPP 3.2 per capita.

In both modelling scenarios, across the EU/EEA countries included in the analysis, Italy is estimated to spend the greatest amount of financial resources to treat complications each year due to resistant infections, both in terms of the total annual spending on AMR and per capita spending. Across non-EU/EEA member OECD countries, Switzerland and the United States are estimated to allocate the highest amount of financial resources each year to treating complications caused by resistant infections. These cross-country differences are driven both by the incidence of resistant infections and the cost of medical treatment.

The cost of inaction to tackle AMR in the next three decades will exceed treatment costs due to COVID-19 in 2020. For the 17 OECD countries and EU/EEA countries for which data were available, the total health expenditure incurred each year due to AMR is about 19% of the total health expenditure due to treating COVID-19 patients in 2020 using the elimination scenario and 4% using the replacement scenario. In effect, this means the cost of treating complications due to AMR incurred about every six years up to 2050 is estimated to be equivalent to the treatment costs associated with the COVID-19 patients in 2020 using the elimination scenario and around 32 years using the replacement scenario.

Figure 3.9. AMR poses a substantial burden on the healthcare budgets

Annual per capita hospital expenditure incurred due to AMR up to 2050, USD PPP



Note: Results for Greece are presented on the right-hand side of the panel because data for *S. pneumoniae* are not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right-hand sides of the panel due to the methodological differences in data collection and data extraction practices.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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Impact of AMR on participation in the workforce and productivity

The OECD SPHeP-AMR model also quantifies the impact of AMR on labour market output by assessing participation in the workforce and workforce productivity. Participation in the workforce is assessed through employment rate – an economic measure of labour supply which reflects the proportion of working-age population age that is employed. Workforce productivity refers to the extent to which labour output may be lost due to AMR either through absence from work due to ill health (i.e. absenteeism) or reduced productivity even though the employee is present at work (i.e. presenteeism). Combined, declines in participation in the workforce and productivity can have important consequences for the economy. Declines in the workforce mean productive workers are no longer in the workforce, resulting in lost economic output. Reductions in productivity – either through absenteeism or presenteeism – mean that wages are paid with no return in terms of productivity. In the OECD analysis, changes in labour supply and workforce productivity are translated to monetary losses using the human capital approach, whereby the duration of work foregone is multiplied by the national average wage.

Resistant infections have a deleterious impact on the labour markets and workforce productivity

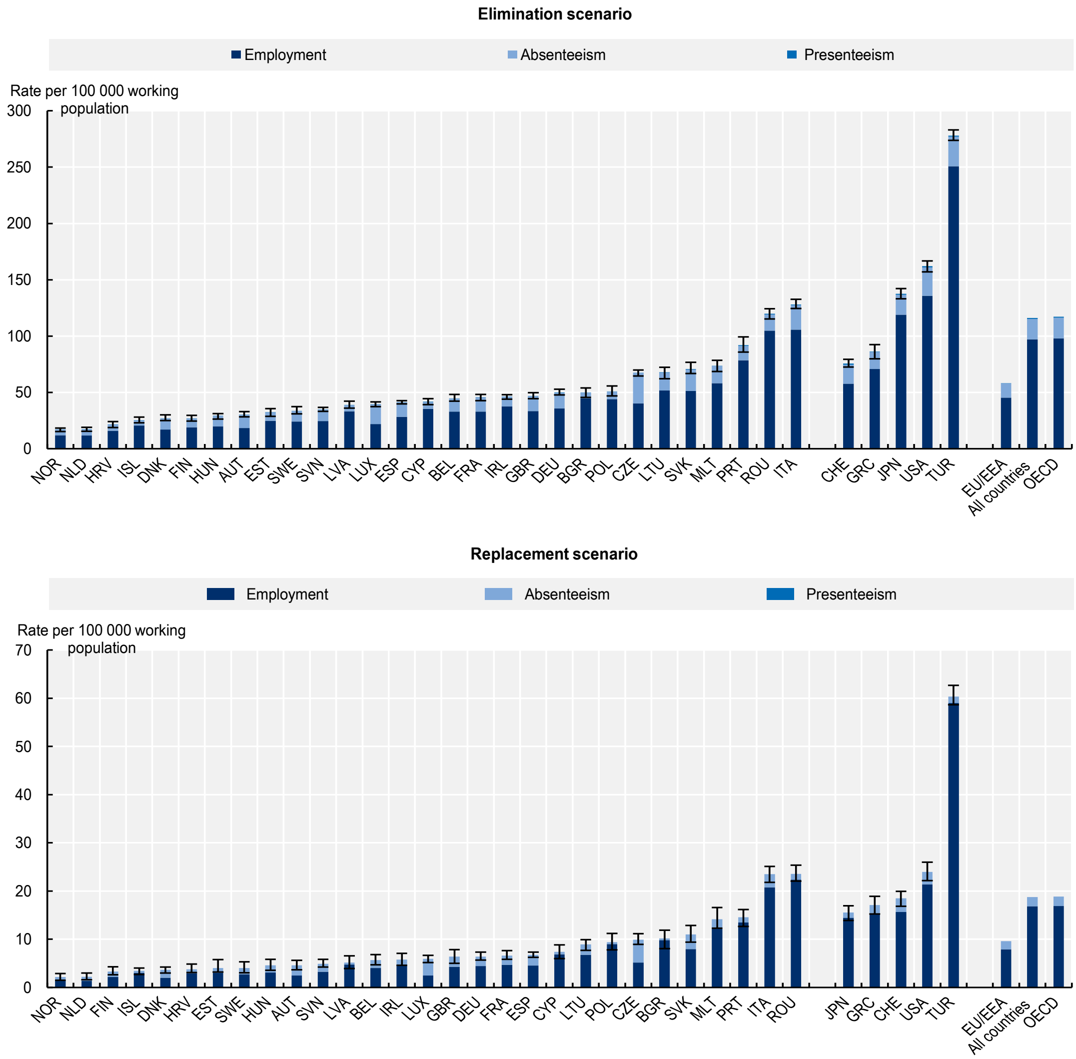
Using the elimination scenario, the average labour market output (i.e. combination of participation in the workforce and productivity) is estimated to decline by 116 full-time equivalents (FTEs) per 100 000 working population every year due to infections caused by resistant pathogens across the 34 countries included in the OECD analysis, corresponding to about 0.12% decline in labour market output (Figure 3.10). Across the EU/EEA countries, the average yearly loss in labour market output stands at around 58 FTEs per 100 000 working population. This figure corresponds to about 0.06% decline in labour market output. Using the replacement scenario, the annual losses in labour market productivity are estimated to average around 18.7 FTEs per 100 000 working population across the 34 countries included in the analysis and 9.6 FTEs per 100 000 working population across EU/EEA countries. These figures correspond to around 0.02% and 0.01% decline in labour market output respectively. Much like previous results, the OECD analysis point to substantial cross-country variation in the labour market output lost due to AMR. Using both modelling scenarios, across EU/EEA countries, Italy and Romania are estimated to face the largest losses. Across other countries, the greatest losses to labour market output are estimated to take place in Türkiye and the United States.

Translating these figures at the population level underlines the urgency of continued action to stem the AMR tide. Using the elimination scenario, the total shrinkage in the workforce due to AMR is estimated to be equivalent to 734 000 FTEs each year across the 34 countries included in the analysis and 161 000 FTEs across the EU/EEA countries. Using the replacement scenario, on average, nearly 119 000 FTEs are estimated to be lost due to AMR each year across all countries included in the analysis and nearly 27 000 across the EU/EEA countries.

Job losses are the primary driver of the declines in labour market outputs across the OECD and EU/EEA countries (Figure 3.10). Across these countries, on average, AMR is estimated to reduce the employment rate by 97 per 100 000 working population each year up to 2050 using the elimination scenario and 17 per 100 000 working population annually using the replacement scenario. Similar reductions are observed across the EU/EEA countries whereby the employment rate is estimated to reduce by 45 per 100 000 working population annually using the elimination scenario and 8 per 100 000 working population each year using the replacement scenario. The magnitude of the reductions in employment rates is estimated to be the highest in Italy, Portugal and Romania across the EU/EEA countries and in Türkiye and the United States across non-EU/EEA member OECD countries.

Figure 3.10. AMR has negative consequences in the labour market by reducing employment and propagating absenteeism and presenteeism

Annual job losses, absenteeism and presenteeism up to 2050



Note: Results for Greece are presented on the right-hand side of the panel because data for *S. pneumoniae* are not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right-hand sides of the panel due to the methodological differences in data collection and data extraction practices.
Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/tf5vms

The OECD analysis further suggests that declines in productivity due to AMR are predominantly due to absenteeism (Figure 3.10). The annual absenteeism rate across the 34 countries included in the analysis averages around 18 per 100 000 working population under the elimination scenario and 2 per 100 000 working population using the replacement scenario respectively. Across the EU/EEA countries, annual absenteeism rates are estimated to reach around 12 and 2 per 100 000 working population under the elimination and replacement scenarios respectively. Across all countries included in the analysis, these estimated average annual absenteeism rates are consistently larger than the estimated rates of presenteeism at work due to AMR under both modelling scenarios.

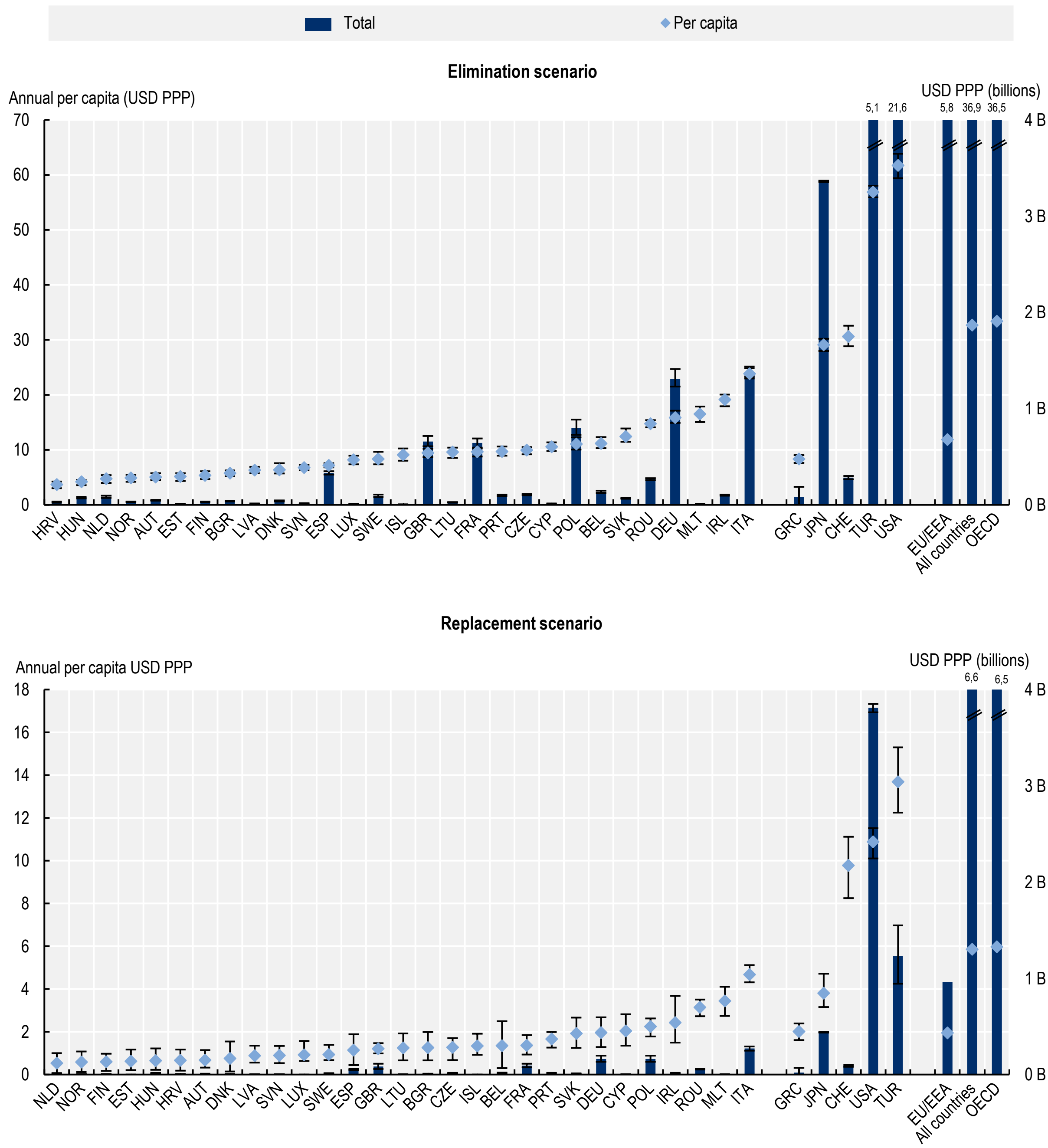
The estimated reductions in labour market outputs translate into considerable financial losses

As shown in Figure 3.11, OECD analysis suggests that the estimated declines in participation in the workforce and productivity translate into considerable financial losses (see Annex 3.A for annual average labour market output per worker by country). Using the elimination scenario, the 34 countries included in the analysis are estimated to lose a total of around USD PPP 36.9 billion each year up to 2050 in labour market output due to AMR, corresponding to around USD PPP 32.7 per capita. This corresponds to roughly one-fifth of GDP in Portugal in 2020. In the same period, the magnitude of the estimated total annual losses in labour market outputs across the EU/EEA countries is estimated to average around USD PPP 5.8 billion, corresponding to around USD PPP 11.8 per capita. The magnitude of the estimated losses in labour market outputs due to AMR is more modest under the replacement scenario. Using the replacement scenario, the total annual losses in labour market outputs due to AMR are estimated to exceed USD PPP 6.6 billion up to the year 2050 across all countries included in the analysis, corresponding to USD PPP 5.9 per capita. Across the EU/EEA countries, AMR is estimated to result in total annual losses in labour market outputs amounting to nearly USD PPP 960 million by 2050, corresponding to USD PPP 1.9 per capita.

There is substantial cross-country variation in the magnitude of the estimated losses in labour market output due to AMR. Under the elimination scenario, Italy, Ireland and Malta are estimated to incur the greatest losses in per capita labour market output each year across the EU/EEA countries, with the magnitude of these losses ranging from around USD PPP 16.5 in Malta to USD PPP 23.8 in Italy. Across non-EU/EEA member OECD countries, the greatest losses in per capita labour market output are estimated to occur in Türkiye and the United States, with the estimated per capita losses reaching around USD PPP 61.8 in the United States and USD PPP 56.9 in Türkiye. Under the replacement scenario, Malta and Romania follow Italy as the 2 countries that risk the greatest losses in labour market output due to AMR, with estimated per capita losses ranging from USD PPP 3.4 in Malta and USD PPP 3.2 in Romania. Across non-EU/EEA member OECD countries, the United States is estimated to incur the greatest amount of losses in per capita labour market output under the elimination scenario, whereas Türkiye is estimated to risk the greatest amount of losses in labour market output per capita using the replacement scenario. These cross-country differences in the magnitude of losses in labour market output reflect the differences in the burden of resistant infections and wages.

Figure 3.11. The impact of AMR on labour market outputs is considerable

Annual average labour market output lost due to AMR based on average wages up to 2050



Note: Results for Greece are presented on the right-hand side of the panel because data for *S. pneumoniae* are not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right-hand sides of the panel due to the methodological differences in data collection and data extraction practices.
B: Billion; PPP: Purchasing power parity.
Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/o2836f

The OECD analysis broadly aligns with previous studies that estimate the health and economic burden of AMR

The results presented in this chapter suggest that around 79 000 deaths can occur across the 34 countries included in the analysis each year up to 2050. Nearly 22 000 of these deaths are estimated to take place across the EU/EEA countries. In comparison, the 2018 OECD publication estimated that, between 2015 and 2050, the annual number of deaths due to AMR is estimated to average around 63 000 deaths across the 33 countries included in the analysis, with around 33 000 of these deaths occurring across the EU/EEA countries (OECD, 2018[2]). The observed differences between the two rounds of OECD analysis are driven primarily by the incorporation of new data collected since the 2018 OECD analysis into the modelling framework, as well as the differences in the sample of countries included in the analysis. The estimated reduction in the number of AMR-related deaths across the EU/EEA countries also suggests that the wide range of policies and interventions put in place across these countries in line with the WHO Global Action Plan on AMR (2015[1]) may have been contributing to the observed reduction in the health impact of AMR.

The results presented in this chapter are broadly consistent with estimates generated by earlier studies that used data sources and methodologies similar to the OECD analysis (see 0 for more detailed descriptions). For example, the 2022 ECDC analysis of the mortality burden of AMR used data from countries that reported them to the EARS-Net network for a similar set of antibiotic-bacterium combinations and showed that, in 2019, the estimated number of deaths due to AMR was 38 710 (95% UI 24 053-43 710) using assumptions and inputs similar to the OECD's elimination scenario. The observed differences in the magnitude of the estimated mortality due to AMR are partly explained by methodological differences. The OECD model opts for a dynamic approach given the modelling period that spans nearly 30 years. In effect, this means that the OECD model takes into account other causes of mortality that compete with AMR, such that it assumes that a person that is recovered from a resistant infection dies due to other illnesses. This assumption was used to avoid implausibly high population estimates by 2050.

In comparison, the results presented in this chapter provide much more conservative estimates compared to those recently generated by the European Antibiotic Resistance Collaborators (Mestrovic et al., 2022[4]). In this study, deaths due to AMR in 2019 are estimated to average around 541 000 under a scenario similar to the OECD's elimination scenario and around 133 000 using a scenario similar to the replacement scenario, suggesting around 25-to-21-fold difference in mortality estimates compared to the OECD estimates. These large differences between the two analyses are driven primarily by the differences in the analytical scope, methodologies and data sources. For example, the study by Mestrovic and colleagues (2022[4]) covered 23 pathogens and 88 antibiotic-bacterium combinations. Whereas consistent with the analyses carried out by the ECDC (ECDC, 2022[11]) and other studies carried out at the national level (CDC, 2022[14]; CCA, 2019[15]), the OECD model focuses on a more limited set of 10 pathogens and 18 antibiotic-bacterium combinations that are regarded as a priority across the OECD and EU/EEA countries. This study provides estimates for 53 countries included in the WHO European region, many of which are shown to have a substantially high AMR burden. In comparison, the OECD analysis focuses on 34 OECD and EU/EEA countries that are generally estimated to have a lower AMR burden. A final significant driver of the difference between the two studies is the number of infections used as input data to feed the two models. The OECD model uses estimates on the number of infections provided by the ECDC, national surveillance systems and the WHO. In comparison, the European Antibiotic Resistance Collaborators use a variety of sources combined through a meta-analytical approach. A direct comparison between the inputs of the two models is not currently possible because data on the number of infections are not publicly available. However, it should be noted that, particularly for some specific antibiotic-bacterium combinations, the number of deaths estimated by the European Antibiotic Resistance Collaborators is significantly higher than the number of infections officially reported by countries included in the OECD analysis.

Conclusion: There is no room for complacency in the fight against AMR

This chapter provided an analysis of the health and economic impact of resistant infections in 34 OECD and EU/EEA countries. Broadly, findings from the chapter demonstrated that AMR has a deleterious impact on population health by exacerbating mortality and morbidity while reducing the life span and the number of years lived in good health. It showed that three pathogens – *E. coli*, *K. pneumoniae* and *S. aureus* – account for around three-quarters of deaths each year that occur due to resistant infections. Further, the chapter showed that while the majority of resistant infections were acquired in community settings, infections acquired in hospital settings account for the majority of deaths caused by resistant infections.

The chapter also demonstrated that AMR imposes a considerable economic burden on the 34 countries included in the analysis. Depending on the modelling scenario, AMR is estimated to result in 6.9-32.5 million extra days spent in hospital every year. Resistance to readily available, affordable treatments will also mean that treatment of these infections will resort to medicines that are more costly, less effective, unavailable or unaffordable in many settings. The annual health expenditure due to AMR is estimated to amount to USD PPP 5.9 to USD PPP 28.9 billion, corresponding to per capita spending of around USD PPP 5.2 to USD PPP 25.6. AMR also has important consequences for participation in the workforce and productivity.

The chapter showed that worrisome discrepancies persisted in the health and economic burden of AMR across countries, with many southern European countries bearing a heavy cost. This cross-country variation reflects the differences in the epidemiology of AMR, health system characteristics and workforce policies in place in each country. Addressing these differences will require countries with heavier AMR burdens to take further steps in line with the priorities highlighted in the WHO Global Action Plan.

Findings from the chapter suggest that the health and economic burden of AMR is comparable to the COVID-19 pandemic. The chapter showed that the estimated loss of life due to AMR can reach up to one-third of the reduction in life expectancy attributable to COVID-19 between 2019 and 2020. Without robust policy action, the estimated costs associated with treating resistant infections can be equivalent to having a COVID-19 pandemic in nearly every five years. Much like the COVID-19 pandemic, the silent pandemic of AMR has important consequences for long-term macroeconomic performance and imposes considerable fiscal pressure. Similar to SARS-CoV-2, resistant bacteria can also evolve over time and adapt to the existing antibiotic treatments, and changes in the epidemiology of bacteria are difficult to predict ahead of time. Combined, these factors make it challenging to quantify the impact of AMR on population health and the economy.

The results presented in this chapter should be interpreted with care. The OECD analysis has several limitations. The OECD model considers priority antibiotic-bacterium combinations that are considered to pose the greatest threat to population health rather than attempting to account for all types of resistant infections. Differences in the data collection methods between countries that report data to the ECDC, the WHO and national AMR surveillance networks impact the comparability of results across countries. The model makes use of several assumptions which may influence the precision of its estimates. For example, the model assumes that resistant infections are not transferred across countries. This means that the potential impacts of the rising AMR trends in countries where the resistant proportions are estimated to be concerningly high are not directly accounted for in the model. Results presented here should be considered conservative because the model does not include the long-term sequelae of AMR, nor does it quantify their costs.

Combined, the results provided in this chapter underline the importance of continuing to invest in multi-sectoral policies to curb AMR. As discussed in detail in Chapter 4, OECD and EU/EEA countries have made important strides in recent years in developing and implementing their national action plans to tackle AMR, which put forward a wide range of policies and interventions to tackle AMR not only in the health sector but also in agricultural practices concerning animal and plant health, and in the environment. As shown in Chapter 5, many of these interventions have been shown effective though the precise magnitude of their effectiveness is influenced by a variety of contextual factors. Chapter 6 examines the cost-effectiveness of 11 interventions in line with the One Health approach to ascertain their impact of population and economy using the OECD SPHeP-AMR model.

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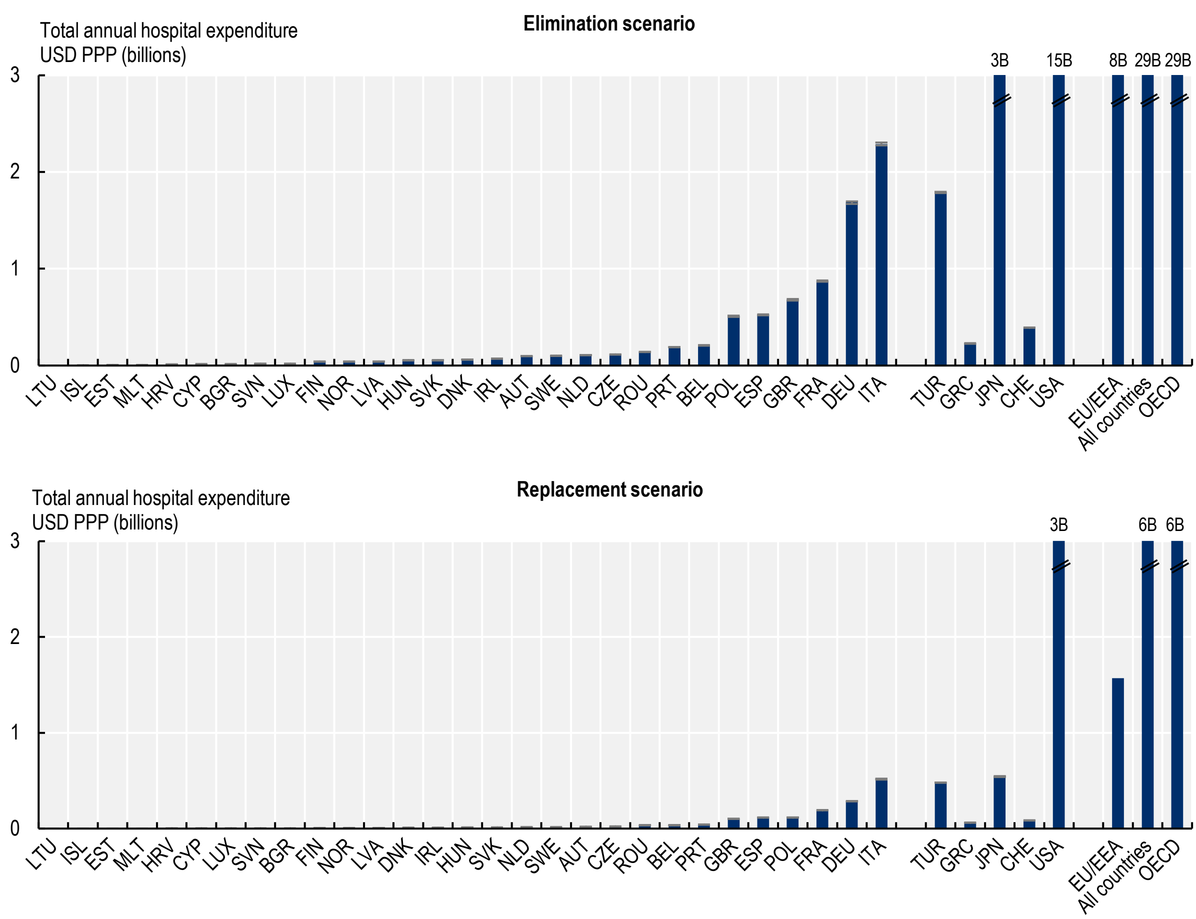
Annex 3.A. Impact of AMR on health expenditure and labour market outputs

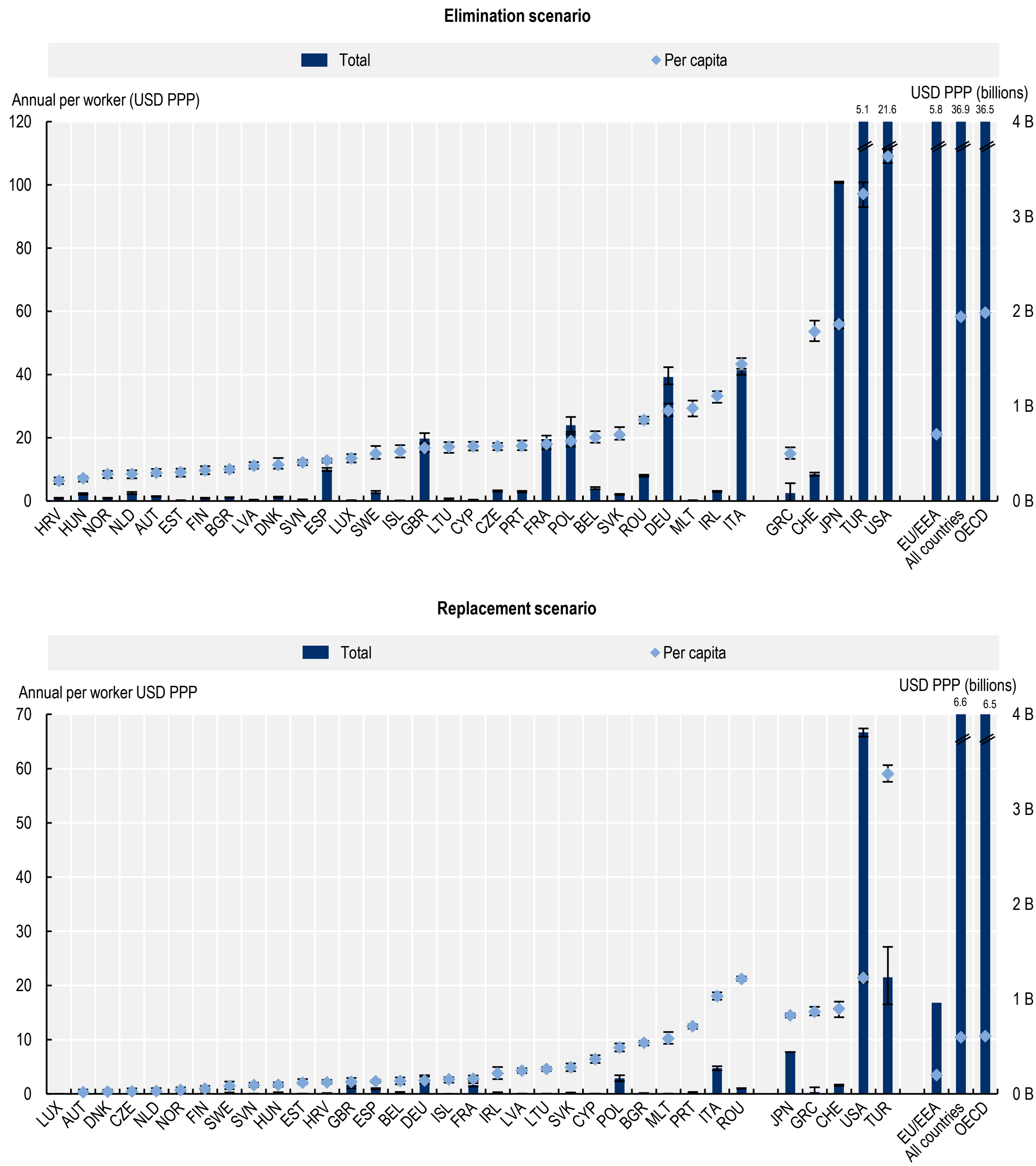
Annex Figure 3.A.1. Total annual hospital expenditure due to AMR up to 2050



Note: Results for Greece are presented on the right-hand side of the panel because data for *S. pneumoniae* are not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right-hand sides of the panel due to the methodological differences in data collection and data extraction practices.
Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/twsnm1

Annex Figure 3.A.2. Annual average labour market output per worker lost due to AMR based on average wages up to 2050



Note: Results for Greece are presented in the right hand-side of the panel because data for S. pneumoniae is not available. Results are presented based on the sources of input data, with data for countries in the group on the left that are all from the same source and calculated with a comparable methodology. Results are not directly comparable for countries on the left- and right hand-side of the panel due to the methodological differences in data collection and data extraction practices. B: Billion; PPP: Purchasing power parity
Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/67gk0h

4 Special focus: Assessing the landscape of national action plans on antimicrobial resistance

This chapter reviews the landscape of national action plans to tackle antimicrobial resistance (AMR-NAPs) developed by OECD member countries, key partners and Group of Twenty (G20) countries. First, the chapter takes stock of the global progress in the development of AMR-NAPs and provides a discussion of factors that enable and/or hinder the implementation of these documents. Then, the chapter provides a comparative assessment of AMR-NAPs from OECD, EU/EEA and G20 countries. The findings are the result of a novel application of natural language processing techniques that make use of text from action plans. In addition, the chapter examines the selected design features of these documents. The chapter concludes by discussing the implications of the findings for the implementation of AMR-NAPs by OECD, EU/EEA and G20 countries.

Key findings

Taking stock of the global progress in the development of national action plans to tackle AMR

- The publication of the Global Action Plan on Antimicrobial Resistance (AMR-GAP) in 2015 augured well for the development of national action plans to tackle AMR (AMR-NAPs). Globally, the share of countries with an AMR-NAP more than doubled, reaching 149 in 2021-22 from 70 in 2017. However, only around 10% (17/166) of countries globally reached the final stage of implementation, which entails including financial provisions for the implementation of AMR-NAPs in the national action plans and budgets.
- In 2021-22, about 92% (47/51) of OECD countries and key partners, European Union (EU) or European Economic Area (EEA) members and G20 countries finished developing their action plans. However, only 20% (10/51) of these countries advanced to the final stage of the implementation of their AMR-NAPs, which involves including financial provisions for the implementation of AMR-NAPs in national action plans and budgets.
- Among OECD countries, key partners, EU/EEA and G20 countries, there are gaps in the implementation of One Health approaches that entail the active involvement of multiple sectors in the development and implementation of AMR-NAPs. In these countries, the animal sector actively contributed to the development and implementation of nearly all of the AMR-NAPs in 2021-22. This is followed by the food safety and the environmental sectors, which played an active role in the development and implementation of 90% (46/51) and 71% (36/51) of AMR-NAPs respectively. In comparison, the food production and the plant health sectors were actively engaged in the development and implementation of 75% (38/51) and 59% (30/51) of action plans respectively.
- Nearly all OECD countries, EU/EEA and G20 countries put in place AMR-relevant multi-sectoral policies consistent with the AMR-GAP. However, there are notable gaps in the implementation of interventions relevant to: optimising antibiotic use in human and animal health; monitoring antibiotic use and AMR surveillance; scaling up infection prevention and control programmes; scaling up nationwide activities to raise AMR awareness; incorporating AMR in the training and education of human healthcare professionals; and implementing good management and hygiene practices in farms and food establishments.
- In 2020, the Group of Seven (G7) and OECD countries remained the primary source of development assistance for health (DAH) allocated to AMR, provided as financial and in-kind contributions transferred through international development institutions. Nonetheless, the current levels of DAH for AMR remain at around 2% and domestic sources of financing for AMR are unlikely to fill the existing funding gaps in low-resource settings.

Assessing the content of AMR-NAPs from 21 OECD countries and key partners, EU/EEA and G20 countries

- On average, AMR-NAPs from the 21 OECD countries and key partners, EU/EEA and G20 countries cover a span of five years. Many AMR-NAPs predate the publication of the AMR-GAP in 2015, while others are nearing the end of the period that they cover.
- There is little cross-country standardisation in the ways in which OECD countries assess their progress towards the goals that they state in their AMR-NAPs, making it difficult to compare cross-country performance over time.

- Only 12 out of 21 AMR-NAPs from OECD countries and key partners, EU/EEA and G20 countries discuss budgetary considerations and less than half refer to the cost-effectiveness of AMR-relevant interventions.
- A high degree of convergence is observed between AMR-NAPs and the AMR-GAP in terms of their strategic objectives. Much like the AMR-GAP, optimising the use of antimicrobials in human and animal health is estimated to be the most frequently featured strategic objective in AMR-NAPs from OECD countries and key partners, EU/EEA and G20 countries, followed by strengthening AMR surveillance, reducing the incidence of infections and making an economic case for sustainable investments. In comparison, improving awareness and understanding of AMR is the least frequently discussed strategic objective in these documents.
- OECD countries and key partners, EU/EEA and G20 countries discuss a wide range of AMR-relevant interventions to achieve their strategic priorities, reflecting the broader historical, socio-economic and health system-related factors that shape the AMR agenda in each setting.
- With respect to strategies to optimise antimicrobial use in human and animal health, OECD countries and key partners, EU/EEA and G20 countries primarily emphasise efforts to strengthen antimicrobial stewardship. Further improvements can be achieved by improving the availability of antibiotic prescribing guidelines beyond hospital and acute care settings, encouraging the use of older antimicrobials and scaling up electronic prescribing programmes.
- While the importance of strengthening AMR surveillance is recognised in the AMR-NAPs from 21 OECD countries and key partners, EU/EEA and G20 countries, these countries will benefit from deepening their engagement with global and regional AMR surveillance networks, enhancing laboratory network capacity and integrating information from new data sources into AMR surveillance.
- In terms of reducing the incidence of infections, the AMR-NAPs from 21 OECD countries and key partners, EU/EEA and G20 countries most frequently emphasise the importance of improving water, sanitation, hygiene and waste management practices and vaccination coverage in human health. There is a need to put more emphasis on veterinary vaccines and enhancing biosecurity.
- In terms of strategies to spur AMR-related research and development (R&D), OECD countries and key partners, EU/EEA and G20 countries primarily focus on a range of incentives aiming to encourage the early stage of drug development, whereas emerging evidence points to the need to supplement these incentives with those that can help improve expectations around future revenues.
- With respect to strategies to enhance AMR awareness and understanding, the selected AMR-NAPs frequently highlight interventions targeting medical professionals and the general public while less emphasis is given to interventions targeting young children.

Antimicrobial resistance (AMR) is a well-recognised global health challenge

In recent years, the global community made important strides to tackle AMR. In May 2015, all members of the World Health Organization (WHO) made a commitment to tackling AMR by adopting the Global Action Plan (AMR-GAP) (WHO, 2015[1]). The AMR-GAP articulated five strategic objectives (Box 4.1) and urged countries to develop their own AMR national action plans (AMR-NAPs) in line with these strategic objectives, as well as the standards and guidelines championed by other intergovernmental bodies like the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (WOAH) and the Codex Alimentarius Commission.

Box 4.1. A multi-pronged approach to curtailing AMR highlighted in the AMR-GAP involves five strategic objectives

Improve awareness and understanding of AMR through effective communication, education and training

Strengthen knowledge and evidence base through surveillance and research

Reduce incidence of infections through effective sanitation, hygiene and infection prevention and control measures

Optimise the use of antimicrobial medicines in human and animal health

Develop an economic case for sustainable investments that considers the needs of all countries and increase investment in new medicines, diagnostic tools, vaccines and other interventions

Source: WHO (2015[1]), *Global Action Plan on Antimicrobial Resistance*, https://apps.who.int/iris/handle/10665/193736.

Following the publication of the AMR-GAP, global efforts to tackle AMR gained momentum. In 2016, the members of the United Nations (UN) reaffirmed their commitment to the vision laid out in the AMR-GAP in the UN Political Declaration on AMR (UN, 2016[2]). The following year, G20 countries endorsed the AMR-GAP and called for the development of a global AMR R&D collaboration hub, which was launched in 2018. In 2019, the UN Ad Hoc Interagency Co-ordination Group on Antimicrobial Resistance (ICGAR) issued an urgent call to establish a One Health Global Leaders Group on Antimicrobial Resistance (WHO, 2019[3]). In 2020, AMR was highlighted as one of the five priority areas for global action in the WHO Thirteenth General Program of Work (2019-23) to improve population health and well-being (WHO, 2020[4]). This programme of work included one indicator – the proportion of bloodstream infections due to resistant organisms – as part of 46 key performance indicators to track progress by 2023 (WHO, 2020[4]). Importantly, many of these efforts have fostered collective, multi-sectoral action widely referred to as the

One Health framework (Box 4.2). In 2022, the WHO, FAO, WOAH and United Nations Environment Programme (UNEP) published a new framework which describes the background and context of collaboration to tackle AMR and presents a theory of change associated with collaboration across agencies, including goals and objectives, desired country-level impact, intermediate outcomes, assumptions and risks, and implementation arrangements (WHO et al., 2022[5]).

Box 4.2. The COVID-19 pandemic brought renewed attention to the One Health approach

A key principle embedded in the AMR-GAP is a collaborative, interdisciplinary, multi-sectoral action, referred to as the One Health approach. This approach recognises that many of the antimicrobial threats to human health are the same as those afflicting the health of animals and plants that share the same ecosystem (FAO and WHO, 2021[6]). It underscores the importance of pairing policies in the human health sector with those that are targeting the drivers of AMR in the animal and plant population, agricultural production, food safety and security, and environmental sectors.

Prior to the advent of the COVID-19 pandemic, the importance of the One Health framework was demonstrated time and again, with the emergence and spread of zoonotic viruses. In 2003, severe acute respiratory syndrome (SARS), caused by a novel coronavirus, spread rapidly across 29 countries in the Americas, Asia and Europe. Following the 2003 SARS epidemic, other zoonotic viruses undermined the performance of health systems across the globe, including the re-emergence and rapid spread of the highly pathogenic avian influenza H5N1 in 2013, the Ebola outbreak in West Africa, Zika in 2014-17 in the Americas and the Pacific regions, and the Middle East Respiratory Syndrome that emerged in 2012. Despite these experiences, the Independent Panel, which was convened at the request of the WHO World Health Assembly, concluded that the One Health framework has been overlooked in efforts to prepare for future health crises (The Independent Panel, 2021[7]).

Today, a new reality is at hand. At the writing of this chapter, the global COVID-19 infections surpassed 770 million confirmed cases and the attributable death toll reached nearly 7 million (Our World in Data, 2023[8]). Much like past pandemics, the COVID-19 outbreak put additional strain on health systems across the globe. Mounting evidence pointing to delays and disruptions in non-COVID19 healthcare provision (Chmielewska et al., 2021[9]; Harris et al., 2021[10]) and interruptions in the implementation of antimicrobial stewardship policies and AMR surveillance (Tomczyk et al., 2021[11]). Echoing calls from numerous international bodies, the Independent Panel strongly urged countries to embed the One Health framework as an integral part of their efforts to plan and prepare for future health emergencies (The Independent Panel, 2021[7]).

Source: Chmielewska, B. et al. (2021[9]), "Effects of the COVID-19 pandemic on maternal and perinatal outcomes: A systematic review and meta-analysis", https://doi.org/10.1016/s2214-109x(21)00079-6; Harris, R. et al. (2021[10]), "Impact of COVID-19 on routine immunisation in South-East Asia and Western Pacific: Disruptions and solutions", https://doi.org/10.1016/j.lanwpc.2021.100140; The Independent Panel (2021[7]), *COVID-19: Make It the Last Pandemic*, https://theindependentpanel.org/wp-content/uploads/2021/05/COVID-19-Make-it-the-Last-Pandemic_final.pdf; Our World in Data (2023[8]), *Coronavirus Pandemic (COVID-19)*, https://ourworldindata.org/COVID-deaths (accessed on 15 January 2022); Tomczyk, S. et al. (2021[11]), "Impact of the COVID-19 pandemic on the surveillance, prevention and control of antimicrobial resistance: A global survey", https://doi.org/10.1093/jac/dkab300.

The goal of this chapter is to review the AMR-NAP landscape in OECD members, key partners and G20 countries. As the first of the two policy chapters included in this publication, it starts by documenting the global progress in the development of AMR-NAPs and describes the factors that enable or hinder the implementation of these documents. Data used for this analysis come primarily from the most recent wave of the Tripartite AMR Country Self-Assessment Surveys conducted by the WHO, WOAH and FAO in 2020-21 (WHO/FAO/WOAH, 2022[12]). Next, the chapter takes a deep dive into the content of 21 AMR-

NAPs selected among OECD and G20 countries. To do this, the chapter provides new evidence on the selected design features of the AMR-NAPs that may influence the effectiveness of the implementation of the vision set out in these documents. Next, the chapter assesses the level of alignment between the AMR-NAPs and the AMR-GAP. Complementing this analysis, Chapter 5 then provides an overview of emerging evidence on the effectiveness of selected AMR interventions.

Global progress in the development and implementation of AMR-NAPs

Key messages

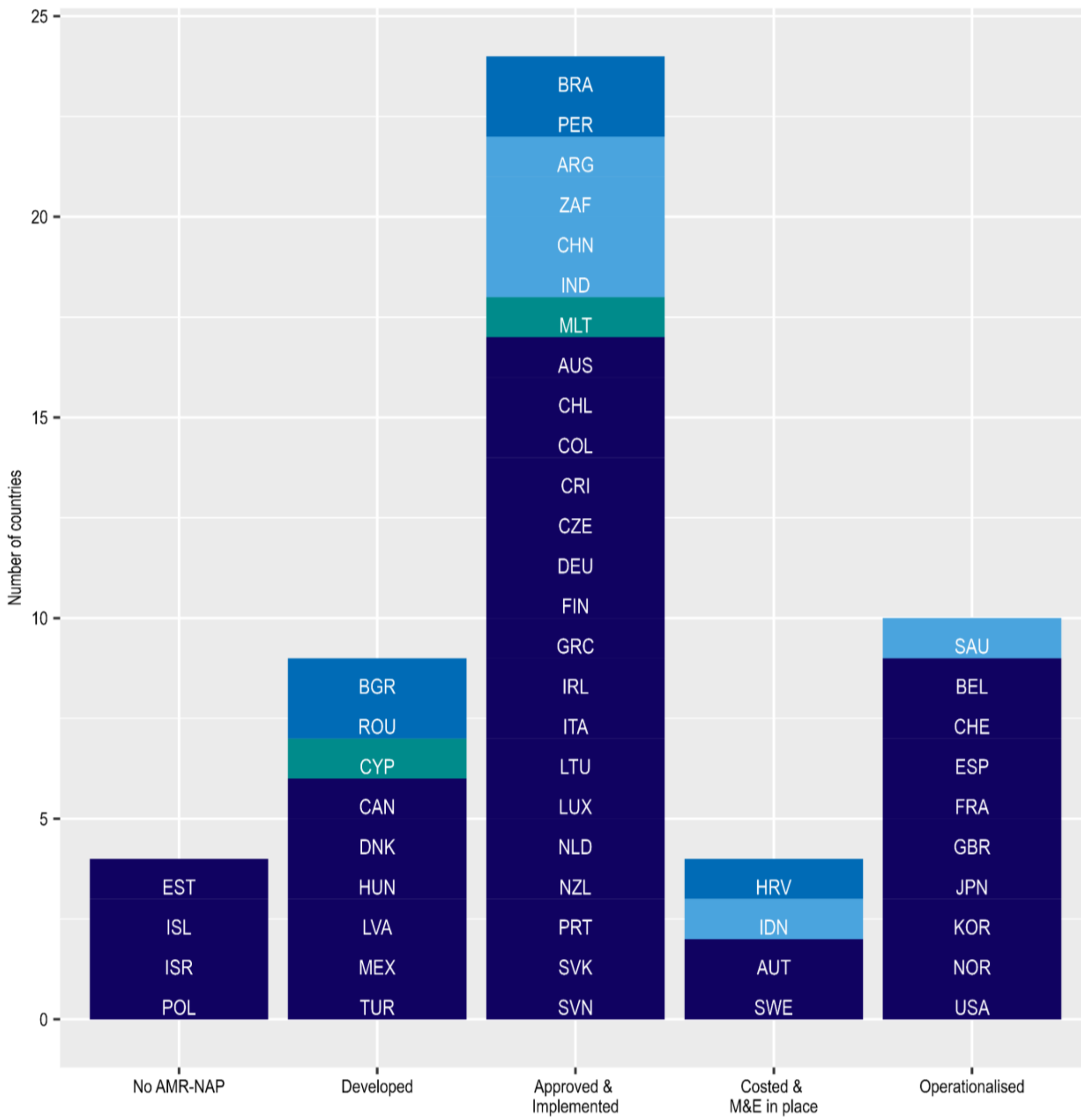
- Globally, the number of countries with AMR-NAPs more than doubled since 2016-17, reaching 149 countries in 2021-22. Yet only 17 out of 166 countries indicated that they included financial provisions for the implementation of their AMR-NAPs in the national action plans and budgets.
- Forty-seven out of 51 OECD countries and key partners, EU/EEA and G20 countries developed AMR-NAPs, but only 20% (10/51) of these countries indicated that they advanced to the final stage of implementation, which involves including financial provisions for the implementation of AMR-NAPs in national action plans and budgets.
- In line with the One Health approach, in all OECD members, EU/EEA and G20 countries, the animal sector was actively involved in the development and implementation of AMR-NAPs in 2021-22. However, there are gaps in multi-sectoral action. In 2021-22, the development and implementation of around 90% (46/51) of action plans from these countries involved the active participation of the food safety sector, whereas 71% (36/51) involved the environmental sector. In this period, the food production and plant health sectors actively contributed to the development and implementation of around 75% (38/51) and 59% (30/51) of the AMR-NAPs respectively.
- Globally, the implementation of AMR-NAPs is marked by a socio-economic development gradient. The current level of development assistance for health devoted to AMR is unlikely to make up for insufficient funding from domestic resources in resource-constrained settings.

Globally, there has been notable progress in the development and implementation of AMR-NAPs but gaps remain in the existing arrangements for including financial provisions for the implementation of AMR-NAPs in national action plans and budgets

The launch of the AMR-GAP in 2015 augured well for the development of AMR-NAPs across the globe, though many countries grapple with challenges in the execution of their action plans. The number of countries with AMR-NAPs more than doubled since 2016-17, reaching 149 countries in 2021-22 (WHO/FAO/WOAH, 2022[12]). Despite this, only 10% (17/166) of action plans proceeded to the most advanced stage of implementation in 2020-21, which involves the inclusion of financial provision for AMR-NAPs in the national plans and budgets (WHO/FAO/WOAH, 2022[12]). These findings are consistent with a recent discussion paper by the UN ICGAR, which showed that most countries face challenges in the execution of their AMR-NAPs rather than the development of these documents (ICGAR, 2018[13]).

AMR remains prominent in the public health agenda in OECD , EU/EEA and G20 countries but challenges persist (Figure 4.1). In 2021-22, about 92% (47/51) of OECD countries, key partners, EU/EEA and G20 countries finished developing their AMR-NAPs. However, the majority of these countries have not yet proceeded to the most advanced stage of implementation. In 2021-22, only around 20% (10/51) of these countries proceeded to the final stage of implementation, where financial provisions for the implementation of AMR-NAPs were included in the national plans and budgets (WHO/FAO/WOAH, 2022[12]). Importantly, many OECD countries reported that the AMR-relevant activities that they highlighted in their AMR-NAPs have been adversely impacted by the COVID-19 pandemic (Box 4.3).

Figure 4.1. Most countries developed an AMR-NAP but further progress is needed to strengthen financial provisions to support implementation



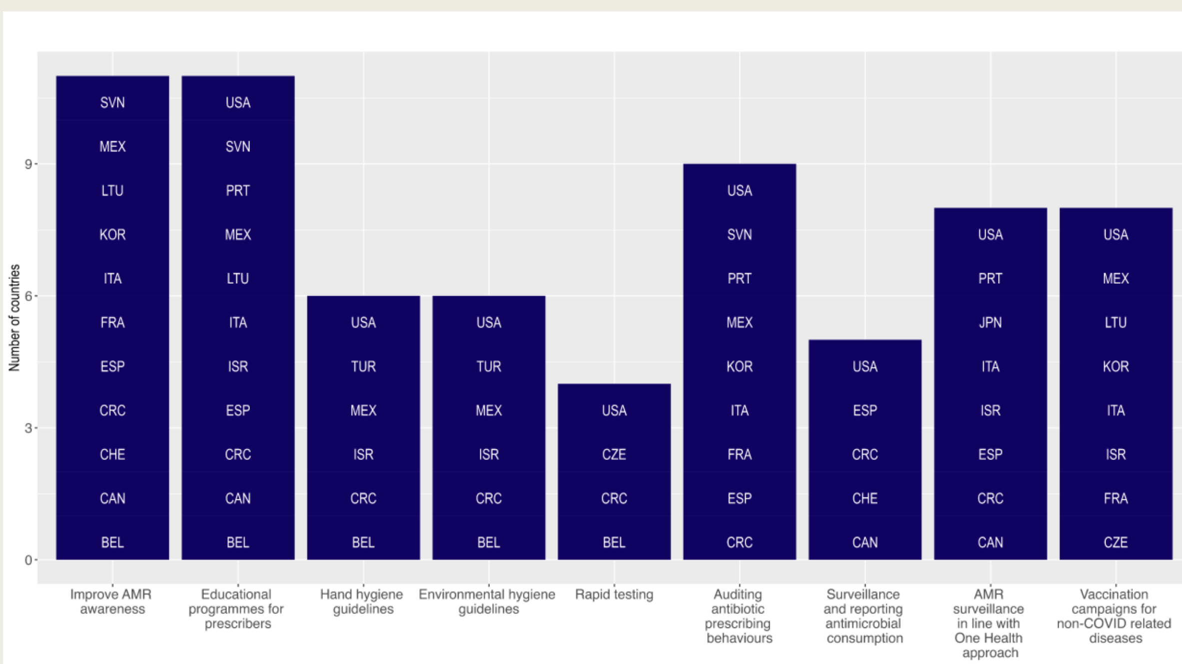
Note: Dark blue = OECD countries; medium blue = OECD accession countries; light blue = non-OECD G20 countries; green = non-OECD EU/EEA countries. The figure above describes the stages of the development of AMR-NAPs in five steps: i) *No AMR-NAP*: No AMR-NAP action plan; ii) *Developed*: AMR-NAP has been developed; iii) *Approved& Implemented*: AMR-NAP approved by government and is being implemented; iv) *Costed & M&E in place*: AMR-NAP has a costed and budgeted operational plan and has monitoring mechanism in place; v) *Operationalised*: Financial provision for the National AMR action plan implementation is included in the national plans and budgets.
Source: WHO/FAO/WOAH (2022[12]), *Tripartite AMR Country Self-Assessment Survey (TrACSS) 2021-2022*, https://amrcountryprogress.org/ (accessed on 4 December 2022).

Box 4.3. In many OECD countries, the implementation of AMR-relevant programmes and activities has been impacted by the COVID-19 pandemic

In many OECD countries, the implementation of many AMR-relevant initiatives featured in national action plans has been disrupted by the COVID-19 pandemic

As shown in Figure 4.2, the implementation of a wide range of activities highlighted in AMR-NAPs of many OECD countries has been disrupted by the COVID-19 pandemic. Evidence emerging from OECD countries suggests that the re-prioritisation of resources to address the COVID-19 pandemic may have adversely impacted the implementation of the AMR agenda. Of the 26 OECD countries that participated in the OECD Resilience of Health Systems questionnaire (OECD, 2023[14]), 11 countries indicated that activities to improve AMR awareness and understanding in the general public and educational programmes for antibiotic prescribers were disrupted due to the pandemic. Further, disruptions were reported by nine OECD countries in terms of monitoring antibiotic prescribing behaviours in healthcare facilities. In addition, eight OECD countries reported interruptions in AMR surveillance in line with the One Health framework, as well as disruptions in vaccine campaigns for non-COVID-19 related health conditions. OECD countries also reported interruptions in the rapid testing of patients and disruptions in the compliance of health workers with the existing hand hygiene and environmental hygiene guidelines in healthcare facilities. In addition, many OECD countries indicated that they were forced to delay revising/updating their AMR-NAPs due to the COVID-19 pandemic while others suggested that final approval and budget allocation of the full implementation of AMR-NAPs were impacted.

Figure 4.2. AMR-relevant activities and programmes were adversely impacted by COVID-19



Source: Analysis of OECD (2023[14]), *Ready for the Next Crisis? Investing in Health System Resilience*, https://doi.org/10.1787/1e53cf80-en.

OECD countries have been actively pursuing approaches to limit the impact of the COVID-19 pandemic on the implementation of their AMR-NAPs

Many OECD countries employed strategies to limit the impact of the COVID-19 pandemic on the implementation of their AMR-NAPs. For example, in Belgium, hospitals were given extra financial resources to support their ongoing antimicrobial stewardship programmes and infection prevention and control interventions. In Portugal, regional AMR teams maintained close contact with local hospitals to avoid major disruptions in the already existing AMR measures. In Korea, online educational programmes were used to support the management of AMR policies. In the United States, the Centers for Disease Control and Prevention, one of the federal agencies leading the AMR agenda, continued to highlight AMR as a top priority by continuing investments in various prevention strategies, including early detection and containment, and infection prevention and control.

Source: Analysis of OECD (2023[14]), *Ready for the Next Crisis? Investing in Health System Resilience*, https://doi.org/10.1787/1e53cf80-en.

Globally, socio-economic disparities exist in the implementation of AMR-NAPs

A socio-economic development gradient emerges in the implementation of AMR-NAPs. In 2021-22, among high-income countries (HICs), about 20% of AMR-NAPs advanced to the final stage of implementation, compared to 7% in upper-middle-income countries (UMICs) and in lower-middle-income countries (LMICs) and none of the low-income countries (LICs) (WHO/FAO/WOAH, 2022[12]). While the evidence base that can help explain these discrepancies remains limited, previous works from low-resource settings point to the deficits in technical capacity and staffing, institutional bottlenecks that hinder efforts to scale up local efforts (ICGAR, 2018[13]) and the differences in the governance approach to managing AMR (Birgand et al., 2018[15]).

Insufficient funding devoted to AMR is another bottleneck. A recent Wellcome Trust analysis concluded that financial limitations present a major impediment to implementing AMR-NAPs in many LMICs. Even when these countries identify funding to support the implementation of their AMR-NAPs, the level of funding may be insufficient to cover all of the intended activities (Wellcome, 2020[16]). In addition, access to high-quality drugs remains a challenge in many LMICs (Hauk et al., 2020[17]), which can exacerbate the emergence of drug-resistant pathogens. In recognition, new pooled funding mechanisms have emerged in recent years to overcome these financial constraints (Box 4.4).

Box 4.4. In the last two decades, the Global Drug Facility (GDF) of the Stop Tuberculosis (TB) Partnership contributed to improving access to quality-assured TB drugs across the globe

In 2020, an estimated 10 million people globally suffered from TB, a substantial proportion of which are multidrug resistant (WHO, 2021[18]). LMICs bear a considerable share of the TB burden worldwide (WHO, 2021[18]). Despite this, about 10% of all medicines in LMICs are considered poor-quality or counterfeit (Hauk et al., 2020[17]). Reliance on poor-quality anti-TB drugs not only decreases the likelihood of successful recovery but also promotes the emergence of drug-resistant TB pathogens. Exacerbating these challenges, many LMICs alone have limited negotiation power to reduce the price of TB drugs, even though patents for many of these drugs have already expired (Arinaminpathy et al., 2013[19]).

Recognising these challenges, the GDF was founded in 2001 as an alternative procurement model to help address issues around low-quality anti-TB drugs. The GDF was designed to ensure countries have equitable and uninterrupted access to high-quality medicines, and pools funds from donors and national governments. By consolidating demand for TB drugs from different countries, it negotiates the price of quality-assured TB medicines directly with drug suppliers (Arinaminpathy et al., 2013[19]). It also provides technical assistance, supply management tools and capacity-building tools to accelerate access to and take up of new TB products in resource-constrained settings.

Today, the GDF is the world's largest provider of TB-related drugs and diagnostics used in a variety of government-administered TB programmes, as well as TB programmes administered by international agencies (Hauk et al., 2020[17]). Since its launch, the GDF services were utilised by 151 countries to increase access to quality-assured TB diagnostics and treatments (Stop TB Partnership, 2021[20]). In 2020, the value of first-line and second-line medicines procured by the GDF reached USD 108 million and USD 141 million respectively, whereas the value of diagnostics reached USD 57.9 million (Stop TB Partnership, 2021[20]).

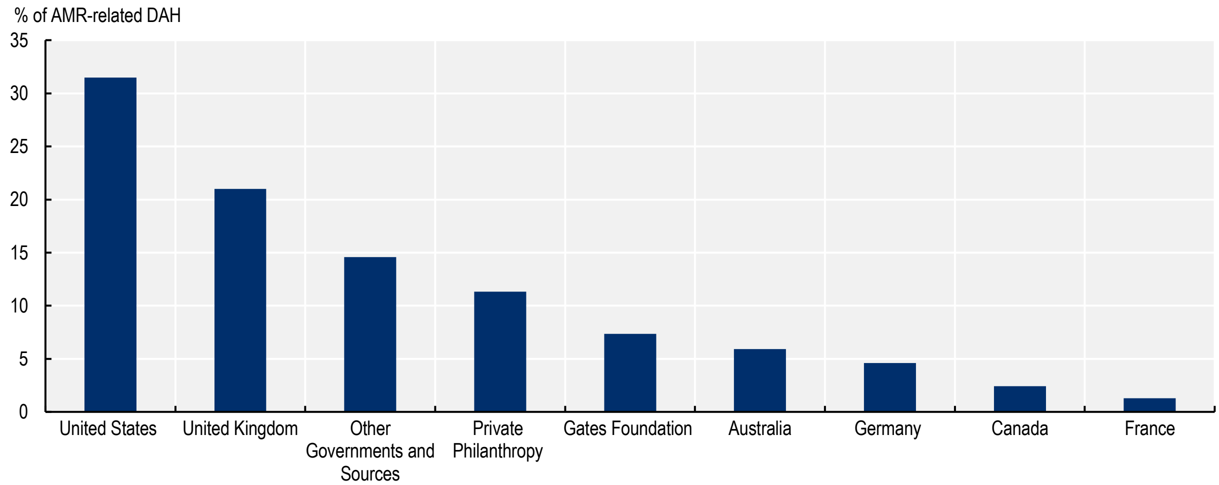
Source: Arinaminpathy, N. et al. (2013[19]), "The Global Drug Facility and its role in the market for tuberculosis drugs", https://doi.org/10.1016/s0140-6736(13)60896-x; Hauk, C. et al. (2020[17]), "Quality assurance in anti-tuberculosis drug procurement by the Stop TB Partnership – Global Drug Facility: Procedures, costs, time requirements, and comparison of assay and dissolution results by manufacturers and by external analysis", https://doi.org/10.1371/journal.pone.0243428; Stop TB Partnership (2021[20]), *GDF Results*, https://www.stoptb.org/mission/gdfs-results (accessed on 30 March 2022); WHO (2021[18]), *Tuberculosis – Factsheet*, https://www.who.int/news-room/fact-sheets/detail/tuberculosis (accessed on 30 March 2022).

G7 and OECD countries are committed to mobilising development assistance for health (DAH) allocated to AMR but the current level of financial assistance is unlikely to address the existing gaps in domestic funding in resource-constrained settings

In recent years, AMR has been reframed as a public health issue with important consequences for socio-economic development in resource-constrained settings. In 2018, the ICGAR suggested that AMR is not perceived as a priority issue in many LMICs (2018[13]). The publication analysis indicated that this perception may limit access to development funding and projects. The following year, the World Bank highlighted the need for reframing AMR not only as a public health challenge but also as a global development issue by arguing that AMR has far-reaching implications for human capital in developing countries, and failing to curb the AMR burden may impede progress towards United Nations Sustainable Development Goals (2019[21]).

G7 and OECD countries remain steadfast in their commitment to financing AMR-related activities across the globe but the current level of development funding allocated to AMR is unlikely to fill the existing gaps in domestic funding (Figure 4.3). In 2020, G7 and OECD countries were the leading sources of DAH allocated to AMR, including Australia, France, Germany, the United Kingdom and the United States (IHME, 2021[22]). Yet, the current level of DAH allocated to AMR remains low, with AMR receiving close to around 2% of DAH dedicated to communicable diseases in 2019. Considering that many countries across the globe are marshalling financial resources to address the COVID-19 pandemic, the current level of DAH for AMR is unlikely to make up for the funding gap in low-resource settings.

Figure 4.3. G7 and OECD countries are still committed to financing AMR activities across the globe, 2019



Source: IHME (2021[22]), *Flows of Development Assistance for Health*, https://vizhub.healthdata.org/fgh/ (accessed on 15 September 2021).

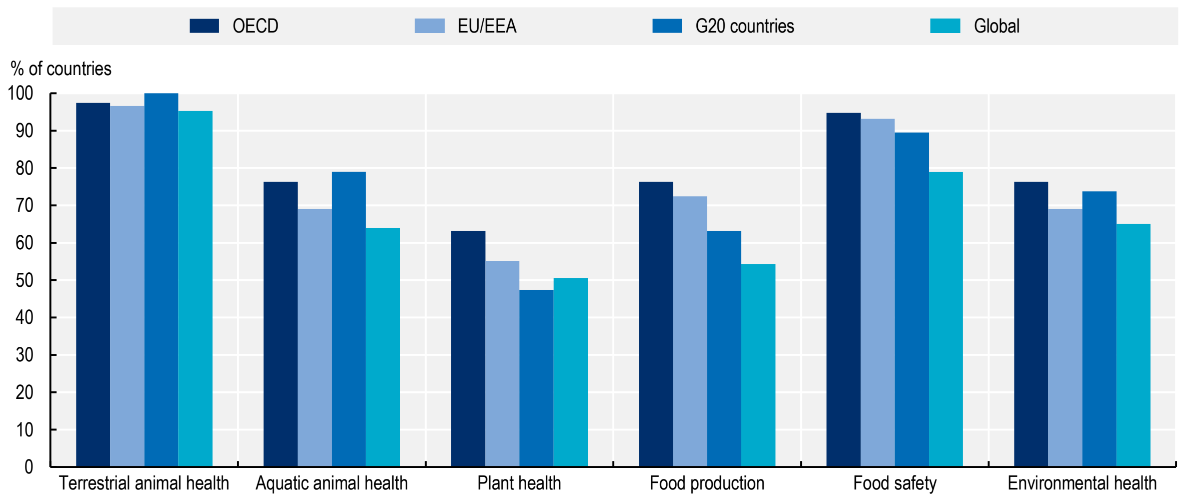
While the animal health sector is actively involved in the development and implementation of AMR-NAPs in most countries, further advancements are needed to incorporate input from other sectors

The period following the publication of the AMR-GAP has seen improvements in the number of countries that sought multi-sectoral feedback while developing their AMR-NAPs. In 2021-22, globally, more than 1 sector was actively involved in the development and implementation of AMR-NAPs in about 98% (162/166) of countries (WHO/FAO/WOAH, 2022[12]). Similarly, in all OECD countries, EU/EEA and G20 countries, at least two sectors actively participated in the development and implementation of action plans in 2021-22 (WHO/FAO/WOAH, 2022[12]). This finding is in congruence with earlier studies which showed that most countries across the globe adopted some form of multi-sectoral approach in the development and implementation of their AMR-NAPs (Munkholm et al., 2021[23]).

Yet, the development and implementation of AMR-NAPs do not always entail the active involvement of all relevant sectors (Figure 4.4). The linkages between human and animal health appears to be well recognised. In 2021-22, in nearly all (165/166) of countries that reported data to the Tripartite AMR Country Self-Assessment Survey, the process to develop and implement AMR-NAPs actively involved the terrestrial animal health sector and, in 96% (158/166) of countries, this process involved the health of aquatic animals. Yet only a fraction of AMR-NAPs, globally, were developed and implemented with the active involvement of the other sectors. In 2021-22, the development and implementation of about 79% (131/166) of AMR-NAPs involved the food safety sector, whereas 65% (108/166) involved the environment, 55% (90/166) food production and only 51% (84/166) reflected the active involvement of the plant health sector (WHO/FAO/WOAH, 2022[12]).

Across OECD countries and key partners, EU/EEA and G20 countries, stakeholders from the animal health sector most commonly take an active role in the development and implementation of AMR-NAPs, whereas stakeholders representing food safety and security, the transmission of AMR in the environment and plant health are less involved. In 2021-22, animal health was nearly universally acknowledged in the AMR-NAPs by OECD members and key partners, EU/EEA and G20 countries. In comparison, in around 90% (46/51) of these countries, the development and implementation of action plans involved the active participation of the food safety sector (WHO/FAO/WOAH, 2022[12]). Similarly, the environment sector was actively involved in the development and implementation of around 71% (36/51) of action plans. In the same period, the food production and plant health sectors were actively involved in the development and implementation of 75% (38/51) and 59% (30/51) of AMR-NAPs respectively.

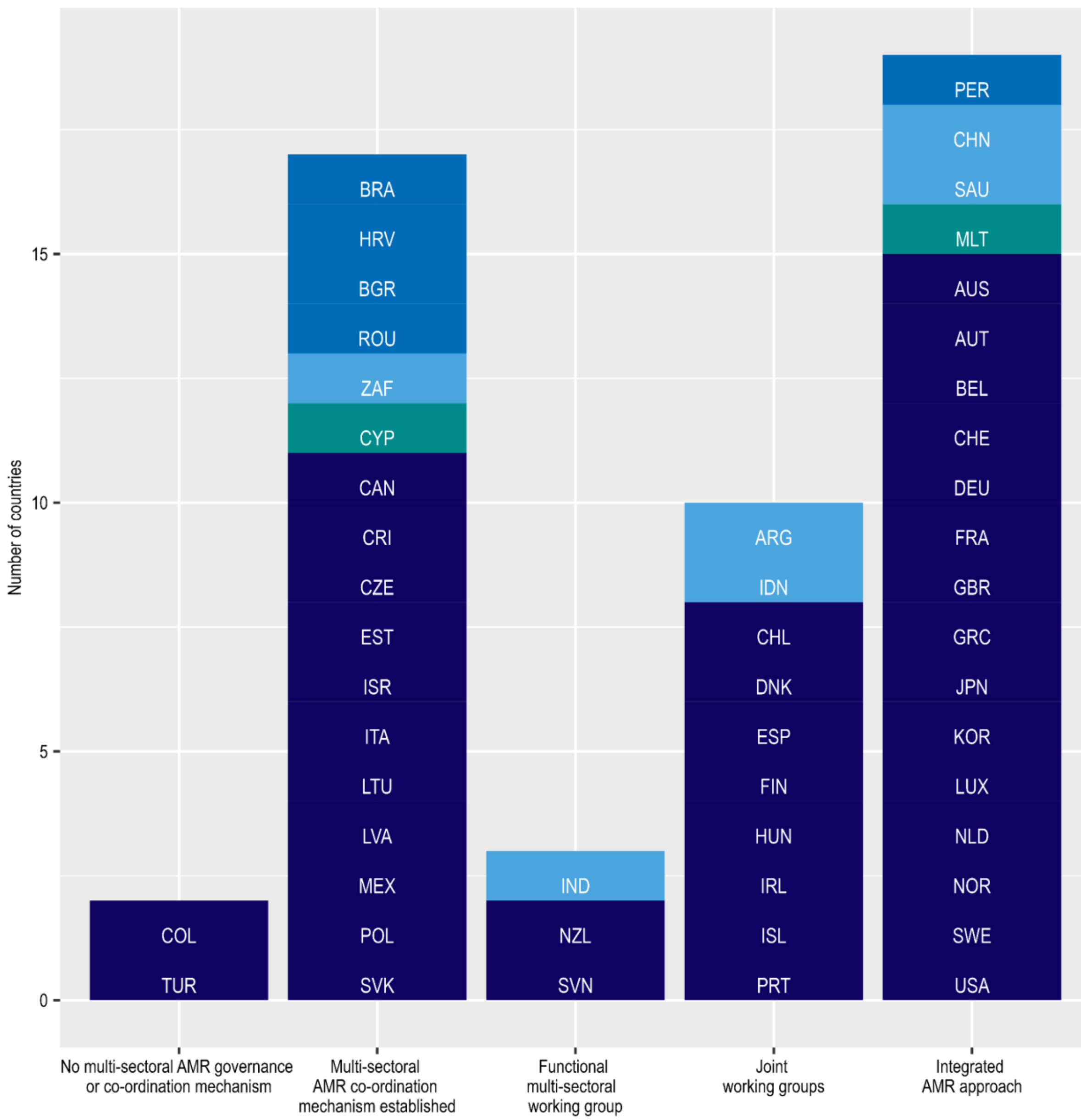
Figure 4.4. The animal sector is the main non-human health sector routinely involved in the development and implementation of AMR-NAPs



Note: EU: European Union; EEA : European Economic Area; G20: Group of Twenty.
Source: WHO/FAO/OEI (2022[12]), *Tripartite AMR Country Self-Assessment Survey (TrACSS) 2020-2021*, https://amrcountryprogress.org (accessed on 4 December 2022).

Globally, important strides have been made in building multi-sectoral co-ordination mechanisms to support multi-sectoral approaches to tackling AMR (Figure 4.5). Establishing multi-sectoral co-ordination mechanisms is an important first step towards facilitating multi-sectoral AMR response (Box 4.5). Globally, 87% (144/166) of countries established some form of a formal multi-sectoral governance or co-ordination mechanism on AMR 2021-22 (WHO/FAO/WOAH, 2022[12]). In 2021-22, nearly all OECD countries, key partners, EU/EEA and G20 countries (49/51) put in place some form of multi-sectoral co-ordination mechanism (i.e. working groups/co-ordination committees) to promote multi-sectoral AMR-relevant policy development and implementation. Importantly, new multinational initiatives emerged to promote multi-sectoral action across countries (Box 4.6). While relatively little is known about the factors that influence the effectiveness of multi-sectoral co-ordination mechanisms, limited evidence suggests that various factors may influence the co-ordination of multi-sectoral action including political will, administrative and financial support, as well as the dearth of available AMR data that can be used to facilitate dialogue and varying priorities across stakeholders (Joshi et al., 2021[24]).

Figure 4.5. Many OECD countries rely on integrated-approaches to implement their AMR-NAPs



Note: Dark blue = OECD countries; medium blue = OECD accession countries; light blue = non-OECD G20 countries; green = non-OECD EU/EEA countries. The figure above describes the stages of multi-sectoral collaboration: i) *No multi-sectoral AMR governance or co-ordination mechanism*; ii) *Multi-sectoral AMR co-ordination mechanism established*: Multi-sectoral AMR co-ordination mechanisms are established with government leadership; iii) *Functional multi-sectoral working group*: Formalised multi-sector co-ordination mechanism with technical working groups established with clear terms of reference, regular meetings and funding for working group(s) with activities and reporting/accountability arrangements defined; iv) *Joint working groups*: Joint work on issues including agreement on common objectives; v) *Integrated AMR approaches*: Integrated approaches are used to implement the AMR-NAP with relevant data and lessons learnt across sectors used to adapt implementation of AMR-NAP.

Source: WHO/FAO/WOAH (2022[12]), *Tripartite AMR Country Self-Assessment Survey (TrACSS) 2021-2022*, https://amrcountryprogress.org/ (accessed on 4 December 2022).

Box 4.5. Co-ordinating multi-sectoral collaboration and co-operation for AMR-relevant action in the United States

In the United States, the government's Interagency Task Force for Combating Antibiotic-Resistant Bacteria (CARB) remains the key driver of multi-sectoral collaboration and co-ordination and that co-ordination enabled the development of the updated AMR-NAP, as well as the implementation of CARB work in general (CARB, 2020[25]). Established in 2015, the CARB Task Force is co-chaired by the Secretaries of the US Departments of Health and Human Services, Agriculture and Defence, as well as representatives from the Departments of the Interior, State, and Veterans Affairs, the Environmental Protection Agency, the US Agency for International Development, the National Science Foundation, as well as representatives from the Executive Office of the President (CARB, 2020[25]). The Health and Human Services Office of the Assistant Secretary for Planning and Evaluation is tasked with the co-ordination of the CARB Task Force, as well as the development of annual progress reports, and led the development of the 2020 AMR-NAP (CARB, 2020[25]). The CARB Task Force meets on a quarterly basis to discuss the ongoing work and reports annually on the progress toward goals stated in the AMR-NAP.

The CARB Task Force recruited more than 100 federal experts from multiple disciplines to work as part of cross-agency teams that helped develop the goals included in the US AMR-NAP published in 2020. Each cross-agency team was comprised of experts from multiple disciplines (e.g. experts on human health surveillance and experts on animal health surveillance). The process to develop the goals included in the 2020 AMR-NAP entailed several steps. First, reviews of the progress towards each milestone highlighted in the previous AMR-NAP dated 2015 were carried out. These reviews looked at the progress in the implementation of actions associated with each milestone, identified both the challenges that had been experienced and opportunities that had risen since 2015, and pointed out the challenges and opportunities that are anticipated in the future. Subsequently, the cross-agency teams proposed, reiterated and refined new objectives and targets included in the 2020 AMR-NAP.

Source: CARB (2020[25]), *National Action Plan for Combating Antibiotic-Resistant Bacteria 2020-25*, https://www.hhs.gov/sites/default/files/carb-national-action-plan-2020-2025.pdf (accessed on 21 June 2022).

Box 4.6. The EU Strategic Approach to addressing pharmaceuticals in the environment rests on multi-sectoral action

In March 2019, the EU member states adopted a common approach to addressing the presence of pharmaceuticals in the environment, including antimicrobials (European Commission, 2019[26]). The EU approach recognises that the presence of antimicrobials used in human and veterinary medicine found in water and soil systems may contribute to the development, maintenance and spread of resistant pathogens. Aligned explicitly with the objectives of the European One Health Action Plan against Antimicrobial Resistance, the EU approach lays out six strategic priority areas for action that cover the lifecycle of pharmaceuticals:

- Increase awareness and promote prudent use of pharmaceuticals, including antimicrobials.
- Support the development of pharmaceuticals intrinsically less harmful to the environment and promote greener manufacturing practices.
- Improve environmental risk assessment and its review.
- Reduce wastage and improve waste management.
- Expand environmental monitoring.
- Fill other knowledge gaps, including the links between the presence of antimicrobials in the environment and the development and spread of AMR.

Since 2019, notable progress has been made in the implementation of the EU strategic approach. For instance, ministers of health in the EU member states started considering options that can help promote the consideration of the environmental impacts of medicines in the prescription decisions of health professionals (European Commission, 2020[27]). Another initiative led by the ad hoc working group through the Pharmaceutical Committee for human medicines was an agreement towards sharing best practices among health professionals across EU member states to promote environmentally safe disposal of medicinal products and clinical waste, as well as the ways in which pharmaceutical residues can be collected in an environmentally safe manner (European Commission, 2020[27]).

Source: European Commission (2019[26]), *European Union Strategic Approach to Pharmaceuticals in the Environment*, https://ec.europa.eu/environment/water/water-dangersub/pdf/strategic_approach_pharmaceuticals_env.PDF; European Commission (2020[27]), *Update on Progress and Implementation: European Union Strategic Approach to Pharmaceuticals in the Environment*, https://ec.europa.eu/environment/water/water-dangersub/pdf/Progress_Overview%20PiE_KH0320727ENN.pdf (accessed on 4 April 2022).

Gaps exist in the implementation of AMR-relevant multi-sectoral policies consistent with the AMR-GAP

Table 4.1 provides a dashboard of AMR-relevant multi-sectoral policies implemented in OECD countries and key partners, EU/EEA and G20 countries in congruence with the AMR-GAP based on responses provided by countries in the latest round of the Tripartite AMR Country Self-Assessment Survey (2021-22) (WHO/FAO/WOAH, 2022[12]) (Annex 4.A provides more detailed information on the methodology used to develop the dashboard). Findings emerging from this dashboard point to important gaps in implementation:

- In nearly all OECD countries and key partners, EU/EEA and G20 countries, there are national policies for antimicrobial governance that pertains to the community and healthcare settings. However, only eight of these countries currently have in place guidelines for optimising antibiotic use in human health for all major syndromes, with data on antibiotic use shared back with prescribers in a systematic manner.

- In nearly all OECD countries and key partners, EU/EEA and G20 countries, a national policy or legislation exists to regulate the quality, safety and efficacy of antimicrobial productions used in terrestrial and aquatic animal health, as well as their distribution sale or use. But, only in 18 of these countries, enforcement and control mechanisms are reportedly in place to ensure compliance with the existing policy or legislation.
- Nearly all OECD countries and key partners, EU/EEA and G20 countries have a national plan or system for monitoring antimicrobial use in their own settings. But only 26 of these countries regularly collect and report data on antimicrobial sales and consumption at the national level for human use, and data on antibiotic prescribing and appropriate/rational antibiotic use are drawn from a representative sample of health facilities in the public and private sectors.
- All OECD countries and key partners, EU/EEA and G20 countries reported having the capacity to: i) generate data on antibiotic susceptibility testing, as well as related clinical and epidemiological data; and ii) report AMR. However, only 14 of these countries have a national AMR surveillance system that links AMR surveillance with antimicrobial consumption and/or use data in the human health sector.
- 23 OECD countries and key partners, EU/EEA and G20 countries reported that infection prevention and control (IPC) programmes are in place and functioning at the national and health facility levels in line with the WHO IPC core components. In these countries, compliance and effectiveness are regularly evaluated and published, and guidance is updated in accordance with monitoring.
- All OECD countries and key partners, EU/EEA and G20 countries promote AMR awareness, but only nine of these countries have in place routine targeted, nationwide, government-supported activities to raise AMR awareness to facilitate behaviour change among priority stakeholders, with regular monitoring of these activities.
- All OECD countries and key partners, EU/EEA and G20 countries provide training and professional education opportunities to raise awareness of AMR among health professionals in the human health sector, though only eleven of these countries systematically incorporate AMR in pre-service training curricula for all relevant human health cadres, and in-service training and other professional education opportunities are taken up by relevant groups for the human health sector in public and private sectors.
- All OECD countries and key partners, EU/EEA and G20 countries reported having in place some systematic efforts to improve good animal husbandry and biosecurity practices in terrestrial animal health. But only eight of these countries monitor the implementation of their nationwide plans periodically. Similarly, 43 OECD countries and key partners, EU/EEA and G20 countries make systematic efforts to improve good practices for aquatic animals and only six of these countries monitor the implementation of their nationwide plans regularly.
- Forty-eight OECD countries and key partners, EU/EEA and G20 countries reported having in place some mechanisms to improve good practices in food processing. However, only ten of these countries monitor the implementation of their nationwide action plans periodically.

Table 4.1. Dashboard on the implementation of selected AMR-relevant policies in OECD countries and key partners, EU/EEA and G20 countries

Country	Optimising antimicrobial use in human health	Optimising antimicrobial use in animal health	National monitoring system for consumption and rational use of antimicrobials in human health	National surveillance system for AMR in humans	Strengthening IPC practices in human healthcare	Raising AMR awareness and understanding	Training and education on AMR in human health	Biosecurity and good animal husbandry practices (terrestrial animal production)	Biosecurity and good animal husbandry practices (aquatic animal production)	Good management and hygiene practices in food processing
Australia										
Austria										
Belgium										
Canada										
Chile										
Colombia										
Costa Rica										
Czech Republic										
Denmark										
Estonia										
Finland										
France										
Germany										
Greece										
Hungary										
Iceland										
Ireland										
Israel										
Italy										
Japan										
Korea										
Latvia										
Lithuania										

Country	Optimising antimicrobial use in human health	Optimising antimicrobial use in animal health	National monitoring system for consumption and rational use of antimicrobials in human health	National surveillance system for AMR in humans	Strengthening IPC practices in human healthcare	Raising AMR awareness and understanding	Training and education on AMR in human health	Biosecurity and good animal husbandry practices (terrestrial animal production)	Biosecurity and good animal husbandry practices (aquatic animal production)	Good management and hygiene practices in food processing
Luxembourg										
Mexico										
Netherlands										
New Zealand										
Norway										
Poland										
Portugal										
Slovak Republic										
Slovenia										
Spain										
Sweden										
Switzerland										
Türkiye										
United Kingdom										
United States										
Argentina										
Brazil										
Bulgaria										
China										
Croatia										
Cyprus										
India										
Indonesia										
Malta										
Peru										
Romania										
Saudi Arabia										
South Africa										

Note: The methodology used to build the dashboard is available in Annex 4.A. OECD and non-OECD countries are listed in alphabetical order.
No data
No implementation
First stage of implementation
Second stage of implementation
Third stage of implementation
Most advanced stage of implementation
Source: WHO/FAO/WOAH (2022[12]), *Tripartite AMR Country Self-Assessment Survey (TrACSS) 2021-2022*, https://amrcountryprogress.org/ (accessed on 4 December 2022).

Assessing the key design features of AMR-NAPs

Key messages

- OECD countries and key partners, EU/EEA and G20 countries will benefit from keeping their AMR-NAPs up to date while streamlining efforts to measure performance over time.
- Deepening engagement with international and regional organisations that facilitate co-ordinated action in line with the One Health approach is needed.
- Many AMR-NAPs can be further improved by incorporating budget considerations and cost-effectiveness assessments.

The remainder of this chapter presents results from a systematic assessment of the content of AMR-NAPs from selected OECD countries and key partners, EU/EEA and G20 countries based on a natural language processing (NLP) approach (Box 4.7). The OECD analysis first looks at the selected design features of AMR-NAPs, including performance tracking over time, engagement with international and regional bodies, and financial considerations and cost-effectiveness assessments. These features were selected because they were proposed as part of key design aspects of the AMR-NAPs that impact the effectiveness of the vision laid out in these documents (Chua et al., 2021[28]; Ogyu et al., 2020[29]; Anderson et al., 2019[30]). Next, the level of alignment between AMR-NAPs and the AMR-GAP is examined in terms of the strategic objectives and interventions recommended in the AMR-GAP.

Box 4.7. The OECD analysis deploys natural language processing techniques to examine the landscape of AMR-NAPs

Using text from AMR-NAPs as analysable data

The OECD analysis presented here is the first application of NLP guided methods to ascertain the level of alignment between AMR-NAPs and the AMR-GAP in 21 OECD countries and key partners, EU/EEA and G20 countries. Reflecting the advancement made in the application of machine learning techniques, NLP-guided techniques are increasingly being used to explore a variety of public health issues ranging from smoking behaviours (Pearson et al., 2018[31]), alcohol consumption (Rudge et al., 2021[32]) and obesity (Chou, Prestin and Kunath, 2014[33]) to public perception of policies to mitigate the impacts of the COVID-19 pandemic (Petersen and Gerken, 2021[34]). The methodology used by the OECD analysis was vetted through a peer-review process in a high-impact Journal (Özçelik et al., 2022[35]) (a brief explanation of the methodology and the list of AMR-NAPs from the OECD countries and key partners, EU/EEA and G20 countries included in the analysis are provided in the Annex 4.A).

The OECD analysis makes use of two commonly used NLP metrics to assess the level of alignment between AMR-NAPs and the AMR-GAP. Term frequency (TF) is the first metric used in the analysis. It is interpreted as the relative emphasis on each strategic objective/intervention in a collection of AMR-NAPs. It is a preferable metric to assess relative emphasis because it enables an analysis that takes into account the differences between the lengths of documents. It quantifies the frequency by which each term is associated with strategic objectives and recommended interventions that occur within an AMR-NAP with respect to the total number of terms in the term dictionary developed by the

OECD. The second NLP metric used in the OECD analysis is term frequency-inverse document frequency (TF-IDF). TF-IDF is calculated to enable a comparative analysis of AMR-relevant interventions that occur in a given AMR-NAP in comparison to how frequently these interventions are featured across the collection of action plans. By evaluating TF-IDF scores, interventions that are most distinctly highlighted in each AMR-NAP compared to other documents can be identified.

Source: Chou, W., A. Prestin and S. Kunath (2014[33]), "Obesity in social media: A mixed methods analysis", https://doi.org/10.1007/s13142-014-0256-1; Gentzkow, M., B. Kelly and M. Taddy (2019[36]), "Text as data", https://doi.org/10.1257/jel.20181020; Petersen, K. and J. Gerken (2021[34]), "#COVID-19: An exploratory investigation of hashtag usage on Twitter", https://doi.org/10.1016/j.healthpol.2021.01.001; Pearson, J. et al. (2018[31]), "Exposure to positive peer sentiment about nicotine replacement therapy in an online smoking cessation community is associated with NRT use", https://doi.org/10.1016/j.addbeh.2018.06.022; Rudge, A. et al. (2021[32]), "How are the links between alcohol consumption and breast cancer portrayed in Australian newspapers?: A paired thematic and framing media analysis", https://doi.org/10.3390/ijerph18147657.

Performance tracking toward the objectives stated in the AMR-NAPs can be enhanced across OECD countries and key partners, EU/EEA and G20 countries

OECD countries and key partners, EU/EEA and G20 countries are diverse in terms of the time period of implementation they cover in their AMR-NAPs. Typically, AMR-NAPs are forward-looking documents that set out strategic goals and objectives to be realised in a predetermined period of time. The OECD analysis shows that, on average, the AMR-NAPs from the countries included in the analysis cover a span of nearly five years. But exceptions arise. The AMR-NAP from the Slovak Republic has the narrowest time span covering the two-year period 2019-21, whereas the AMR-NAP from Australia sets a 20-year vision for the years from 2020 to 2040. In addition, the OECD analysis shows that AMR-NAPs from 6 OECD countries and key partners, EU/EEA and G20 countries predate the AMR-GAP and have not yet been updated since their initial publication, while many other AMR-NAPs are approaching the end of their coverage period.

There is a need to streamline the process to track performance relevant to the commitments made in the AMR-NAPs. Once they develop their AMR-NAPs, OECD members rely on different approaches to tracking their performance. For example, following the publication of its AMR-NAP in 2015, Germany regularly published interim reports that describe the national and subnational progress towards the goals stated in its AMR-NAP. France provides annual updates on the country's progress towards the strategic priorities discussed in its AMR-NAP. Similarly, Australia publishes technical reports and analyses in regular intervals to continue to improve AMR awareness in hospital and community settings (ACSQHC, 2021[37]). While these efforts provide a valuable avenue to assess each country's performance, there is little cross-country standardisation in the ways in which OECD countries examine their performance, making it difficult to compare cross-country performance over time.

Closer engagement with international organisations can help facilitate co-ordinated action in line with the One Health approach

The OECD countries and key partners, EU/EEA and G20 countries explicitly recognise that curtailing AMR requires building international alliances and partnerships, but the nature of engagement with international bodies is often left undiscussed. While all 21 AMR-NAPs referred to the WHO as a key partner in tackling AMR, only around 71% (15/21) directly referenced the AMR-GAP. In addition to the WHO, nearly all OECD countries and key partners, EU/EEA and G20 countries made references to the WOAH, reflecting increasing attention to animal health as a pathway to tackle AMR. In comparison, the FAO was mentioned only by two-thirds of AMR-NAPs (14/21) and UNEP was highlighted in less than 15% (4/21) of these documents. Importantly, even when these documents reference international bodies in their action plans, they do not often provide details on the extent of their engagement.

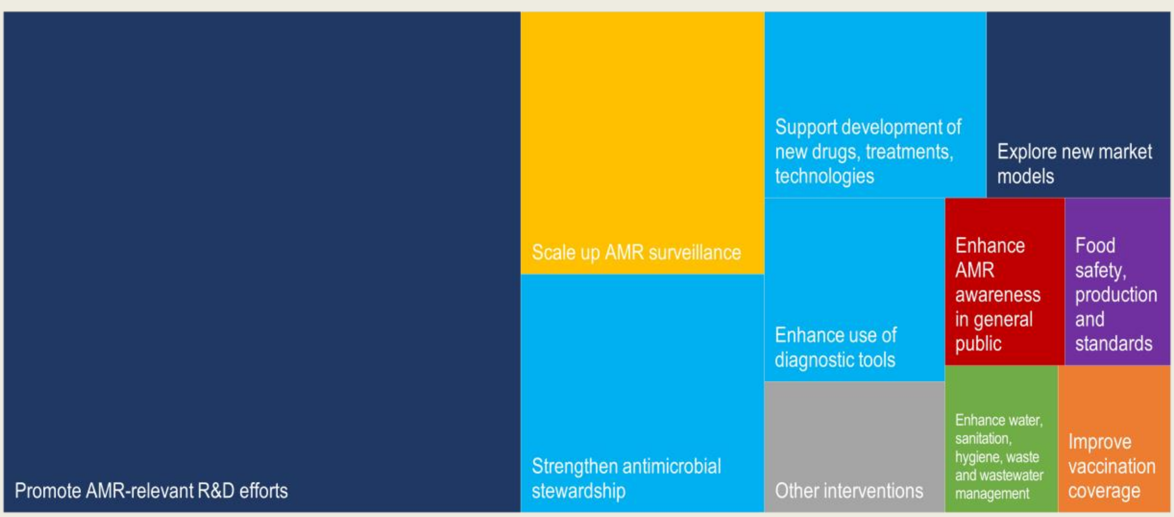
Globally, a number of regional AMR initiatives proliferated in recent years to tackle AMR (Box 4.8). In 2017, EU member states adopted the 2017 European One Health Action Plan against Antimicrobial Resistance, with the aim of bringing the EU to the forefront of efforts to tackle AMR (European Commission, 2017[38]). Another important regional initiative was initiated when AMR was included in the five-year work programme of the Association of the Southeast Asian Nations (ASEAN) from 2016 to 2020 (Yam et al., 2019[39]). ASEAN members reiterated their commitment to regional co-operation in tackling AMR in the 2017 Joint Declaration on Action against AMR and 2018 ASEAN Plus Three Leaders’ Statement on Co-operation against Antimicrobial Resistance. In 2018, the newly launched Africa Centres for Disease Control and Prevention (Africa CDC) network developed a framework for tackling AMR (Africa CDC, 2018[40]). In this framework, the members of Africa CDC committed to establishing the Antimicrobial Resistance Surveillance Network, which will serve as a platform to foster collaboration across national public health institutions in the region.

Box 4.8. The European One Health Action Plan provides an important platform for cross-country collaboration and co-operation to tackle AMR

Developed in 2017, the European One Health Action Plan supports the EU and its member states through a three-pillar strategy of making the EU a best-practice region, boosting research, development and innovation, and shaping the global AMR agenda. Each pillar details actionable, interdependent steps to be pursued concurrently by the EC (European Commission, 2017[38]). The EU action plan stipulates that the member states are primarily responsible for identifying policies in alignment with their own needs and priorities, though the highlighted policies are considered to offer substantial value. Recently, the European Commission's Directorate-General for Health and Food Safety published a review of the policy priorities highlighted in the EU member states' AMR-NAPs (European Commission, 2022[41]).

As shown in Figure 4.6, policies that receive the greatest attention in the EU action plan include supporting AMR-relevant R&D, exploring new economic models and incentives that promote AMR-relevant innovations, scaling up AMR surveillance and stewardship interventions that promote the prudent use of antibiotics in the EU and beyond. In comparison, policies that promote improved water, sanitation, hygiene, waste and wastewater management practices are featured to a lesser extent, as well as policies to improve AMR awareness in the general public, enhancing food safety and improving food production and standards.

Figure 4.6. Top 10 interventions highlighted most frequently in the EU One Health Action Plan



Note: The colour dark blue denotes interventions that can help develop an economic case for sustainable investment; the light blue depicts interventions that aim to optimise antimicrobial use in human and animal health; the colour yellow denotes interventions to strengthen knowledge and evidence base through surveillance and research; the colour red represents interventions that can help improve awareness and understanding of AMR; orange denotes interventions to improve vaccination coverage and the colour grey denotes other interventions.
Source: OECD analysis focusing on the content of the EU One Action Plan in terms of the relative emphasis of policy interventions linked to strategic objectives highlighted in the WHO-GAP. Emphasis on each policy is measured as a function of the frequency of terms associated with that policy relative to the frequency of terms linked to all of the strategic objectives.
Source: European Commission (2017[38]), *A European One Health Action Plan against Antimicrobial Resistance (AMR)*, https://health.ec.europa.eu/system/files/2020-01/amr_2017_action-plan_0.pdf; European Commission (2022[41]), *Overview Report: Member States' One Health National Action Plans against Antimicrobial Resistance*, https://health.ec.europa.eu/system/files/2022-11/amr_onehealth_naps_rep_en.pdf.

OECD countries and key partners, EU/EEA and G20 countries can further improve their action plans by integrating financial considerations and cost-effectiveness assessments in these documents

Most AMR-NAPs lack detailed discussions around financial resources allocated to supporting the AMR agenda. The AMR-GAP underscores that countries need to make financial commitments to ensure advancements towards the policy vision laid out in their action plans (WHO, 2015[1]). Further, the WHO, FAO and WOAH recommend that countries perform regular assessments and reviews of the existing financial commitments in order to ascertain whether funds are dispersed in a timely fashion and in accordance with the priorities discussed in the AMR-NAPs (WHO/FAO/WOAH, 2019[42]). Despite this, only 57% (12/21) of the AMR-NAPs from OECD countries and key partners, EU/EEA and G20 countries discuss financial considerations and, even when financial considerations are mentioned, the level of financial resources committed to the AMR agenda often remains unclear.

Return on AMR-relevant investments can be better understood by utilising evidence generated by cost-effectiveness assessments of interventions highlighted in AMR-NAPs. The OECD analysis shows that only around 43% (9/21) of OECD countries and key partners, EU/EEA and G20 countries refer to the cost-effectiveness of AMR-relevant investments that they consider in their action plans. For instance, the AMR-NAP from Switzerland highlights that research efforts focusing on the development of new diagnostic products are considered to be a cost-effective measure to facilitate the rapid detection of AMR. The AMR-NAP from the United Kingdom also alludes to the cost-effectiveness of diagnostic tools and suggests that evidence generated by cost-effectiveness models that demonstrate the value of diagnostic tools can be used to spur behaviour change among prescribers and health commissioners and encourage greater use of diagnostic tools. The AMR-NAP from Canada highlights that establishing a fast-track process to license antimicrobial drugs, alternatives to antimicrobials and new diagnostics is a cost-effective strategy to scale up investments in the development of pharmaceuticals. In the AMR-NAP from Malta, raising the awareness of employers on the benefits of extending options for home rest for employees who recover from mild infections is highlighted as a cost-effective strategy to interrupt the transmission of diseases in the workplace.

Assessing the alignment between AMR-NAPs and the AMR-GAP

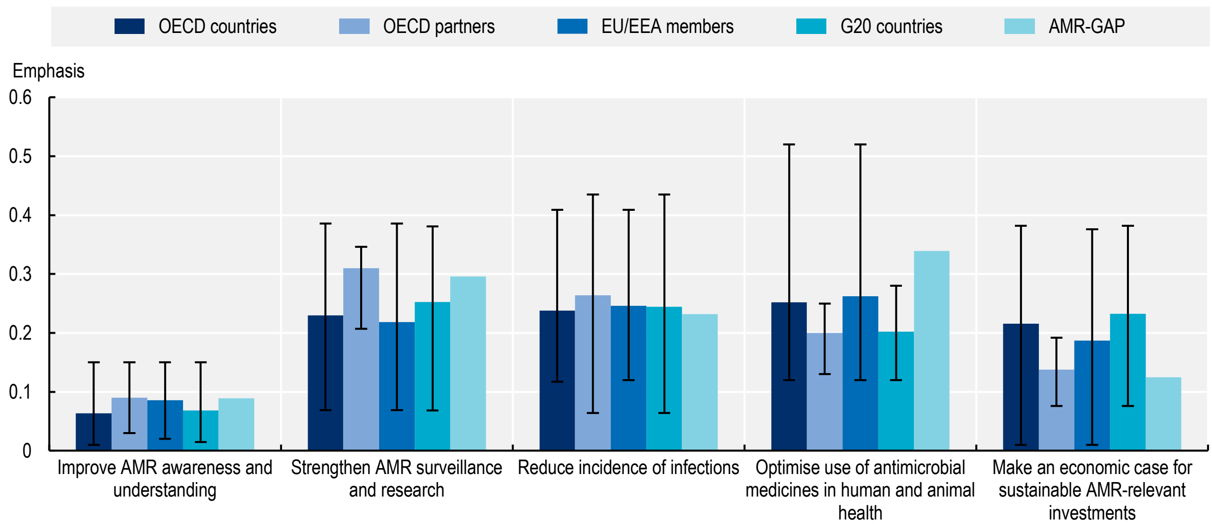
Key messages

- OECD countries and key partners, EU/EEA and G20 countries are consistent with the AMR-GAP in terms of the strategic objectives that they adopt in their action plans. There is a diversity of approaches across countries in terms of the range of interventions highlighted in AMR-NAPs to achieve these strategic objectives.
- Optimising the use of antimicrobial medicines in human and animal health is the most prominently featured strategic priority but further improvements can be achieved:
  - Even though some older classes of antibiotics can still be used to treat certain indications, only about 24% of AMR-NAPs (5/21) reference older antimicrobials.
  - Less than half of AMR-NAPs (10/21) include discussions around AMR among the elderly populations, even though providers frequently prescribe antibiotics to their older patients as part of their treatment.

- There are notable gaps in the monitoring of antibiotic consumption, with only around 19% of AMR-NAPs (4/21) referring to having at least one indicator based on a measure of defined daily doses or days of therapy.
    - In animal health, about one-third of AMR-NAPs (6/21) lack any references to the antibiotics critically important to human health altogether.
- While OECD countries and key partners, EU/EEA and G20 countries well recognise the centrality of strengthening AMR surveillance, deficits exist in engagement with global and regional AMR surveillance networks, enhancing laboratory network capacity and collecting information from new data sources.
- The existing infection prevention and control programmes can be further advanced by incorporating strategies that promote food security and safety, and enhance biosecurity:
    - In 2021-22, 49 out of 51 OECD, EU/EEA and G20 countries had in place national and facility-level IPC programmes in line with the WHO IPC core components, but only 23 out of 51 of these countries reported having IPC programmes that operate at the national and facility levels, where compliance and effectiveness are monitored and evaluated regularly.
    - Only a handful of AMR-NAPs mention IPC measures like decolonisation (i.e. the eradication or the reduction in the asymptomatic carriage of bacteria) and environmental hygiene and only 12 out of 21 AMR-NAPs stress the importance of hand hygiene practices.
    - Only 3 out of 21 AMR-NAPs refer to biosecurity measures in farm settings.
- The OECD countries remain the largest financers of AMR-related R&D but there is room for new commitments to push incentives and harness public-private partnerships.
- With respect to strategies to improve AMR awareness and understanding, OECD countries and key partners, EU/EEA and G20 countries put greater emphasis on interventions targeting medical professionals and the general community, whereas interventions targeting young children receive less attention.

The OECD countries and key partners, EU/EEA and G20 countries are consistent with the AMR-GAP in terms of strategic objectives that they adopt in their action plans (Figure 4.7). Much like the AMR-GAP, the most frequently emphasised strategic objective by OECD, EU/EEA and G20 countries relates to interventions aiming to optimise the use of antimicrobial medicines in human and animal health, followed by strengthening AMR surveillance, enhancing sanitation, hygiene and waste management practices and spurring investments in AMR technologies. In comparison, increasing AMR awareness and education is the least frequently discussed strategic priority by countries and key partners, EU/EEA and G20 countries, as well as the AMR-GAP.

Figure 4.7. AMR-NAPs in most countries are well-aligned with the AMR-GAP in terms of the five strategic priorities



Note: The five strategic objectives displayed in the graph above are adapted from those discussed in the AMR-GAP. Emphasis on each strategic objective is quantified as a function of the total number of terms associated with that strategic objective relative to the total number of terms included in the term dictionary. Strategic objectives with greater term frequency are discussed more frequently in the text compared to those with lower term frequency. The whiskers represent the lowest and highest emphasis given to each strategic objective across the collection of AMR-NAPs.
Countries included in the analysis: Australia, Canada, China, Denmark, Finland, France, Germany, India, Indonesia, Ireland, Japan, Malta, New Zealand, Norway, South Africa, Saudi Arabia, the Slovak Republic, Sweden, Switzerland, the United Kingdom and the United States.
AMR-GAP: Global Action Plan on Antimicrobial Resistance; EU: European Union; EEA: European Economic Area; G20: Group of Twenty.
Source: Özçelik, E.A. et al. (2022[35]), "A comparative assessment of action plans on antimicrobial resistance from OECD and G20 countries using natural language processing", https://doi.org/10.1016/j.healthpol.2022.03.011.

OECD countries and key partners, EU/EEA and G20 countries are highly diverse in the interventions that they distinctly highlight in their action plans

Different AMR-relevant interventions receive varying levels of attention across AMR-NAPs from the OECD countries and key partners, EU/EEA and G20 countries. For instance, with respect to interventions aiming to raise AMR awareness and understanding, Denmark and France stand out as countries that more frequently emphasise strategies to improve public awareness of AMR compared to others. Integrating AMR in professional education and training is more frequently highlighted in the action plans from Germany and the Slovak Republic. In terms of strengthening AMR knowledge and surveillance, Japan, New Zealand and the United States more frequently emphasise considerations around integrating new data sources into AMR surveillance, compared to the other countries included in the analysis. With respect to interventions to optimise antimicrobial use, Denmark, France and Norway more frequently discuss efforts to monitor antimicrobial consumption compared to other countries. Discussions around the importance of vaccines are more distinctly highlighted by Norway compared to other countries. In comparison, Finland, France and Japan more frequently discuss concerns related to enhancing biosecurity, and food safety and security. With respect to initiatives that aim to make an economic case for AMR investments, Switzerland and the United Kingdom more distinctly include discussions around exploring new market models and economic incentives, whereas Australia and France more distinctly highlight promoting public-private partnerships (PPP).

Several factors help explain the diverging patterns in interventions that countries emphasise in their AMR-NAPs. A greater emphasis on one intervention does not imply that countries neglect other interventions. Instead, these diverging patterns may reflect the range of challenges that influence health system performance in each country at the time that policy makers develop these guiding documents. For example, India – one of the global AMR hotspots – is among the countries that explicitly highlight the importance of restricting the sale of antimicrobials without proper prescription. This pronounced emphasis may be partly due to the high prevalence of informal healthcare providers with no formal medical training in prescribing antimicrobials without prescription (Das et al., 2016[43]).

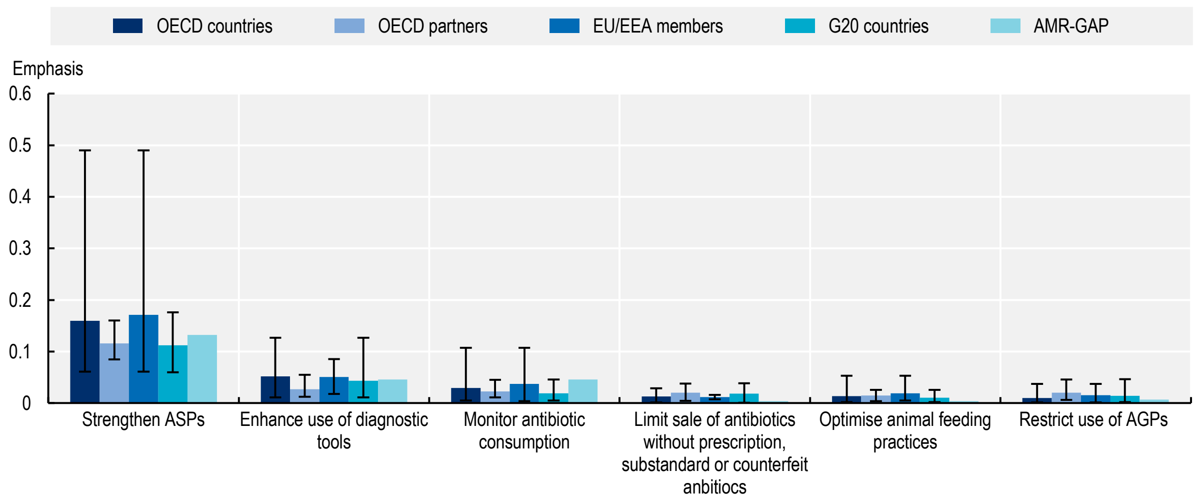
Alternatively, countries may choose to highlight strategies that they aspire to implement in the future rather than discussing strategies that they already put in place. For instance, Denmark does not provide in-depth discussions on the use of antimicrobials as growth promoters in its action plan even though this practice has been outlawed in the country in 1995. Similarly, in the United States, the AMR action plan does not specifically refer to electronic prescribing (e-prescribing) because this practice is considered to be well-integrated into the health system. Another alternative explanation relates to the socio-economic, historical and political factors, as well as the broader health system governance arrangements that may influence which interventions are ultimately featured in the AMR-NAPs. For instance, in Denmark and Sweden, veterinarians, farmers and regulatory authorities have a long history of co-operation and collaboration, which has been shown to affect the ways in which the AMR agenda has developed in these countries (Björkman et al., 2021[44]; FAO, 2020[45]).

OECD countries and key partners, EU/EEA and G20 countries highlight a wide range of interventions in their AMR-NAPs to optimise the use of antimicrobial medicines in human and animal health

Most policies that aim to optimise the use of antibiotics recognise that the choices made by individuals are an important part of antibiotic use. Health professionals' prescription behaviours are influenced by a range of factors including their medical training, the availability of systems that support clinical decision-making, provider compensation methods, professional and social preferences, and norms. Similarly, patient knowledge, preferences and attitudes play an important role in antibiotic use. Patient behaviours such as self-medication and non-compliance with the recommended course of treatment undermine efforts to curb AMR. Interactions between healthcare providers and patients have also been shown to influence behaviours around antibiotics.

All 21 AMR-NAPs explicitly recognise the importance of optimising the use of antibiotics, though these documents lay out a wide array of approaches to achieve this goal (Figure 4.8). Much like the AMR-GAP, AMR-NAPs from OECD countries and key partners, EU/EEA and G20 countries most frequently highlight efforts to strengthen antimicrobial stewardship programmes (ASPs) to promote the prudent use of antimicrobials. ASPs typically refer to a set of complex programmes that involve the implementation of multiple interventions designed to improve the ways in which antibiotics are prescribed by health professionals and used by patients. In addition to ASPs, enhancing the use of diagnostic tools is another frequently mentioned strategy in action plans, as well as monitoring the consumption of antimicrobials. In comparison to other interventions to optimise antibiotic use, OECD countries and key partners, EU/EEA and G20 countries less frequently mention efforts to limit the sale of antibiotics without a prescription and counterfeit or substandard antimicrobial sales, optimise animal feeding practices and restrict the use of antibiotics as growth promoters.

Figure 4.8. Antimicrobial stewardship programmes in human and animal health are the most highlighted interventions in AMR-NAPs



Note: The graph above displays a set of interventions selected from those recommended by the WHO to optimise antimicrobial use in human and animal health. Emphasis on each AMR-relevant intervention is quantified as a function of the total number of terms associated with that intervention relative to the total number of terms included in the term dictionary. Interventions with greater term frequency are discussed more frequently compared to interventions with lower term frequency. The whiskers represent the lowest and highest emphasis given to each intervention across the collection of AMR-NAPs.

Countries included in the analysis: Australia, Canada, China, Denmark, Finland, France, Germany, India, Indonesia, Ireland, Japan, Malta, New Zealand, Norway, South Africa, Saudi Arabia, the Slovak Republic, Sweden, Switzerland, the United Kingdom and the United States.

AGPs = antimicrobials as growth promoters; AMR-GAP: Global Action Plan on Antimicrobial Resistance; ASPs = antimicrobial stewardship programmes; EU: European Union; EEA: European Economic Area; G20: Group of Twenty.

Source: Özçelik, E.A. et al. (2022[35]), "A comparative assessment of action plans on antimicrobial resistance from OECD and G20 countries using natural language processing", https://doi.org/10.1016/j.healthpol.2022.03.011.

Support antimicrobial stewardship programmes in human health

OECD countries rely on ASPs with varying design features to optimise antibiotic use to reflect the needs and priorities in their own settings. For example, in its AMR-NAP, Denmark considers a range of national and local measures to reduce the overall consumption of antibiotics in primary healthcare, with a recognition that different regions may require different measures to achieve the desired reductions in antibiotic consumption. The Danish approach has an explicit focus on the treatment of specific target groups like respiratory infections in children, coughs in adults or urinary tract infections in women. In addition, the Danish AMR-NAP encourages delayed prescribing practices, co-operation with regional consultants and promotion of tools that can provide electronic overviews and comparisons of prescribing practices. In comparison, in its AMR-NAP, Sweden aims to promote the responsible use of antibiotics rather than an overall reduction in antibiotic consumption. To achieve this goal, Sweden relies on a multi-modal approach that includes a continued focus on antibiotics prescriptions by authorised professionals, continued measurement of data on compliance with treatment guidelines both in human healthcare and veterinary medicine, adequate access to new and older antibiotics, and an emphasis on quality assured and adequate diagnostics, as well as the management of common infections. Importantly, Sweden combines interventions focusing on prescribing behaviours in the human health sector with efforts to promote responsible antibiotic manufacturing, safe disposal of antibiotics and waste management to promote responsible use in the lifetime of the antibiotics, as well as efforts to optimise antibiotic prescribing in veterinary medicine.

Recent WHO guidance points out that course corrections may be needed in the implementation of activities carried out under the overall organisation of ASPs over time. These modifications may be introduced either by altering the ways in which the interventions are implemented on the ground or by introducing new interventions to reflect the evolving needs in a given context of care (WHO, 2019[46]). The WHO guidance notes that the ease of implementation of each type of ASP will largely correlate with the availability of resources and competencies in health facilities and recommends the prioritisation of interventions in accordance with resource availability in a given context.

The effectiveness of many ASPs can be enhanced by extending antibiotic guidance to healthcare settings beyond hospital and acute care. The OECD analysis shows that hospitals and acute care facilities constitute around 75% of different types of healthcare settings discussed in AMR-NAPs from OECD countries and key partners, EU/EEA and G20 countries, followed by primary healthcare, and community settings (14%) and long-term care (11%). Moreover, none of the AMR-NAPs makes any references to developing guidance for telemedicine, even though this mode of healthcare delivery had already been on the rise even before the COVID-19 pandemic (Oliveira Hashiguchi, 2020[47]).

Only a handful of OECD countries adopt a comprehensive approach to tackling AMR in older populations. For example, Japan is considering options to incorporate materials concerning AMR, IPC and antimicrobial stewardship into the undergraduate curriculum and training guidelines for professionals deployed in nursing care. In addition, the national qualification examinations for nursing care staff will expand their focus on these topics. Japan also aims to strengthen AMR surveillance in nursing care, while conducting research to establish the current status of AMR in nursing care facilities. Complementing these efforts, Japan aims to establish clinical reference centres for AMR at the local level. These centres will be responsible for developing AMR-relevant educational materials to be used in a variety of settings, including nursing homes. These interventions will be supported by revising the IPC guidelines and manuals, which will introduce AMR and AMR screening components.

The Access, Watch and Reserve (AWaRe) framework offers another important avenue for OECD countries to support their local, national and global efforts to strengthen ASPs. The WHO developed the AWaRe framework in 2017 as part of the Essential Medicines List (EML) (WHO, 2021[48]). The AWaRe classifications provide a valuable framework for monitoring the use of antibiotics, setting targets and evaluating the effectiveness of ASPs (WHO, 2021[48]). It also provides a list of drugs that are is considered essential for the provision of basic healthcare services. In 2021, the AWaRe framework classified a total of 258 antibiotics across three groups:

- **Access**: Broadly, Access antibiotics are comprised of lower-spectrum drugs used primarily as first- or second-line therapies. The WHO recommends that Access antibiotics constitute at least 60% of total consumption at the national level by 2023.
- **Watch:** The Watch antibiotics contain broad-spectrum antibiotics and they pose a greater risk for AMR. The WHO recommends that Watch antibiotics are used only for treating specific indications.
- **Reserve:** The Reserve antibiotics should be considered as a last resort, with their use being monitored closely and targeting multidrug resistant infections.

Emerging evidence suggests that, without urgent policy action, the WHO national-level targets for Access antibiotics is unlikely to be met. In its General Programme of Work 2019-23, the WHO adopted a country-level target of the Access antibiotics accounting for at least 60% of the total consumption by 2023 (WHO, 2020[4]). Recent trends in antibiotic use across the globe suggest that this goal is unlikely to be met. Between 2000 and 2015, global antibiotic consumption increased by 39% between 2000 and 2015 (Klein et al., 2018[49]). While a rise in antibiotic use does not necessarily imply a rise in the imprudent use of antibiotics, this period has seen an alarming rise in the use of Watch antibiotics, especially in LMICs. The consumption of Watch antibiotics rose as much as 91% from 2000 to 2015, as measured by an increase from 3.3 to 6.3 defined daily doses (DDD) per 1 000 inhabitants per day (Klein et al., 2021[50]). At the same time, per-capita consumption of Access antibiotics as a share of total antibiotic consumption has seen an increase of 26% from 2000 to 2015 (Klein et al., 2021[50]). Compared to the Access and Watch antibiotics, the consumption of the Reserve group remains low. The rapid rise of Watch antibiotics points to challenges in the execution of ASPs, particularly in LMICs, and makes it difficult to achieve the WHO target for the use of Access antibiotics by 2023 (Klein et al., 2021[50]; Roberts and Zembower, 2021[51]).

The OECD countries and key partners, EU/EEA and G20 countries should also consider increasing access to older antibiotics. As discussed earlier, some older classes of antibiotics like tetracyclines and temocillin can still be used to treat certain indications. Despite this, only about 24% of AMR-NAPs (5/21) included in the analysis reference older antimicrobials. Different OECD countries put forward different motivations for promoting the use of older antibiotics in their AMR-NAPs. For instance, Sweden indicates that the use of older antibiotics, combined with access to newer antibiotics, is one strategy to increase the availability and use of antibiotics in the drug market in order to provide the best possible care. The United States also highlights the need for identifying new avenues for using older agents. In its AMR-NAP, the United States aims to make progress towards this goal by supporting data collection and evaluation, and by supporting the establishment/revision of antibiotic susceptibility testing standards.

E-prescribing offers another promising avenue to improve monitoring antimicrobial use. Only 4 out of 21 AMR-NAPs included in the OECD analysis reference e-prescribing. E-prescribing practices are often featured in the AMR-NAPs as a way to improve the existing arrangements for monitoring antimicrobial use in healthcare settings. For example, the AMR-NAP from the United Kingdom indicates that, in Scotland, unique patient identifiers are used across primary and secondary care to track patients and monitor changes in antimicrobial use over time. In Finland, the option to use e-prescribing is explored as an option to improve the surveillance of the consumption of antimicrobials. In Malta, e-prescribing is considered as one option to measure antibiotic use at the farm level and information gathered through e-prescribing can be used to link clinical indication, microbiological and consumption data.

Enhance the use of diagnostics

Enhancing the use of diagnostics is another highly emphasised strategy by OECD countries and key partners, EU/EEA and G20 countries. New diagnostic technologies like rapid diagnostic tests can aid providers in their decisions in the course of medical treatment by helping to obtain information about their patients rapidly, thereby curbing the unnecessary use of antibiotics. In recent years, OECD countries have made important strides to improve the availability of rapid diagnostics. For instance, the United Kingdom established the Longitude Prize in 2014 – an innovation fund aimed at incentivising the development of novel rapid tests to help reduce the overuse and misuse of antibiotics in human health. In the United States, the Antimicrobial Resistance Diagnostic Challenge – a federal prize competition – seeks to incentivise the development of novel rapid point-of-care and in-vitro laboratory diagnostic tests that can help identify and categorise resistant bacteria and/or discriminate between viral and bacterial infections (NIH, 2020[52]). These continued investments in the development of new diagnostic technologies have been instrumental in the development of a new point-of-care *Clostridioides difficile* diagnostic assay in 2017 and a diagnostic test for gonorrhoea in 2020 (Trevas et al., 2020[53]).

Monitor antibiotic consumption

Most AMR-NAPs do not include indicators to monitor the consumption of antimicrobials. The AMR-GAP and subsequent guidance from the WHO, FAO and WOAH underscore the importance of tracking patterns in the consumption of antimicrobials to assess the performance of antimicrobial stewardship efforts (WHO/FAO/WOAH, 2019[42]; WHO, 2015[1]). Despite this, only around 19% of AMR-NAPs (4/21) refer to having at least one indicator based on a measure of DDDs or days of therapy. Moreover, none of the countries included in the OECD analysis refer to performance indicators that can help track changes in the fraction of bloodstream infections due to selected AMR organisms as recommended by the WHO (2020[4]).

OECD countries vary substantially in terms of the quantifiable performance targets that they adopt (Table 4.2). For example, in its AMR-NAP dating October 2020, the United States sets out a 20% reduction in the number of healthcare-associated resistant infections by 2025 and a 10% decline in community-acquired resistant infections. In comparison, the AMR-NAP from Denmark describes three related goals for optimising antibiotic consumption from 2016 to 2020. In the primary healthcare sector, a 24% reduction is set in the number of antibiotic prescriptions redeemed from 450 to 350 per 1 000 inhabitants from 2016 to 2020. In this period, a 10% reduction is aimed at the consumption of critically important antibiotics, while increasing its reliance on narrow-spectrum antibiotics like penicillin V. Norway also sets a comprehensive list of targets in optimising antibiotic use in its AMR-NAP. For instance, Norway aims to become one of the European countries with the lowest levels of antibiotic consumption. To achieve this goal, a 30% reduction in antibiotic use is set from 2012 to 2020, as measured in DDD per 1 000 inhabitants per day. In addition, Norway aims to reduce the use of antibiotics prescribed for respiratory infections by 20% in the same period. These targets in the human health sector are supplemented with quantifiable targets in animal health. For instance, for food-producing animals and household pets, Norway aims to achieve at least a 10% and 30% respective reduction in antimicrobial use from 2013 to 2020.

Table 4.2. Example quantifiable performance targets used in the AMR-NAPs from OECD countries

Country	Target
Denmark	24% reduction in the number of antibiotic prescriptions redeemed from 450 to 350 per 1 000 inhabitants between 2016 to 2020 10% reduction in the consumption of critically important antibiotics between 2016 to 2020
Norway	30% reduction in antibiotic use between 2012 to 2020 as measured in DDD per 1 000 inhabitants per day 20% reduction in antibiotic use for respiratory infections from 2012 to 2020 as measured in DDD per 1 000 inhabitants per day 10% reduction in antibiotic use for food-producing animals from 2013 to 2020 30% reduction in antibiotic use for food-producing animals from 2013 to 2020
United States	Decrease healthcare-associated antibiotic-resistant infections by 20% from 2020 to 2025 Reduce community-acquired antibiotic-resistant infections by 10% from 2020 to 2025

Optimise antimicrobial use in animal health

Providers in the human and animal health sectors often rely on the same or highly related antibiotics for treatment (WHO, 2017[54]). The WHO systematically groups antimicrobials into separate categories in accordance with their importance to human health: important, highly important or critically important for human medicine. This classification system underpins the WHO List of Critically Important Antimicrobials for Human Medicine (CIA List). CIAs are antibiotic classes that are used either: i) as the sole or among the limited therapies to treat serious bacterial infections in humans; or ii) to treat infections in humans caused by either bacteria that may be spread from non-human sources, or bacteria that may attain resistance genes from non-human sources (WHO, 2017[54]).

The WHO urges countries to consider the list of CIAs in the development and implementation of interventions to manage risks associated with antimicrobial use in food animals (WHO, 2017[54]). Yet, the OECD analysis suggests that gaps remain in the available antibiotic guidance in veterinary medicine, with about one-third of AMR-NAPs (6/21) from 21 countries included in the analysis lacking any references to the CIAs altogether. Moreover, none of the action plans include a performance measure to track the volume of CIAs sold, even though this is one of the indicators recommended by the WHO to assess progress in the implementation of the AMR-GAP (WHO, 2017[55]).

Efforts to provide guidance on the veterinary use of antibiotics are often supplemented with regulatory measures to limit the use of antimicrobials as growth enhancers on otherwise healthy animals to accelerate weight gain and improve feed efficiency as recommended by the WHO (2017[54]). Currently, regulatory frameworks that restrict the use of antimicrobials for growth promotion remain uneven across geographic regions. In 2018, around 23% (35/153) of countries that participated in the most recent WOAH global survey indicated that they currently allowed the use of antimicrobials for growth promotion (WOAH, 2020[56]). Most countries that allowed antibiotics to be used for growth promotion were located in the Americas region (17/30), followed by the Asia, Far East and Oceania regions (9/25) and the Africa region (8/44). In contrast, in Europe, only 1 out of 48 countries in the region allowed antimicrobials to be used as growth promoters (WOAH, 2020[56]).

Most OECD countries and EU/EEA members have regulations in place that restrict access to veterinary antimicrobials (e.g. purchases only through authorised pharmacies, veterinarians and wholesalers and based on prescription). For instance, in early 2022, the Veterinary Medicinal Products Regulation (i.e. Regulation EU 2019/6) became applicable (EMA, 2022[57]). This regulation contains measures which outlaw the use of antimicrobial medicinal products, including designated antimicrobials, for prophylactic purposes with certain exceptions and enforce new restrictions for metaphylactic use (EMA, 2018[58]). Moreover, the new regulations include measures for imports from third parties outside the EU area. Specifically, with the new regulations, third county operators that export animals and animal products to the EU area are required to abide by the bans on the use of antimicrobials for growth enhancement purposes (Article 107(2)) and the use of antimicrobials for treating certain infections in human health (Article 37(5)) (EMA, 2018[58]). This is in stark contrast to many LMICs where the over-the-counter purchase of veterinary antimicrobials without the need for a prescription remains the norm and access to veterinary antimicrobials is largely unchecked due to the existing regulatory gaps and difficulties around enforcing existing regulations (Sulis et al., 2020[59]).

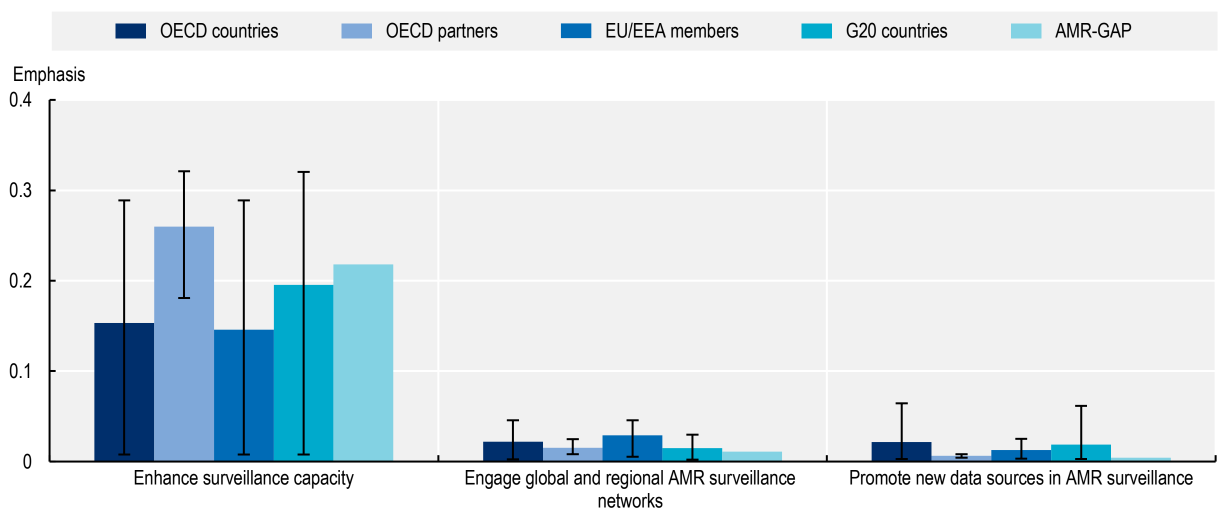
Enhancing animal feeding practices is another strategy to optimise the veterinary use of antimicrobials. The FAO indicates that improving animal feeding practices can help reduce the need to use antibiotics by enhancing gut health, fortifying the immune system and building resistance against the pathogens that exist in the environment (FAO, 2012[60]). OECD analysis has showed that OECD countries and key partners, EU/EEA and G20 countries do not consistently refer to options to improve animal feeding practices in their own settings, with only around 52% (11/21) of action plans referring to this strategy.

Some OECD countries are making headways in improving animal feeding practices in their own settings. In 2019, the EC adopted a new regulation in 2019 (i.e. Regulation EU 2019/4), which regulates the use of medicated feed in animal populations (European Commission, 2022[61]). With the introduction of the new regulatory framework, the EU banned the use of antimicrobials in medicated feed for prophylaxis and growth enhancement purposes, established common limits for including antimicrobials in ordinary feed and set common standards for manufacturing safe medicated feed (European Commission, 2022[61]). In addition, the new regulations serve as a legal framework for manufacturing and distributing medicated feeds used for pets.

The centrality of strengthening AMR surveillance is acknowledged by all OECD countries and key partners, EU/EEA and G20 countries, though substantial efforts are needed to improve AMR surveillance

Strengthening AMR surveillance is key to addressing the AMR burden. Data gathered through surveillance provide the basis for developing and revising clinical treatment guidelines and inform the design and implementation of many ASPs and IPC guidelines, as well as the implementation of public health initiatives like vaccination programmes. Similar to the AMR-GAP, all OECD countries and key partners, EU/EEA and G20 countries included in the OECD analysis refer to the importance of strengthening AMR surveillance. These countries most frequently discuss strategies to enhance AMR surveillance capacity, while options to deepen the level of engagement with global and regional AMR surveillance networks and to promote new data sources in AMR surveillance are discussed to a lesser extent (Figure 4.9).

Figure 4.9. AMR-NAPs are generally well-aligned with the AMR-GAP on actions to enhance surveillance capacity



Note: The graph above displays a set of interventions selected from those recommended by the WHO to strengthen AMR surveillance. Emphasis on each AMR-relevant intervention is quantified as a function of the total number of terms associated with that intervention relative to the total number of terms included in the term dictionary. Interventions with greater term frequency are discussed more frequently compared to interventions with lower term frequency. The whiskers represent the lowest and highest emphasis given to each intervention across the collection of AMR-NAPs.

Countries included in the analysis: Australia, Canada, China, Denmark, Finland, France, Germany, India, Indonesia, Ireland, Japan, Malta, New Zealand, Norway, South Africa, Saudi Arabia, the Slovak Republic, Sweden, Switzerland, the United Kingdom and the United States.

AMR-GAP: Global Action Plan on Antimicrobial Resistance; EU: European Union; EEA: European Economic Area; G20: Group of Twenty.

Source: Özçelik, E.A. et al. (2022[35]), "A comparative assessment of action plans on antimicrobial resistance from OECD and G20 countries using natural language processing", https://doi.org/10.1016/j.healthpol.2022.03.011.

Enhance AMR surveillance capacity

While OECD countries and key partners, EU/EEA and G20 countries universally acknowledge the centrality of AMR surveillance in their action plans, further advancements can be made by harmonising methodological approaches in data collection. A lack of harmonisation in the standardisation of epidemiological definitions of AMR, coupled with the variations in data and sample collection approaches, and microbial testing methods and data sharing policies hinder reliable and collaborative AMR surveillance. For instance, one recent study found that only one-third of EU/EEA member states with AMR surveillance networks provide a clear definition of AMR in their technical guidelines and close to half do not indicate whether the definitions that they use are consistent with the definition used by European Committee on Antimicrobial Susceptibility Testing or Clinical and Laboratory Standards Institute guidelines (Tacconelli et al., 2018[62]).

Expanding the laboratory network capacity can help enhance rapid detection of AMR, identify new threats and inform the development of strategies to prevent the emergence of infections. Efforts to expand the laboratory network capacity are not often discussed in the AMR-NAPs, though there are notable exceptions. For instance, in its AMR-NAP, the United States refers to the Antibiotic Resistance Laboratory Network, which was established in 2016 as a network of laboratories across 50 states, including 7 regional laboratories and the National TB Molecular Surveillance Centre. In Europe, 29 EU countries participate in the European Antimicrobial Resistance Surveillance Network (EARS-Net), which is the largest publicly funded AMR surveillance platform. Other OECD countries are also taking steps to improve the existing standards around laboratory testing. As part of an effort to establish national minimum standards for laboratory testing and reporting antimicrobial susceptibility, New Zealand aims to establish a committee that will be tasked with providing expert guidance for laboratories and other stakeholders, with a specific focus on human susceptibility testing and reporting. This move will be supplemented with efforts to standardise the methodology and reporting of AMR data from human health laboratories.

Engage with global and regional AMR surveillance networks

OECD countries, EU/EEA and G20 countries will benefit from clarifying the ways in which they engage with the existing global and regional surveillance networks. Since 2000, more than 72 supranational networks have been developed to monitor AMR in bacteria, fungi, human immunodeficiency virus (HIV), TB and malaria (Ashley et al., 2018[63]). Yet earlier studies suggest that many local and national AMR surveillance systems have very little co-ordination, harmonisation and information sharing with international surveillance frameworks (Tacconelli et al., 2018[62]). Consistent with this study, the OECD analysis shows that 16 out of 21 OECD countries and key partners, EU/EEA and G20 countries make references to global and regional AMR surveillance networks like the Central Asian and European Surveillance of Antimicrobial Resistance (CAESAR), EARS-Net, the Global Antimicrobial Resistance and Use Surveillance System (GLASS) and the Global Antibiotic Research and Development Partnership (GARDP). However, even when countries refer to these networks, they do not consistently describe the ways in which they engage with these networks, nor do they always provide a vision for future engagement.

Further progress is needed to scale up international and national-level surveillance systems for AMR in animal populations and in the food chain. While some OECD countries lack surveillance systems to monitor AMR in animals, others have made efforts in recent years to build their own systems, including the Czech Republic, Denmark, Finland, France, Germany, Norway, Sweden and the United Kingdom (EU-JAMRAI, 2021[64]). While this is good news, previous studies highlight that the existing surveillance networks are highly fragmented, with countries monitoring different animal specials, antimicrobials and bacterial species (EU-JAMRAI, 2021[64]). Moreover, cross-country comparison of available data is often not possible due to methodological differences in data collection efforts.

Integrate data from new sources in the AMR surveillance

Investing in timely and targeted dissemination of surveillance data is another vital strategy to strengthen AMR surveillance. Currently, point-prevalence surveys and laboratory-based surveillance are the primary sources of AMR-related information in many countries (Tacconelli et al., 2018[62]). Data collected through these means often take time to publish and disseminate, which limits the usefulness of these data for informing clinical and regulatory decision making. Many OECD countries continue to rely primarily on point-prevalence surveys and laboratory-based surveillance. For instance, in Europe, only about 3% of AMR surveillance systems are equipped to provide access to real-time data (Tacconelli et al., 2018[62]).

Integrating data from novel sources can help enhance AMR surveillance and help generate more accurate estimates of the true AMR burden. A growing body of evidence demonstrates the potential of new data sources and technologies like whole-genome sequencing and whole-metagenome sequencing to study the genetic determinants of AMR (Boolchandani, D'Souza and Dantas, 2019[65]). Some OECD countries refer to these technologies in their AMR-NAPs. For instance, in its action plan, the United States sets goals to improve the data infrastructure, data collection and analysis methods. As part of these efforts, it aims to build a new accelerator programme that will progress the implementation of whole-genome sequencing, metagenomics and other molecular testing for resistant pathogens in human, animal and plant populations, food as well as in the environment.

Integrating data from novel sources will require co-ordination across multiple stakeholders. For instance, in the United States, the Genomics for Food Safety (Gen-FS) consortium is one body that co-ordinates efforts to facilitate whole-genome sequencing among federal and state partners, with a focus on crosscutting priorities for molecular sequencing of foodborne and other zoonotic pathogens causing human illness, including the emergence and spread of the genetic determinants of antibiotic resistance, and using this information to support surveillance and outbreak investigation activities. The Gen-FS includes the U.S. Department of Agriculture, Food Safety and Inspection Service, as well as the Food and Drug Administration, the US Centers for Disease Control and Prevention (CDC), the Agricultural Research Service (ARS), the Animal and Plant Health Inspection Service (USDA/APHIS) and the National Center for Biotechnology Information (NIH/NLM/NCBI).

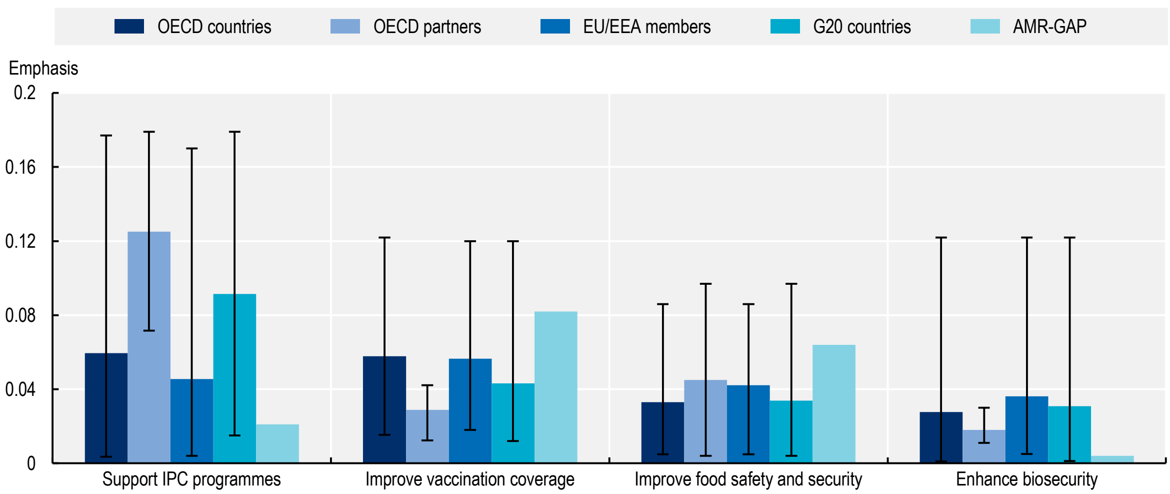
Interventions to improve infection prevention and control in human and animal health are key to tackling AMR in human and animal health sectors

Efforts to reduce the incidence of infections through improved IPC measures are vital to tackling AMR. While all 21 AMR-NAPs from OECD countries and partners, EU/EEA and G20 countries are consistent with the AMR-GAP in that they all highlight the importance of IPC measures, they differ from the AMR-GAP in terms of the interventions that they most frequently emphasise (Figure 4.10). For instance, the AMR-GAP most frequently highlights the need for improving vaccination coverage. In comparison, the OECD countries and partners, EU/EEA and G20 countries most frequently focus on supporting their IPC programmes and practices. Both in the AMR-GAP and the AMR-NAPs from OECD countries and partners, EU/EEA and G20 countries, options to promote food safety and security and enhance biosecurity are given less emphasis compared to the other IPC measures.

Support IPC programmes

The AMR-GAP underscores the importance of IPC programmes and guidelines to creating a robust framework to tackle AMR. Despite this, in 2021-22, about 9% of countries (14/163), globally, lacked a national IPC programme or operational plan, compared to 11.4% (18/158) in 2017 (WHO/FAO/WOAH, 2022[12]). The first Global Report on the status of IPC also pointed to important deficits in the implementation of IPC programmes across countries different levels of socio-economic development (WHO, 2022[66]).

Figure 4.10. AMR-NAPs place the highest emphasis on infection prevention and control policies in human health



Note: The graph above displays a set of interventions selected from those recommended by the WHO to reduce the incidence of infections by strengthening IPC measures. Emphasis on each AMR-relevant intervention is quantified as a function of the total number of terms associated with that intervention relative to the total number of terms included in the term dictionary. Interventions with greater term frequency are discussed more frequently compared to interventions with lower term frequency. The whiskers represent the lowest and highest emphasis given to each intervention across the collection of AMR-NAPs. OECD, EU/EEA and G20 countries included in the analysis include: Australia, Canada, China, Denmark, Finland, France, Germany, India, Indonesia, Ireland, Japan, Malta, New Zealand, Norway, South Africa, Saudi Arabia, the Slovak Republic, Sweden, Switzerland, the United Kingdom and the United States. AMR-GAP: Global Action Plan on Antimicrobial Resistance; EU: European Union; EEA: European Economic Area;; G20: Group of Twenty; IPC = Infection prevention and control.
Source: Özçelik, E.A. et al. (2022[35]), "A comparative assessment of action plans on antimicrobial resistance from OECD and G20 countries using natural language processing", https://doi.org/10.1016/j.healthpol.2022.03.011.

The OECD analysis reveals that all AMR-NAPs from the selected OECD countries and key partners, EU/EEA and G20 countries explicitly reference the importance of IPC programmes in healthcare settings but only a fraction of these countries have mechanisms in place to monitor these programmes. The results from the OECD analysis are in line with the latest AMR Country Self-Assessment Survey. In 2021-22, nearly all OECD members, key partners and G20 countries (49/51) indicated that had in place national and facility-level IPC programmes in accordance with the WHO Guidelines on Core Components of IPC but only 45% (23/51) reported having IPC programmes that function both at the national and health facility levels consistent with the WHO IPC core components guidelines, where compliance and effectiveness are monitored and evaluated on a regular basis and guidance is updated in accordance with the results from monitoring (WHO/FAO/WOAH, 2022[12]). While the OECD countries and key partners, EU/EEA and G20 countries frequently discuss IPC interventions, they do not always describe efforts to improve the existing IPC practices. For instance, only a handful of AMR-NAPs mention IPC measures like decolonisation and environmental hygiene, and only around 57% (12/21) AMR-NAPs highlight the importance of hand hygiene practices.

Even when these documents refer to IPC measures, specific actions to enhance the existing IPC practices are not always described. Some exceptions emerge. For example, South Africa indicates in its AMR-NAP that it aims to scale up community outreach to enhance hand hygiene practices and aspires to supplement this activity with changes in legislation and national guidelines to include core IPC requirements and facilities for improved hand hygiene practices, whereas Ireland integrates compliance with the WHO's My 5 Moments for Hand Hygiene approach into its monitoring and evaluation framework by tracking the level of compliance among hospital staff as a key performance measure of the performance of the overall health system. In Australia, the National Hand Hygiene Initiative was launched in 2008, which relies on a multi-model strategy involving the use of alcohol-based hand rubs at the point of care, provision of IPC education and training, monitoring of hand hygiene compliance and feedback, and encouraging culture change around hand hygiene practices (ACSQHC, 2008[67]).

Improve human and veterinary vaccination coverage

Increasing vaccination coverage is another widely recognised strategy to curb the spread of infections. All AMR-NAPs refer to vaccines as part of efforts to prevent the spread of resistant infections in human health. Moreover, OECD countries like Norway, the United Kingdom and the United States indicate in their action plans to continue supporting vaccination campaigns in other countries not only through bilateral contributions but also by funding contributions to international initiatives like Gavi, the Vaccine Alliance. The widespread recognition of the value of vaccines is also reflected in the high vaccination coverage among OECD members, though some countries are facing challenges in maintaining the vaccination rates high (Chapter 5 provides more detailed information on a wide range of strategies to improve vaccination coverage).

Less attention has been paid to improving the coverage of veterinary vaccines. Norway is among the OECD countries that place veterinary vaccines at the centre of efforts to curb the spread of infections. In its action plan, Norway attributes the near elimination of antimicrobial use in aquaculture production since 1987 to the expansion of access to and use of veterinary vaccines. The country highlights that the scale-up of veterinary vaccines over the last three decades coincided with a 20-fold increase in national fish production, allaying potential concerns over agricultural production capacity. Building on its own experience, Norway stresses that the advancements in the development and application of veterinary vaccines remain to be the most prominent strategy to avoid the need for using antibiotics in aquaculture production.

Enhance biosecurity in farm settings

Biosecurity measures can help curb the emergence and spread of infections among animals that share the same environment. Broadly, biosecurity measures can be classified into two groups (Alarcón, Alberto and Mateu, 2021[68]): external and internal. Combined, these measures are meant to reduce the transmission of pathogens between and within farms. External biosecurity covers the range of strategies that aim to prevent the emergence of pathogens within the farm (e.g. test livestock and feed before their purchase; develop a list of health requirements for incoming animals that group diseases in accordance with risks they present to the farm, and identify verification tests that will be routinely performed; protect feed from contact with wildlife; practice safe animal transport) (Alarcón, Alberto and Mateu, 2021[68]). In comparison, internal biosecurity relates to strategies that can help reduce the spread of pathogens once they are already detected on the farm. Internal biosecurity measures can be grouped as: those that relate to herd management (e.g. strict application of an all-in/all-out system); improvements in sanitary measures (e.g. separate infected animals from the rest of the animals; avoid reusing bedding from infected animals); cleaning and disinfection (e.g. cleaning and disinfecting facilities before a new batch of animals enters into the farm); and farm personnel strategies (e.g. use gloves; practice routine hand washing and foot baths) (Alarcón, Alberto and Mateu, 2021[68]).

Despite its potential benefits, enhancing biosecurity in agricultural production is not a frequently mentioned strategy by OECD countries and key partners, EU/EEA and G20 countries in their AMR-NAPs. Only 3 out of 21 countries included in the OECD analysis discuss biosecurity measures in their AMR-NAPs. Among OECD countries that discuss biosecurity in their action plans, different approaches are pursued. For instance, France highlights that biosecurity measures will focus on strengthening stockbreeding conditions. Whereas Ireland underscores the need to adopt a holistic approach to biosecurity and animal husbandry, which involves actions to scale up of national guidelines and standards on biosecurity and hygiene practices. In comparison, the United Kingdom highlights the importance of raising awareness around the centrality of disease prevention and co-ordinating with the livestock industry and animal keepers.

The OECD countries play a crucial role in promoting AMR-related R&D across the globe

Curtailing the AMR burden will require new developments in new antimicrobial drugs, treatments and diagnostic tools. Currently, 50 antibiotics are in different stages of clinical trials, 32 of which target pathogens identified in the WHO's priority list (WHO, 2020[69]). However, the vast majority of these antibiotics offer only marginal benefits in comparison to already existing antibiotics. Recognising this, the AMR-GAP acknowledges that the existing deficits in investments for AMR-related R&D partly reflect the deteriorating market conditions that limit the potential revenue streams and concerns over lower expected return on investment compared to other therapeutic fields. To address these concerns, the AMR-GAP stresses the importance of spurring AMR-related R&D activities through incentives and public-private partnerships.

Incentivise AMR-related R&D

Broadly, countries have in their arsenal two types of incentives to spur AMR-related R&D: pull and push (Table 4.3). Push incentives typically refer to those that aim to reduce entry barriers by reducing costs associated with developing new drugs (Renwick, Simpkin and Mossialos, 2016[70]). In comparison, pull incentives are those that aim to spur the development of new drugs by increasing the expected future revenues. Previous works note that both types of incentives come with certain advantages and caveats and that countries may benefit from adapting a mixed strategy that combined these incentives to spur AMR-related innovation (Simpkin et al., 2017[71]; Outterson, 2021[72]).

Table 4.3. Example push and pull incentives to spur AMR-related R&D

Incentive type	Example
Push incentives	• Support open access to research • Scientific grants, conditional grants • Direct funding • Funding for translational research • Tax incentives • Refundable tax credits • Product development partnerships
Outcome-based pull incentives	• End prizes, milestone prizes • Pay-for-performance payments • Patent buyout • Payer license • Research tournament • Advanced market commitment • Strategic antibiotic reserve • Service availability premium
Lego-regulatory pull incentives	• Accelerated assessments and approvals • Market exclusivity extensions • Transferable intellectual property rights • Conservation-based market exclusivity • Liability protection • Antitrust waivers • Intellectual property rights • Value-based reimbursement • Targeted approval specifications • Priority review vouchers

Source: Adapted from Renwick, M., V. Simpkin and E. Mossialos (2016[70]), *Targeting Innovation in Antibiotic Drug Discovery and Development: The need for a One Health – One Europe – One World Framework*, https://pubmed.ncbi.nlm.nih.gov/28806044/.

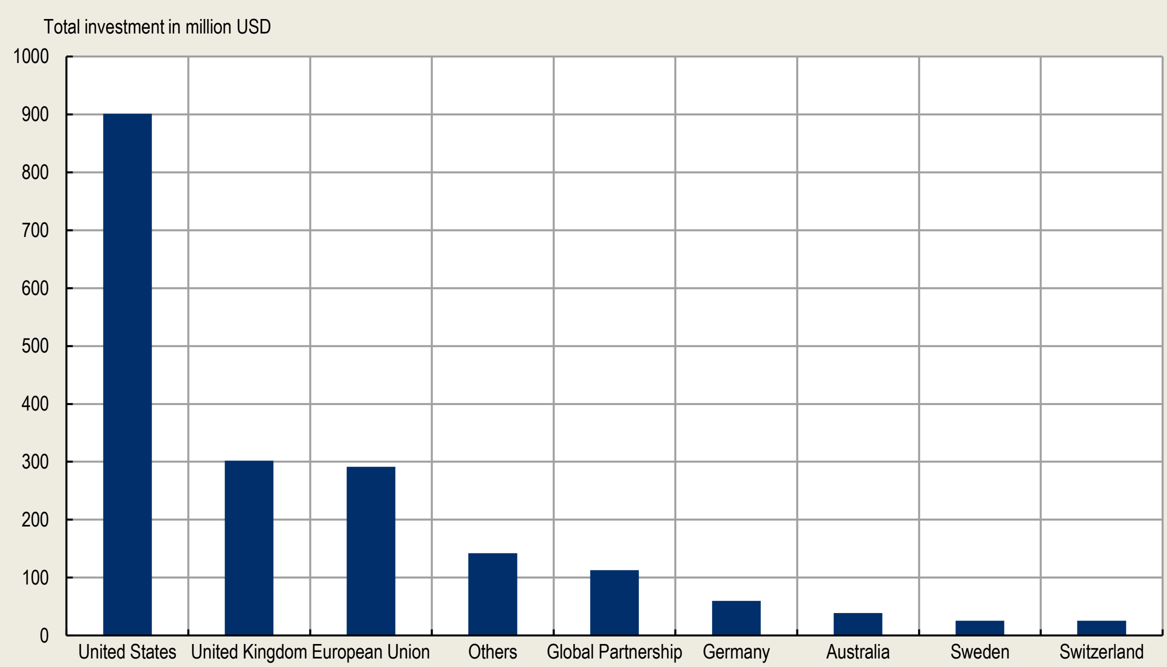
OECD countries will benefit from putting greater emphasis on the pull incentives to spur AMR-related innovations without scaling back on their current comments for push incentives (Box 4.9). With respect to strategies to spur sustainable AMR investments, 21 countries included in the OECD analysis primarily highlight push incentives in their action plans such as direct funding, product development partnerships, scientific grants dedicated to AMR-related research projects and increasing engagement with domestic and international scientific research communities and collaborations. This finding is in congruence with earlier works showing that the major international R&D funding programmes, as well as those funded by the EU, the United Kingdom and the United States prioritise early-stage push incentives (Simpkin et al., 2017[71]). While a robust commitment to push incentives is welcomed, recent modelling studies underscore the need to supplement push incentives with additional commitments to pull incentives (Outterson, 2021[72]).

Box 4.9. OECD countries remain the leading source of financing for R&D relevant to AMR but the overall financing for R&D has been on a decline

Globally, resources allocated to R&D relevant to AMR is shrinking

Between 2017 and 2020, the total spending on R&D for AMR remained relatively stable, with a slight decline from USD 1.67 billion in 2017 to USD 1.92 billion in 2020 (Global AMR Hub, 2023[73]). In 2020, G7 and OECD countries, including Germany, the United Kingdom and the United States, as well as EU/EEA member states, were the lead source of financing for R&D allocated to AMR (Figure 4.11).

Figure 4.11. In 2020, G7 and OECD countries remained the main source of funding for AMR innovations



Note: The "Others" category includes all other countries listed in the Dynamic Dashboard of the Global AMR Hub.
Source: Global AMR Hub (2023[73]), *Dynamic Dashboard: Investing in AMR R&D*, https://dashboard.globalamrhub.org/reports/investments/overview (accessed on 12 June 2023).

Increasing funding dedicated to the later stages of antimicrobial development is crucial

It is crucial to supplement funding allocated to the earlier stages of clinical development with additional funding directed towards the later stages to incentivise market access and attract private investment. In 2020, most R&D funding for AMR was allocated to funding basic research, development of therapeutics, operational and implementation research that can help support decision-making and management strategies, and diagnostics and capacity-building activities (Global AMR Hub, 2023[73]). This finding is consistent with studies that examined earlier periods, which concluded that the majority of R&D funding for AMR is allocated to supporting basic research and preclinical trials (Simpkin et al., 2017[71]). While this emphasis on the early stage of antimicrobial development is essential, increasing financial resources available for the later stages of clinical development can offer an important incentive that facilitates timely access to pharmaceutical markets in newly developed antibiotics. Moreover, increasing late-stage incentives can help attract greater private investments.

Sources: Simpkin, V. et al. (2017[71]), "Incentivising innovation in antibiotic drug discovery and development: Progress, challenges and next steps", https://doi.org/10.1038/ja.2017.124; Global AMR Hub (2023[73]), *Dynamic Dashboard: Investing in AMR R&D*, https://dashboard.globalamrhub.org/reports/investments/overview (accessed on 23 July 2020).

A handful of OECD countries highlight in their AMR-NAPs a range of pull incentives and pilot initiatives to encourage AMR-related innovations. For example, in Japan, new regulatory approval processes have been introduced, including priority reviews for new antimicrobials that can be used for treating resistant infections. The United States is considering obtaining antibiotic products directly through Public Health and National Security purchases to encourage commercialisation. Some OECD countries are also enacting pull incentives for AMR-related innovations. Since publishing its AMR-NAP, the United Kingdom embarked on a new pilot project in 2019 that aims to interrupt the link between sales volume and sales revenues. Through this programme, the National Health Service committed to paying an annual subscription fee of up to GBP 10 million per each new antibiotic covering WHO-priority pathogens regardless of the consumption volume of the antibiotic.

There is a need to build a measurement framework that can help track cross-country progress in bolstering the different stages of AMR-relevant R&D activities over time. Currently, only a handful of OECD countries use measurable performance indicators to track performance in spurring AMR-relevant R&D over time, with a particular emphasis on the earlier stage of clinical development. For example, the United States – the leading funder of AMR-relevant R&D – measures performance using three indicators: i) support the publication of at least 1 000 publications focusing on basic, traditional, and clinical AMR research by 2021; ii) support the training of at least 60 new/early career researchers whose research is applicable to AMR; and iii) build at least two collaborations between human health and agriculture sectors via agreements across agencies. Japan is another country that uses evaluation indices for measuring progress in supporting R&D innovations. These indices include: i) the number of publications applicable to AMR funded through national grants; and ii) the number of genomes accumulated in the genome database to promote AMR genome surveillance.

Foster PPPs

Fostering PPPs to garner AMR innovations is an overlooked area, though notable examples are emerging. PPPs offer an important means to harness the comparative advantage of public and private organisations. Around 67% (14/21) of OECD and G20 countries explicitly reference considerations around PPPs. In recent years, examples of PPPs relevant to AMR emerged. For example, in 2016, the Combating Antibiotic-Resistant Bacteria X (CARB-X) was launched as a global partnership to help finance the preclinical development of drug candidates to prevent and treat resistant infections (CARB-X, 2021[74]). Today, CARB-X has become the world's largest PPP that funds the early development pipeline of new antibiotics, diagnostics and relevant products, with contributions from the United Kingdom and the United States. In Europe, the Innovative Medicines Initiative (IMI) was formed in 2007 as a PPP between the European Union and the European pharmaceutical industry. Considered to be the largest life sciences PPP globally, the IMI aims to enhance the efficiency and effectiveness of drug development processes. In 2012, the IMI created the New Drugs for Bad Bugs project that funded eight projects costing EUR 650 (IMI, 2017[75]). In 2018, the IMI launched the AMR Accelerator which aims to develop new medicines for preventing and treating resistant infections with *Mycobacterium tuberculosis*, nontuberculous mycobacteria and Gram-negative bacteria.

Compared to the other strategic objectives highlighted in the AMR-GAP, the AMR-NAPs included in the OECD analysis put the least emphasis on improving AMR awareness and understanding

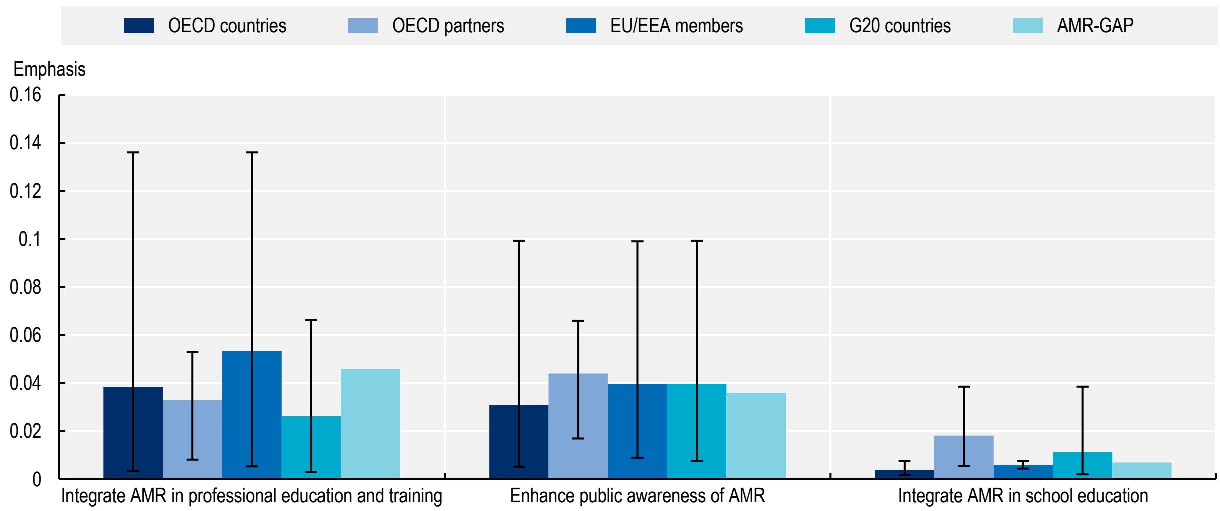
Raising awareness and understanding around AMR is paramount to promoting behaviour change among antibiotic prescribers and users. In recognition, the AMR-GAP urges countries to scale up programmes targeting a variety of stakeholders in the human and animal health sectors, including prescribers, pharmacists, veterinarians, farmers and consumers (WHO, 2015[1]). Much like the AMR-GAP, OECD countries and key partners, EU/EEA and G20 countries primarily emphasise interventions that aim to raise AMR awareness and understanding among healthcare professionals and the general public, whereas school-based interventions for young children are less frequently discussed (Figure 4.12).

Integrate AMR in professional education and training

OECD countries and key partners, EU/EEA and G20 countries pursue a range of interventions to integrate AMR-relevant materials in the education and training of health professionals across different stages of their professional development. Many countries rely on revising/updating the curriculum in undergraduate and postgraduate training to include materials relevant to infection and disease prevention and AMR. For example, in Ireland, undergraduate and postgraduate core curricula and examinations involve academic materials on disease prevention, AMR as well as prudent antibiotic use. In Switzerland, infectious disease specialists undergo extensive training and education on AMR as part of their specialisation requirements. In Germany, health professionals have access to advanced training programmes on rational antibiotic therapy, as well as training courses on the prevention of nosocomial infections in hospital settings. AMR-related materials are also integrated into the licensing and accreditation examinations. This is the case in Japan, where the national examinations for obtaining the required qualifications as a professional in human and veterinary medicine, nursing care and public welfare are aimed at including a more expanded focus on AMR, IPC and antimicrobial stewardship.

In addition, OECD countries provide new avenues for continuous professional education (e.g. organising training workshops, websites, e-learning initiatives). For instance, France recently launched new webpages on AMR and the prudent use of antibiotics for both healthcare professionals as well as the general public. In the United Kingdom, a new Animal Medicines Best Practice training course, a set of online courses targeting farmers and veterinary surgeons, was kicked off in 2018 in order to promote the prudent use of antibiotics in farm settings.

Figure 4.12. Similar to the AMR-GAP, improving AMR awareness in the public and among health professionals is frequently emphasized in AMR-NAPs



Note: The graph above displays a set of interventions selected from those recommended by the WHO to improve awareness and understanding of AMR. Emphasis on each AMR-relevant intervention is quantified as a function of the total number of terms associated with that intervention relative to the total number of terms included in the term dictionary. Interventions with greater term frequency are discussed more frequently compared to interventions with lower term frequency. The whiskers represent the lowest and highest emphasis given to each intervention across the collection of AMR-NAPs.
Countries included in the analysis: Australia, Canada, China, Denmark, Finland, France, Germany, India, Indonesia, Ireland, Japan, Malta, New Zealand, Norway, South Africa, Saudi Arabia, the Slovak Republic, Sweden, Switzerland, the United Kingdom and the United States.
AMR-GAP: Global Action Plan on Antimicrobial Resistance; EU: European Union; EEA: European Economic Area; G20: Group of Twenty.
Source: Özçelik, E.A. et al. (2022[35]), "A comparative assessment of action plans on antimicrobial resistance from OECD and G20 countries using natural language processing", https://doi.org/10.1016/j.healthpol.2022.03.011.

Improve antibiotic awareness and understanding in the public

The OECD countries and key partners, EU/EEA and G20 countries often rely on antibiotic awareness campaigns to raise awareness and education in the general public. Awareness campaigns offer a tempting option for governments, as they can help disseminate valuable information to large audiences at a relatively low cost (Huttner et al., 2019[76]). They are typically organised by public health authorities and target the general community and healthcare professionals at the same time. They tend to rely on communication and educational materials disseminated through print materials, television, radio and online platforms.

The OECD analysis shows that 16 out of 21 OECD countries and key partners, EU/EEA and G20 countries explicitly discuss activities related to some version of an antibiotic awareness campaign (e.g. World Antibiotic Awareness Week) in their own setting. For instance, across EU/EEA members included in the analysis, five out of nine explicitly highlighted the European Antibiotic Awareness Day.

Translating AMR knowledge into changes in attitudes and behaviours around antibiotics remains an important public health challenge. Echoing earlier works, the 2018 Eurobarometer survey found that 85% of respondents were aware of the adverse effects of unnecessary use of antibiotics and 85% indicated that they knew that compliance with prescribed antibiotic dosage was important (Eurobarometer, 2018[77]; Paget et al., 2017[78]). But the same survey also showed that having AMR knowledge did not guarantee changes in attitudes towards antibiotics and behaviours. Only 29% of respondents indicated that AMR information changed their views on the misuse of antibiotics and 7% indicated that they used antibiotics in the last 12 months without a prescription.

Integrate AMR in the education of young children

The OECD analysis suggests that integrating AMR into the education of young children is not a consistently used strategy among OECD countries and key partners, EU/EEA and G20 countries. Broadly, interventions that attempt to incorporate AMR in the education of school-aged children aim at improving the knowledge and understanding of antimicrobials among future users. A promising body of evidence suggests that these interventions may decrease infections among children and reduce school absenteeism (Willmott et al., 2015[79]). Despite this, the OECD analysis shows that only a handful of AMR-NAPs from OECD countries and key partners, EU/EEA and G20 countries explicitly mention the potential options to introduce and scale up educational initiatives targeting young children.

In recent years, the e-Bug programme has emerged as one international education initiative aiming to enhance hygiene and AMR knowledge among young children by providing free educational materials. Launched in 2006, e-Bug has been adopted by 29 countries by 2019 (Hayes et al., 2020[80]). Emerging evidence, primarily from OECD countries such as the Czech Republic, France and the United Kingdom shows that the e-Bug programme can be effective in improving awareness and understanding of antibiotics and hygiene among young children (e-Bug Working Group, 2010[81]; Farrell et al., 2011[82]; Hawking et al., 2013[83]). Some OECD countries explicitly refer to the programme in their AMR-NAPs. For instance, in its AMR-NAP, Ireland indicates that first- and secondary-level school students are among the primary target of activities to improve AMR knowledge and awareness, and the e-Bug initiative should be adopted in primary and post-primary curricula. The United Kingdom also refers to a recent e-Bug initiative, which was specifically designed in collaboration with Farming and Countryside Education and farmers to improve young school children's understanding of farm hygiene.

Conclusion

This chapter provides an overview of the global progress made in the implementation of action plans to tackle AMR. Findings from the chapter demonstrate that there have been important advancements in the development of action plans to tackle AMR across the globe. However, the implementation of AMR-NAPs globally is characterised by a socio-economic development gradient, with LMICs lagging in terms of advancing the implementation and financing of AMR-NAPs.

Among OECD countries and key partners, EU/EEA and G20 countries, there has been notable progress in the uptake of multi-sectoral approaches, with the animal sector being involved in the development of all action plans. Yet, further progress is needed to expand multi-sectoral action to include plant health and the AMR transition in the environment. Having developed their action plans, many of these countries are now grappling with the implementation of their AMR-NAPs. Rigorous monitoring and evaluation of the implementation of AMR-NAPs are paramount to ensure course corrections can be made based on lessons learned from the execution of these documents on the ground.

Further, the OECD analysis pointed to the importance of keeping the AMR-NAPs up to date. It showed that some OECD countries have not updated their action plans since their initial publication, while others are nearing to the end of their coverage period. At a time when health systems across the world are grappling with the COVID-19 pandemic, updating and/or revising AMR-NAPs is key to ensuring that these documents reflect the lessons learned from implementation, filling the gaps in the existing guidance and incorporating new guidance that considers the evolving health financing and delivery needs.

The analysis also suggested little cross-country standardisation in measuring performance over time in terms of the goals stated in AMR-NAPs, which hinders efforts to benchmark cross-country performance. Another important finding showed that funding considerations and cost-effectiveness of interventions to tackle AMR are often left undiscussed. Addressing these gaps in the design of the action plans helps improve the effectiveness of the vision laid out in these documents.

Finally, the chapter presented a systematic assessment of the strategic priorities and interventions adapted by OECD countries and key partners, EU/EEA and G20 countries in action plans using the AMR-GAP as a blueprint. The results suggested a high degree of alignment between countries included in the OECD analysis and the AMR-GAP in terms of their strategic objectives. Coupled with this, there is a diversity of interventions countries consider to achieve their strategic objectives. The diverging patterns in terms of the preferred interventions are likely a reflection of the health system challenges, as well as the broader historical, socio-economic and political factors that shape policy design and implementation in each setting. Combined, evidence generated by this chapter suggests that countries that are considering developing new action plans and/or revising the existing ones will benefit from examining the main drivers of AMR in their own settings and identify interventions to address these challenges in congruence with the strategic objectives and interventions recommended by the WHO.

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Annex 4.A. National language processing (NLP) techniques used in the OECD analysis

NLP techniques used in the analysis of national action plans to tackle antimicrobial resistance (AMR-NAPs)

In this chapter, a combination of NLP-guided techniques is deployed to systematically examine the content included in the AMR-NAPs from OECD countries and key partners, EU/EEA and G20 countries. First, a unique, text-based dataset was assembled. This was done by identifying the AMR-NAPs that were developed after the publication of the Global Action Plan on Antimicrobial Resistance (AMR-GAP) and extracting them from the World Health Organization (WHO) AMR-NAP repository, the European Centre for Disease Prevention and Control (ECDC) AMR-NAP library and publicly available websites. In occasions when more than one AMR-NAP was published by a country in the analysis period, only the most recent document was included. Supplementary materials (e.g. progress reports, commentaries, complementary operational sectoral plans) were excluded. Only documents written in English were included. These steps resulted in the inclusion of 21 AMR-NAPs in the final assessment. A list of countries included in the OECD analysis is provided.

Building an analysable dataset using AMR-NAPs

The text from 21 AMR-NAPs was transformed into an analysable dataset in several steps. First, the pages that may not include substantive information were discarded (e.g. acknowledgements, cover pages). Next, each document was split into smaller units referred to as tokens (e.g. words, web links, punctuations) and tokens that may contain little analytical value were removed. Once this procedure was completed, the entirety of the sample was converted to lowercase characters. The next step entailed the removal of stop words: high-frequency terms that contribute no substantive information (e.g. and, also, a, etc.). Next, all terms were stemmed such that different variations of the same term are recorded as the same entry with the same root. Finally, the pre-processed data were transformed into a document term matrix, which enabled to count the number of times each term occurred in each AMR-NAP.

Dictionary-based analysis

Dictionary-based NLP techniques were deployed to assess the level of alignment between the AMR-NAPs and the AMR-GAP. Dictionary-based methods offer a suitable option for textual analysis when reliable information is already available to help guide the development of a term dictionary, with limited availability of datasets that can be used to train text-based models (Gentzkow, Kelly and Taddy, 2019[36]). An AMR term dictionary was developed using a two-step approach. As the first step, the AMR-GAP was reviewed to extract terms that were used to describe each strategic objective and recommended intervention. Next, the other AMR publications were reviewed, with the aim of identifying additional terms. The process of building the term dictionary was iterative. Multiple labels were assigned to interventions that were relevant to more than one strategic objective.

Methods that rely on simply counting the number of times that terms occur in a document are not sufficient to consider the differences in the length of documents. Recognising this, the OECD analysis makes use of two commonly used NLP metrics to assess the level of alignment between AMR-NAPs and the AMR-GAP: i) term frequency (TF); and ii) term frequency-inverse document frequency (TF-IDF). TF is a measure of the frequency with which each term occurs within an AMR-NAP with respect to the entire length of that document. Quantifying TF associated with each strategic objective/intervention facilitates a comparative assessment of the relative prominence of each strategic objective/intervention in the collection of AMR-NAPs. TF-IDF facilitates a comparative analysis of the interventions to tackle AMR that occur in a given AMR-NAP in comparison to how frequently it features across the collection of documents. By deriving TF-IDF scores, the interventions that are most distinctly highlighted in each AMR-NAP compared to the others are identified.

Annex Table 4.A.1. National action plans on AMR included in the OECD analysis

Country	National action plan	Period
Australia	Australia's National Antimicrobial Resistance Strategy 2020 & Beyond	2020-40
Canada	Tackling Antimicrobial Resistance Use: A Pan-Canadian Framework for Action	2017-onwards
China	National Action Plan to Contain Antimicrobial Resistance (2016-20)	2016-20
Denmark	National Action Plan on Antibiotics in Human Healthcare: Three Measurable Goals for a Reduction of Antibiotic Consumption Towards 2020	2017-20
Finland	National Action Plan on Antimicrobial Resistance 2017-2 021	2017-21
France	Interministerial Roadmap for Controlling Antimicrobial Resistance – 13 Overarching Interministerial Measures 40 Actions	2016-onwards
Germany	DART 2020 – Fighting antibiotic resistance for the good of both humans and animals	2015-20
India	National Action Plan on Antimicrobial Resistance (NAP-AMR) 2017-2 021	2017-21
Indonesia	National Action Plan on Antimicrobial Resistance Indonesia 2017-2 019	2017-19
Ireland	Ireland's National Action Plan on Antimicrobial Resistance (2017-20)	2017-20
Japan	National Action Plan on Antimicrobial Resistance (AMR) 2016-2 020	2016-20
Malta	A Strategy and Action Plan for the Prevention and Containment of Antimicrobial Resistance in Malta 2020-2 028	2020-28
New Zealand	New Zealand Antimicrobial Resistance Action Plan	2017-21
Norway	National Strategy against Antibiotic Resistance 2015-2 020	2015-20
South Africa	South African Antimicrobial Resistance National Strategy Framework; A One Health Approach 2018-2 024	2018-24
Saudi Arabia	Kingdom Saudi Arabia National Action Plan on Combating Antimicrobial Resistance	2017-onwards
Slovak Republic	National Action Plan on Antimicrobial Resistance in the Slovak Republic 2019-2 021	2019-21
Sweden	Swedish Strategy to Combat Antibiotic Resistance 2020-2 023	2020-23
Switzerland	Strategy on Antibiotic Resistance Switzerland	2015-onwards
United Kingdom	Tackling Antimicrobial Resistance 2019-24: The UK Five-Year National Action Plan	2019-24
United States	National Action Plan for Combating Antimicrobial-Resistant Bacteria 2020-2 025	2020-25

Methodology used to generate the dashboard on the implementation of selected AMR-relevant policies in OECD countries, EU/EEA and G20 countries

The OECD analysis relies on the self-reported responses recorded in the WHO Tripartite AMR Country Self-Assessment Survey (2021-22) to characterise the implementation of selected AMR-relevant multi-sectoral policies in each country. All questions extracted from this survey include a five-point rating scaling (from A to E) to summarise a country's progress. In the OECD analysis, countries that reported an "A" rating for any question were categorised as having no implementation with respect to that specific intervention whereas countries that reported an "E" rating were grouped as achieving the most advanced stage of implementation.

The questions and response categories from the Tripartite AMR Country Self-Assessment Survey (2021-22) used to build the dashboard are as follows:

Annex Table 4.A.2. Questions and response categories extracted from the Tripartite AMR Country Self-Assessment Survey (2021-22)

Questions	Response categories
Optimising antimicrobial use in human health (Question 3.6.)	A. No/weak national policies for appropriate antimicrobial use including availability, quality and disposal of antimicrobials. B. National policies promoting appropriate antimicrobial use/antimicrobial stewardship activities developed for the community and healthcare settings. C. National guidelines for appropriate use of antimicrobials are available and antimicrobial stewardship programmes are being implemented in some healthcare facilities. D. National guidelines for appropriate use of antimicrobials are available and antimicrobial stewardship programmes are being implemented in most healthcare facilities nationwide. Monitoring and surveillance results are used to inform action to update treatment guidelines and essential medicines lists. E. National guidelines on optimising antibiotic use are implemented for all major syndromes and data on use are systematically fed back to prescribers.
Optimising antimicrobial use in animal health (terrestrial and aquatic) (Question 4.11.)	A. No national policy or legislation regarding the quality, safety and efficacy of antimicrobial products and their distribution, sale or use. B. National legislation covers some aspects of national manufacture, import, marketing authorisation, control of safety, quality and efficacy and distribution of antimicrobial products. C. National legislation covers all aspects of national manufacture, import, marketing authorisation, control of safety, quality and efficacy and distribution of antimicrobial products. D. The national regulatory framework for antimicrobial products incorporates all of the elements included in the related international standards on responsible and prudent use of antimicrobials (e.g. WOAH Terrestrial Animal Health Codes, Codex Alimentarius) according to animal species and/or production sector). E. Enforcement processes and control are in place to ensure compliance with legislation.
National monitoring system for consumption and rational use of antimicrobials in human health (Question 3.2.)	A. No national plan or system for monitoring the use of antimicrobials. B. System designed for surveillance of antimicrobial use that includes monitoring national-level sales or consumption of antibiotics in health services. C. Total sales of antimicrobials are monitored at the national level and/or some monitoring of antibiotic use at the subnational level. D. Prescribing practices and appropriate antibiotic use are monitored in a national sample of healthcare settings. E. On a regular basis (every year/two years), data are collected and reported on: a) antimicrobial sales or consumption at the national level for human use; and b) antibiotic prescribing and appropriate/rational use, in a representative sample of healthcare facilities, public and private.
National surveillance system for AMR in humans (Question 3.3.)	A. No capacity for generating data (antibiotic susceptibility testing and accompanying clinical and epidemiological data) and reporting on antibiotic resistance. B. AMR data are collated locally for common bacterial infections in hospitalised and community patients, but data collection may not use a standardised approach and lacks national co-ordination and/or quality management. C. AMR data are collated nationally for common bacterial infections in hospitalised and community patients, but national co-ordination and standardisation are lacking. D. There is a standardised national AMR surveillance system collecting data on common bacterial infections in hospitalised and community patients, with established network of surveillance sites, a designated national reference laboratory for AMR and a national co-ordinating centre producing reports on AMR. E. The national AMR surveillance system links AMR surveillance with antimicrobial consumption and/or use data for human health.
IPC practices in human healthcare (Question 3.5.)	A. No national IPC programme or operational plan is available. B. A national IPC programme or operational plan is available. National IPC and water, sanitation and hygiene (WASH) and environmental health standards exist but are not fully implemented. C. A national IPC programme and operational plan are available and national guidelines for healthcare IPC are available and disseminated. Selected healthcare facilities are implementing the guidelines, with monitoring and feedback in place. D. National IPC programme available according to the WHO IPC core components guidelines and IPC plans and guidelines implemented nationwide. All healthcare facilities have a functional built environment (including

Questions	Response categories
	water and sanitation) and the necessary materials and equipment to perform IPC, as per national standards. E. IPC programmes are in place and functioning at the national and healthcare facility levels according to the WHO IPC core components guidelines. Compliance and effectiveness are regularly evaluated and published. Plans and guidance are updated in response to monitoring.
Raising awareness and understanding of AMR risks and response (Question 2.9.)	A. No awareness-raising activities on risks of antimicrobial resistance. B. Some activities to raise awareness about the risks of antimicrobial resistance and actions that address it. C. Some awareness activities at the local and/or sub-national levels about risks of antimicrobial resistance and actions to address it, targeting some but not all relevant stakeholders, based on stakeholder analysis. D. Nationwide, government-supported antimicrobial resistance awareness-raising campaign targeting all or the majority of priority stakeholder groups, utilising targeted messaging accordingly within sectors. E. Targeted, nationwide government-supported activities regularly implemented to change the behaviour of key stakeholders within sectors, with monitoring undertaken over the last two to five years.
Training and professional education on AMR in the human health sector (Question 3.1.)	A. No training for human health workers on AMR. B. Ad hoc AMR training courses in some human health-related disciplines. C. AMR is covered in: i) some pre-service training; and ii) some in-service training or other continuing professional development (CPD) for human health workers. D. AMR is covered in pre-service training for all relevant cadres. In-service training or other CPD covering AMR is available for all types of human health workers nationwide. E. AMR is systematically and formally incorporated in pre-service training curricula for all relevant human health cadres. In-service training or other CPD on AMR is taken up by relevant groups for human health nationwide, in public and private sectors.
Biosecurity and good animal husbandry practices (terrestrial animal production) (Question 4.9.)	A. No systematic efforts to improve good production practices. B. Some activities in place to develop and promote good production practices. C. National plan agreed to ensure good production practices in line with international standards (e.g. WOAH Terrestrial, Codex Alimentarius). Nationally agreed guidance for good production practices developed, adapted for implementation at the local farm and food production levels. D. Nationwide implementation of a plan to ensure good production practices and national guidance published and disseminated. E. Implementation of the nationwide plan is monitored periodically.
Biosecurity and good animal husbandry practices (aquatic animal production) (Question 4.10.)	A. No systematic efforts to improve good production practices. B. Some activities in place to develop and promote good production practices. C. National plan agreed to ensure good production practices in line with international standards (e.g. WOAH Aquatic, Codex Alimentarius). Nationally agreed guidance for good production practices developed, adapted for implementation at the local farm and food production levels. D. Nationwide implementation of plan to ensure good production practices and national guidance published and disseminated. E. Implementation of the nationwide plan is monitored periodically.
Good management and hygiene practices to reduce the development and transmission of AMR in food processing (Question 5.5.)	A. No systematic efforts to improve good management and hygiene practices. B. Some activities in place to develop and promote good management and hygiene practices. C. National plan agreed to ensure good management and hygiene practices in line with international standards (e.g. Codex Alimentarius). Nationally agreed guidance for good practices developed and adapted for implementation according to local food processing approaches. D. Nationwide implementation of a plan to ensure good management and hygiene practices and national guidance published and disseminated. E. Implementation of the nationwide plan is monitored periodically.

5 Tackling antimicrobial resistance in One Health framework: Policy approaches

This chapter aims to inform policy makers of the choice of policies to tackle antimicrobial resistance (AMR) in the human health, animal and environmental sectors. For each sector, the chapter starts by describing policy options aiming to address the main drivers of AMR. It then presents an overview of the current state of evidence, with a particular focus on the design features and contextual factors that can enable or hinder the effectiveness of each policy. Throughout, a number of global AMR initiatives and good practice examples are documented. The chapter concludes by providing a summary of key lessons emerging from the literature.

Key messages

- Since the previous OECD publication *Stemming the Superbug Tide: Just a Few Dollars More* (2018[1]), evidence based on AMR interventions in the human health sector has grown. Complementing previous OECD work, the current analysis shows that, in human health, prudent use of antibiotics can be promoted through: an array of pharmaceutical regulations; interventions that support healthcare providers' prescribing decisions at the point of care; and information-based strategies focusing on improving the general public's knowledge and perceptions around antimicrobials.
- The introduction and scale-up of a wide range of infection prevention and control (IPC) interventions have been shown to reduce the burden of resistant healthcare-associated infections (HAIs) and strengthen AMR surveillance. Specifically, the current analysis looks at the available evidence that demonstrates the effectiveness of selected IPC interventions on curbing AMR, including: integrating AMR in HAI surveillance; IPC monitoring, evaluation and feedback interventions; creating dedicated IPC leadership at health facilities that promote IPC training and education activities and encourage greater compliance with IPC guidelines; and optimising the organisation of care. Available evidence also suggests that the effectiveness of measures to promote prudent use of antimicrobials may be enhanced if implemented in conjunction with IPC interventions.
- Public health programmes to improve vaccination coverage can help interrupt AMR transmission. Broadly, vaccination coverage among OECD members remains relatively high but some countries are experiencing significant challenges in maintaining performance partly due to hesitancy towards the available vaccines. A range of individual- and community-level interventions have been suggested as effective tools to curb vaccine hesitancy across OECD countries.
- Globally, food consumption is rising faster than production, exerting pressure on producers to resort to intensive agricultural practices in livestock and crop production that depend on antimicrobials. Regulations that promote the prudent use of veterinary antimicrobials, particularly those that limit the use of antimicrobials as growth promoters, have been shown to reduce the AMR burden.
- In addition, enhancements in farm management and biosecurity practices and improvements in the coverage of animal vaccines have been shown to reduce the likelihood of resistant infections emerging and spreading among animal and human populations. In plant production, there are important cross-country gaps in regulatory frameworks relevant to the use of antimicrobials, as well as notable challenges in the existing capacity to monitor and evaluate the changes in antimicrobial use over time.
- Supplementing efforts to improve animal and plant health, the rollout and implementation of rigorous food safety compliance systems have been associated with reductions in AMR transmission across the food supply chain.
- Emerging evidence suggests that improvements in wastewater treatment facilities as well as waste management practices in pharmaceutical manufacturing, agricultural production and healthcare settings are linked with reductions in the transmission of AMR by promoting the safe disposal and removal of antimicrobials from the environment. But available evidence suggests that these measures alone are unlikely to halt AMR transmission in the environment due to the limitations of the existing technologies.
- In addition, scaling up drug take-back programmes for households offers a promising avenue for interrupting AMR transmission in the environment.

Key lessons emerging from the literature

- In human and animal health, flexible AMR policies that aim to create an enabling work environment that promotes prudent use of antimicrobials achieve similar levels of improvements in antibiotic prescribing behaviours compared to restrictive policies that limit the opportunities for using antibiotics.
- Getting input and buy-in from key stakeholders (e.g. healthcare providers, veterinarians, farmers) in the design and implementation of AMR policies improves the effectiveness of these policies.
- The effectiveness of AMR policies may change over time, necessitating modifications in the design and implementation of these policies to address evolving needs in a given setting.
- Even when AMR interventions are effective, unintended consequences may occur.
- Improving the availability and accessibility of information from novel data sources offers an important avenue for supporting rigorous evaluations of AMR policies in line with the One Health framework.

Since the last OECD publication, the evidence base on the effectiveness of AMR-relevant policies has grown

In 2018, the OECD published a landmark report – *Stemming the Superbug Tide: Just A Few Dollars More* – which evaluated the health and economic impact of AMR (OECD, 2018[1]). Using the OECD Strategic Public Health Planning for AMR model and advanced modelling techniques, this publication showed that AMR rates are high and estimated to grow in Group of Seven (G7) countries, OECD members and key partners. A key contribution of this publication was a review of policies to tackle the growing AMR burden in the human health sector. Since this publication, the evidence base that sheds light on the effectiveness of AMR policies in human health and other sectors has grown. The complexities around designing and implementing policies to tackle AMR means it is imperative to re-examine the emerging evidence on the effectiveness of various policy options in line with the One Health framework (see Chapter 4). In the context of the ongoing COVID-19 pandemic, concerted efforts to tackle AMR remain ever more pertinent, which emphasise the importance of the complex interlinkages between human, animal and environmental health (Box 5.1).

Box 5.1. A threat or an opportunity: What does the COVID-19 pandemic mean for tackling AMR?

The ongoing pandemic may present a threat or an opportunity for efforts to stem the AMR tide. The COVID-19 pandemic threatens to accelerate the burden of AMR in several ways:

- In many countries, antibiotic stewardship programmes (ASPs) are experiencing disruptions as health workers are diverting efforts away from core ASP activities to pandemic response (see Chapter 4).
- Adherence to the World Health Organization (WHO) guidance on antibiotic use for COVID-19 patients appears low. The WHO recommends antibiotic treatment for mild/moderate COVID-19 cases only if signs of a bacterial infection are present (Getahun et al., 2020[2]). Yet, two recent literature reviews reported that antibiotics were used to treat 72-74.6% of hospitalised COVID-19 patients (Rawson et al., 2020[3]; Langford et al., 2021[4]), while it is estimated that only about 8% of COVID-19 patients reported having bacterial and fungal co-infections (2020[3]). Similarly, Langford et al. (2021[4]) suggested that bacterial co-infections among COVID-19 patients were around 8.6%.
- Increases in hospitalisations may elevate the risk of healthcare-associated infections (HAIs) and transmission of multidrug-resistant organisms (Saleem et al., 2019[5]). This elevated risk may be exacerbated by increased workload among health workers and fluctuations in compliance with infection prevention and control (IPC) measures in healthcare settings. This was evident during the 2003 SARS epidemic, with evidence suggesting that poor compliance with IPC measures was linked to increases in the acquisition of methicillin-resistant *Staphylococcus aureus* (MRSA) (Yap et al., 2004[6]).
- Service delivery disruptions for non-COVID patients can hinder efforts to curb AMR. To date, several systematic reviews looked at disruptions in service delivery based on data gathered primarily from OECD countries. One review concluded that, among patients who suffer from acute cardiovascular disease, the COVID-19 pandemic resulted in significant reductions in the rate of hospital admissions and the number of medical procedures carried out (Kiss et al., 2020[7]). This study also showed that the length of hospital stay for these patients was shortened, while there were longer delays between the onset of symptoms and treatment at a hospital. Another systematic review examined evidence from France, Italy, South Korea and the United States (US) and concluded that there were notable delays in the provision of emergency medical services outside hospital settings for patients suffering from cardiac arrest (Scquizzato et al., 2020[8]). Similar delays and disruptions were observed in routine cancer care (Riera et al., 2021[9]).

The ongoing pandemic also offers important lessons:

- Building on lessons learnt during the COVID-19 pandemic is paramount to tailoring ASPs for future health emergencies. Moving forward, ASPs can be updated to cover the rapid changes in healthcare delivery modalities to respond to evolving health needs. For instance, to date, integrating relatively newer modes of care (e.g. telemedicine) into ASPs was shown to yield beneficial impacts in promoting the prudent use of antibiotics and reducing AMR (dos Santos et al., 2018[10]).
- The COVID-19 pandemic brought renewed attention to the importance of comprehensive IPC strategies to curtail HAIs in the context of health emergencies (Lucien et al., 2021[11]). One living systematic review by Chou et al. (2020[12]) shows that, in healthcare settings, IPC measures were linked with reductions in the probability of infections among health workers in the context of the current and previous outbreaks like SARS-CoV-1 and MERS-CoV. Specifically, global evidence is mounting on the effectiveness of enhancing hand hygiene practices, IPC training and education and personal protective equipment (Chou et al., 2020[12]). Lessons learnt from countries that have explicitly integrated IPC strategies in the context of the ongoing pandemic can foster further improvements in IPC practices.
- The rapid development of COVID-19 vaccines demonstrated that medical innovations can be fast-tracked. Prior to COVID-19, the fastest vaccine development took place in the 1960s for tacking mumps (Bloom et al., 2021[13]). In many countries, COVID-19 vaccination programmes are being rolled out at an unprecedented rate, providing lessons for tackling demand- and supply-side barriers that may impede the accessibility and use of vaccines.
- Innovative modes of inter-governmental co-operation and financing platforms emerged since the outset of the pandemic. These experiences proved crucial for scaling up vaccine research efforts in multiple settings at the same time (Bloom et al., 2021[13]). Lessons learnt from these experiences can provide a powerful means for scaling up research and development (R&D) initiatives in support of the development of new antimicrobials.

Source: Getahun, H. et al. (2020[2]), "Tackling antimicrobial resistance in the COVID-19 pandemic", https://doi.org/10.2471/blt.20.268573; Rawson, T. et al. (2020[3]), "Bacterial and fungal co-infection in individuals with coronavirus: A rapid review to support COVID-19 antimicrobial prescribing", https://doi.org/10.1093/cid; Langford, B. et al. (2021[4]), "Antibiotic prescribing in patients with COVID-19: Rapid review and meta-analysis", https://doi.org/10.1016/j.cmi.2020.12.018; Saleem, Z. et al. (2019[5]), "Point prevalence surveys of health-care-associated infections: A systematic review", https://doi.org/10.1080/20477724.2019.1632070; Yap, F. et al. (2004[6]), "Increase in methicillin-resistant Staphylococcus aureus acquisition rate and change in pathogen pattern associated with an outbreak of severe acute respiratory syndrome", https://doi.org/10.1086/422641; Kiss, P. et al. (2020[7]), "The impact of the COVID-19 pandemic on the care and management of patients with acute cardiovascular disease: A systematic review", https://doi.org/10.1093/ehjqcco/qcaa084; Scquizzato, T. et al. (2020[8]), "Effects of COVID-19 pandemic on out-of-hospital cardiac arrests: A systematic review", https://doi.org/10.1016/j.resuscitation.2020.10.020; Riera, R. et al. (2021[9]), "Delays and disruptions in cancer health care due to COVID-19 pandemic: Systematic review", https://doi.org/10.1200/go.20.00639; dos Santos, R. et al. (2018[10]), "Antimicrobial stewardship through telemedicine and its impact on multi-drug resistance", https://doi.org/10.1177/1357633x18767702; Lucien, M. et al. (2021[11]), "Antibiotics and antimicrobial resistance in the COVID-19 era: Perspective from resource-limited settings", https://doi.org/10.1016/j.ijid.2020.12.087; Chou, R. et al. (2020[12]), "Epidemiology of and risk factors for coronavirus infection in health care workers", https://doi.org/10.7326/m20-1632; Bloom, D. et al. (2021[13]), "Moving beyond traditional valuation of vaccination: Needs and opportunities", https://doi.org/10.1016/j.vaccine.2016.12.001.

The goal of this chapter is to review the global evidence on policy options to tackle AMR building on previous OECD analysis. This chapter complements the first policy chapter, which presents the global progress in the implementation of AMR policy priorities highlighted in the WHO Global Action Plan on Antimicrobial Resistance (GAP AMR) and the content of action plans from selected OECD, European Union/European Economic Area (EU/EEA) countries and Group of Twenty (G20) countries. Although the focus of this chapter is on human health (Box 5.2), policies concerning animal health, plant health, agri-food systems and the environment are also presented in line with the One Health approach. To be as useful as possible for policy makers, each section is organised according to the aim of each policy option in different thematic areas. The choice of evidence presented in this chapter is purposeful. While the chapter aims to be as comprehensive as possible in its synthesis of evidence, it does not attempt to present a summary of all available evidence on all policy options. Due to data limitations, most evidence comes from the OECD, EU/EEA and G20 countries, as well as OECD partners. Studies from low- and middle-income countries (LMICs) are presented whenever possible.

Box 5.2. AMR-relevant policies in human health covered in previous and current OECD analyses

The previous and current OECD analyses complement each other (Figure 5.1). The previous OECD publication – *Stemming the Superbug Tide: Just a Few Dollars More* – focused on a wide array of policies in human health (2018[1]). Since then, the evidence base on the effectiveness of these interventions has grown, further underscoring the importance of each strategy. This chapter expands the scope of previous OECD analyses. Whenever possible, the chapter emphases the design features of AMR policies and contextual factors that can enable or hinder the effectiveness of AMR policies. In line with the One Health framework, the chapter also presents lessons emerging from different strands of the literature.

Figure 5.1. AMR-relevant policies included in previous and current OECD analyses

Antibiotic stewardship programmes (ASPs)
- Prescriber education
- Delayed prescribing
- Financial incentives

Supporting prescribers' decision making
- Using computerised decision support and mobile technologies
- Feedback interventions
- E-prescribing

Pharmaceutical regulations
- Limits on antibiotic use without prescription
- Restrictions on counterfeit, substandard antimicrobials
- Promoting forgotten antibiotics
- Separating prescribing and dispensing

Information-based interventions
- Mass information campaigns
- Improving health literacy

Infection prevention and control (IPC) interventions
- Integrating AMR in healthcare acquired infection (HAI) surveillance
- IPC monitoring, evaluation and feedback
- Dedicated IPC leadership in health facilities
- Optimising organisation of health care delivery

Water, sanitation and hygiene (WASH) interventions
- Improved environmental and hand hygiene
- Screening and isolating infected patients
- Decolonisation

Improving vaccination coverage
- Addressing hesitancy towards vaccines through communication, dialogue-based and behavioural interventions

Source: OECD (2018[1]), *Stemming the Superbug Tide: Just a Few Dollars More*, https://doi.org/10.1787/2074319x.

Policies to tackle AMR in human health

Policies to promote prudent use of antibiotics

Antibiotic stewardship programmes (ASPs)

Policy interventions

- Persuasive interventions aiming to create an enabling environment for prudent use of antibiotics.
- Restrictive strategies limiting opportunities to use antibiotics.
- Strategies targeting structural elements of care.

Key messages

- ASPs are effective in reducing imprudent use of antibiotics without increasing the risk of death.
- Restrictive or persuasive ASPs can be effective in reducing imprudent use of antibiotics. Supplementing restrictive interventions with persuasive ones enhances the effectiveness of the former.
- Effectiveness of ASPs will be enhanced by tracking performance over time in accordance with the context of care.
- Effectiveness of ASPs can be elevated by addressing the existing gaps in the available antibiotic guidance and extending guidance for relatively new modes of healthcare delivery such as telehealth.
- In countries where the prevalence of informal healthcare providers is high, addressing antibiotic prescription outside of clinical settings is crucial to support efforts to build effective ASPs in clinical settings.

Since the release of *Stemming the Superbug Tide: Just a Few Dollars More* (OECD, 2018[1]), empirical evidence on the effectiveness of ASPs in different healthcare settings has accumulated. ASPs have been shown to effectively reduce imprudent use of antibiotics without exacerbating the risk of mortality (Davey et al., 2017[14]). In hospital settings, ASPs have been linked to reductions in the duration of antibiotic treatment, shorter hospital stays (Van Dijck, Vlieghe and Cox, 2018[15]; Honda et al., 2017[16]; Nathwani et al., 2019[17]) and lower treatment costs, though the degree to which countries realise savings in costs varies across settings (Honda et al., 2017[16]; Nathwani et al., 2019[17]). While the expansion of the analytical base on the effectiveness of ASPs is encouraging, further improvements are needed in methods used to assess the impact of ASPs (Schweitzer et al., 2019[18]; de Kraker et al., 2017[19]).

In 2019, the WHO published a practical toolkit that provides guidance for ASPs in healthcare settings, which groups ASPs into three broad categories as shown in Table 5.1 (WHO, 2019[20]):

- Persuasive strategies that rest on provider education and feedback efforts to induce behaviour change.
- Restrictive strategies that limit opportunities to use antibiotics.
- Structural strategies that target organisational elements of care.

Table 5.1. WHO groupings of AMR interventions to improve antibiotic prescribing behaviours in healthcare settings

Intervention type	Example interventions
Persuasive (education)	• Educational meetings (e.g. basics on antibiotic use, case-based discussions, morbidity and mortality, significant event analysis, lectures on specified topics) • Distribution of and training on educational material (e.g. clinical practice guidelines) • Using local key opinion leaders/champions to advocate for key messages • Reminders provided verbally, on paper or electronically • Antimicrobial stewardship (AMS) e-learning resources made available to all personnel • AMS education as part of continuing medical education
Persuasive (feedback)	• Audit with feedback to prescribers on their prescribing practice • AMS as a component of ward rounds (e.g. real-time feedback with educational component) • Patient handover meetings between two shifts with real-time feedback by consultants • Local consensus processes for changes in antibiotic treatment or surgical prophylaxis
Restrictive	• Formulary restrictions • Restricted prescribing of identified antibiotics (e.g. expert approval prior to prescription) • Compulsory order forms for targeted antibiotics • Automatic stop orders (e.g. after a single dose of surgical prophylaxis) • Selective susceptibility reporting from the laboratory
Structural	• Rapid laboratory testing made available • Therapeutic drug monitoring

Source: Adapted from WHO (2019[20]), *Antimicrobial Stewardship Programmes in Health-care Facilities in Low- and Middle-income Countries: A WHO Practical Toolkit*, https://apps.who.int/iris/handle/10665/329404.

The design and implementation of ASPs vary substantially across countries but useful lessons emerge. The WHO guidance indicates that restrictive interventions can yield relatively quick gains in antibiotic use but the effectiveness of these interventions reaches similar levels compared to those achieved through persuasive interventions around a six-month time frame (WHO, 2019[20]). In congruence with the WHO guidance, one recent systematic review suggested that both restrictive and persuasive policies can achieve improvements in antibiotic behaviours at similar magnitudes and that supplementing restrictive interventions with persuasive ones may augment the effectiveness of the former (Davey et al., 2017[14]). Emerging evidence also points to promising results in improvements in antibiotic behaviours among providers in response to structural strategies (WHO, 2019[20]).

The effectiveness of ASPs can be improved by embedding measurement frameworks that track performance over time. Yet, an important limitation of many ASPs is that they set out ambitious targets for promoting the prudent use of antibiotics in clinical settings without a clear mechanism for assessing performance over time. To address this gap, several international bodies have developed guidance around AMR measurement. For instance, in 2015, the Transatlantic Taskforce on Antimicrobial Resistance (TATFAR) developed a measurement framework, which consisted of a set of performance indicators that aim to track progress towards building more effective ASPs and to identify best practices (Box 5.3). In 2019, the WHO published a new toolkit that provided additional guidance for designing and implementing ASPs in low- and middle-income countries (LMICs). Similar to the TATFAR measurement framework, the WHO proposed a set of clearly defined performance indicators that aim to track progress across multiple dimensions of care, including the structure and process of care, as well as patient outcomes (WHO, 2019[20]).

Box 5.3. TATFAR measurement framework for hospital-based antimicrobial stewardship programmes

Many ASPs lack performance targets to track progress in the prudent use of antibiotics in clinical settings. In recognition, TATFAR published a measurement framework in 2015, which consisted of a set of AMR-relevant indicators to help facilitate a common understanding of best practices in ASPs. The framework was developed through an iterative process, involving consultations with a multidisciplinary expert group convened by the US Centres for Disease control (CDC) and the European Centres for Disease Control (ECDC) (TATFAR, 2015[21]).

The TATFAR measurement framework consists of 33 AMR-relevant indicators (Table 5.2). Combined, these indicators capture important dimensions of ASPs in multiple domains, including their feasibility, clinical importance and relevance for minimising the AMR burden. Of these indicators, 17 are core indicators that can be used to characterise various dimensions of ASPs and the remaining 16 are optional indicators.

Table 5.2. TATFAR core indicators for hospital-based ASPs

Policy domain	Indicator
Infrastructure	1. Does your facility have a formal antimicrobial stewardship programme accountable for ensuring appropriate antimicrobial use?
	2. Does your facility have a formal organisational structure responsible for antimicrobial stewardship (e.g. a multidisciplinary committee focused on appropriate antimicrobial use, pharmacy committee, patient safety committee or other relevant structure)?
	3. Is an antimicrobial stewardship team available at your facility (e.g. greater than one staff member supporting clinical decisions to ensure appropriate antimicrobial use)?
	4. Is there a physician identified as a leader for antimicrobial stewardship activities at your facility?
	5. Is there a pharmacist responsible for ensuring appropriate antimicrobial use at your facility?
	6. Does your facility provide any salary support for dedicated time for antimicrobial stewardship activities (e.g. percentage of full-time equivalent for ensuring appropriate antimicrobial use)?
	7. Does your facility have the information technology (IT) capability to support the needs of antimicrobial stewardship activities?
Policy and practice	8. Does your facility have facility-specific treatment recommendations based on local antimicrobial susceptibility to assist with antimicrobial selection for common clinical conditions?
	9. Does your facility have a written policy that requires prescribers to document an indication in the medical record or during order entry for all antimicrobial prescriptions?
	10. Is it routine practice for specified antimicrobial agents to be approved by a physician or pharmacist in your facility (e.g. pre-authorisation)?
	11. Is there a formal procedure for a physician, pharmacist or other staff members to review the appropriateness of an antimicrobial at or after 48 hours from the initial order (post-prescription review)?
Monitoring and feedback	12. Has your facility produced a cumulative antimicrobial susceptibility report in the past year?
	13. Does your facility monitor if the indication is captured in the medical record for all antimicrobial prescriptions?
	14. Does your facility audit or review surgical antimicrobial prophylaxis choice and duration?
	15. Are results of antimicrobial audits or reviews communicated directly with prescribers?
	16. Does your facility monitor antimicrobial use by grammes defined daily dose (DDD) or counts days of therapy (DOT) of antimicrobial(s) by patients per day? Has an annual report focused on antimicrobial stewardship (summary antimicrobial use and/or practices improvement initiatives) been produced for your facility in the past year?

Source: TATFAR (2015[21]), *Modified Delphi Process for Common Structure and Process Indicators for Hospital Antimicrobial Stewardship Programs*, https://www.cdc.gov/drugresistance/pdf/summary_of_tatfar_recommendation_1.pdf.

The effectiveness of many ASPs can be enhanced by addressing the existing gaps in antibiotic guidance. For instance, in the United States, significant efforts have been made in recent years to provide antibiotic guidance for nursing homes, outpatient care and hospitals. Yet, one recent study found that about 28% of the outpatient antibiotic prescriptions filled for medication patients from 2004 to 2013 could not be linked with a record of a clinical encounter with a health worker in the previous week (Fischer et al., 2020[22]). Despite this, about half of the non-visit-based prescriptions had claims associated with laboratory tests or home care services. These results suggest that some prescribers may be responding to results obtained from tests or calls from home care services without having a clinical encounter with their patients.

Alternatively, extending guidance for relatively new modes of healthcare delivery can help improve the effectiveness of the existing ASPs. For instance, many ASPs lack guidance for antibiotic prescription during telehealth consultations, a relatively novel mode of healthcare delivery that gained popularity in the context of the ongoing COVID-19 pandemic (Webster, 2020[23]). While the analytical base for the effectiveness of interventions that embedded telehealth services in the existing ASP guidelines is limited, emerging evidence offers promising results. For instance, the rollout of a telehealth-based ASP in 2 community hospitals in the United States was associated with a 24% decline in the prescription of broad-spectrum antibiotics within a 6-month time frame (Shively et al., 2019[24]). In this period, consultations between local pharmacists and infectious disease physicians rose by 40.2% and the intervention led to savings on antimicrobial expenses. Another study from Brazil found that integrating telemedicine in an existing ASP led to a 30-percentage point increase in the rate of appropriate antimicrobial prescribing (dos Santos et al., 2018[10]). This study also found significant declines in the use of fluoroquinolones, first-generation cephalosporins, vancomycin and polymyxins, as well as significant reductions in the rate of carbapenem-resistant *Acinetobacter* spp. Isolation (dos Santos et al., 2018[10]).

In countries where the prevalence of informal healthcare providers is high, an important policy priority is to address antibiotic prescription outside of formal clinical settings. In many OECD countries and key partners, antibiotics can only be prescribed by licensed health workers with formal medical education. Yet, in many LMICs, informal providers are an important source of healthcare. For instance, in India, an important global hotspot for AMR, informal providers without formal medical training represent a substantial fraction of the healthcare workforce. Much like many healthcare professionals with formal training, informal providers have been shown to rely frequently on antibiotics. For instance, one recent study from the West Bengal state found that, in nearly half of standardised patient interactions, informal providers prescribed antibiotics and about 70% of these prescriptions were unnecessary or harmful medicines (Das et al., 2016[25]).

Supporting prescribers' decision making

Policy interventions

- Computerised decision support systems and mobile health solutions.
- Feedback interventions.
- E-prescribing.

Key messages

- Computerised decision support tools (CDSTs) improve access to accurate antibiotic information relevant to prescribers' decisions around dose optimisation and de-escalation while facilitating AMR surveillance.
- Mobile health technologies promote greater compliance with antibiotic guidelines.
- Feedback interventions, including audits, real-time feedback and peer comparisons, encourage the prudent use of antibiotics.
- E-prescribing systems can enhance the quality of medical records that are used to inform the design and implementation of interventions to optimise prudent use of antibiotics.

Using computerised decision support systems and mobile health solutions

CDSTs can help optimise antibiotic use by accelerating access to accurate information at the time of prescription. In doing so, CDSTs can aid prescribers' decisions around antibiotics including dose optimisation and de-escalation. Systematic reviews focusing on CDSTs suggest that these technologies can spur greater compliance with antibiotic guidelines, with the effect size ranging from 6.9% to 61% (Curtis, Al Bahar and Marriott, 2017[26]). In community settings, significant improvements in antibiotic prescribing behaviours were documented in the treatment of acute otitis media (Holstiege, Mathes and Pieper, 2014[27]). Similarly, in hospital settings, one meta-analysis by Curtis and colleagues (2017[26]) found that the use of CDSTs is associated with around twice as much appropriateness of antibiotic prescribing in line with the existing ASP guidelines (OR = 2.11, 95% CI, 1.67 to 2.66) (Curtis, Al Bahar and Marriott, 2017[26]).

Evidence is mixed in terms of the impact of CDSTs on antibiotic prescribing patterns as well as the use of healthcare resources. For instance, one study found that the rollout of the CDSTs in an intensive care unit was linked with reductions in antibiotic use, which was mirrored in the declines in the fraction of patients who were prescribed carbapenems, third-generation cephalosporins and vancomycin (Thursky et al., 2006[28]). This study also found a rise in the de-escalation to narrower spectrum antibiotics. In comparison, one study from the United States found conflicting results in prescribing behaviours following the rollout of a CDST tool, with an 11.1% decline in intravenous defined daily dose and an accompanying 3.5% rise in oral defined daily dose (Fischer et al., 2003[29]). The evidence remains mixed in terms of the effects of CDSTs on the length of hospital stay and antimicrobial expenditures (Curtis, Al Bahar and Marriott, 2017[26]).

Mobile health technologies offer another avenue for improving access to accurate information at the point of care (Box 5.4). For instance, in New Zealand, one study used a mobile application that mapped the existing antibiotic guidelines directly to the prescribers' mobile devices (Yoon et al., 2019[30]). This study found that the use of mobile applications was associated with an 8% increase in compliance with antibiotic guidelines for treating adult patients with community-acquired pneumonia. In Brazil, the rollout of a similar mobile application led to notable changes in prescribing patterns, with increases in the consumption of the recommended antibiotics like cefepime and concurrent declines in the use of piperacillin/tazobactam and meropenem (Tuon et al., 2017[31]).

Box 5.4. Supporting prescribers' decision making through mobile technologies in the United Kingdom: Imperial Antibiotic Prescribing Policy (IAPP) application

In 2011, the IAPP application (app) was launched in a network of teaching hospitals within the overall organisation of the Imperial College Healthcare Trust, with the aim of ensuring prescribers' access to antimicrobial prescribing policies at the point of care by replacing a physical pocket guide (Charani et al., 2017[32]). The IAPP app was developed through a collaborative process that involved the academic and clinical staff across Imperial College and took into account the prevalence of smartphone use among health workers (Charani et al., 2017[32]).

Importantly, a multimodal ASP was already in place in the participating hospitals prior to the launch of the app including (Charani et al., 2017[32]): i) dedicated multi-professional teams and pharmacists providing advisory services; ii) multidisciplinary ASP stewardship ward rounds; iii) a pocket guide that described all policy options distributed to all junior physicians upon start of employment and links to hospital intranet; iv) dedicated IPC control teams comprised of infection control nurses; v) a multidisciplinary Antibiotic Review Group responsible for developing and updating guidelines for antimicrobial use and infection treatment; and vi) activities around AMR awareness, education and feedback.

The IAPP was rolled out in a context where compliance with ASP guidelines was already high. Nonetheless, the introduction of the IAPP led to further increases in compliance in the tune of 6.48-6.63% across different medical departments (Charani et al., 2017[32]). Importantly, the level of improved compliance was sustained over a 12-month period. However, available evidence also suggests that the IAPP may have had unintended consequences, as the rollout of IAPP was associated with reductions in the fraction of prescriptions with a stop/review date, as well as declines in the documentation of indication (Charani et al., 2017[32]).

Source: Charani, E. et al. (2017[32]), "Effect of adding a mobile health intervention to a multimodal antimicrobial stewardship programme across three teaching hospitals: an interrupted time series study", https://doi.org/10.1093/jac/dkx040.

Feedback interventions

A range of feedback interventions, including audits, real-time feedback and peer comparisons, can promote the prudent use of antibiotics. A key advantage of feedback interventions is that they can facilitate a rapid assessment of the existing challenges in prescription behaviours. Ideally, audits are carried out by ASP teams, which may be comprised of infectious disease physicians, clinical microbiologists and clinical pharmacists (Chung et al., 2013[33]). While audits can be carried out prospectively and retrospectively, the WHO recommends prospective audits whenever possible (WHO, 2019[20]). Real-time feedback can also be provided by ASP teams during ward rounds in oral or written form for either all inpatients or patients staying in high-risk areas like the intensive care unit. This feedback can subsequently be used for optimising antibiotic use (e.g. dose optimisation, intravenous (IV)-to-oral switch).

Audits and real-time feedback interventions lead to improvements in compliance with antibiotic guidelines and reduce the use of hospital resources. One systematic review found that feedback interventions were commonly used in ASPs in paediatric care in hospital and outpatient settings and these interventions were associated with increases in compliance with antibiotic guidelines among physicians and attributable declines in the cost of treatment (Donà et al., 2020[34]). Another systematic review found that embedding feedback interventions into persuasive strategies used in ASPs may improve antibiotic prescribing behaviours in line with antibiotic guidelines (Davey et al., 2017[14]). Concerning hospital resources use, another systematic review found that these interventions were associated with 1 to 3.7-day declines in the number of antibiotic treatment days in the intensive care unit (Van Dijck, Vlieghe and Cox, 2018[15]).

Peer comparison interventions can induce behaviour change among prescribers by increasing their awareness of their own antibiotic prescribing patterns in comparison to their peers (Navathe and Emanuel, 2016[35]). For instance, one cluster-randomised trial from the United States examined the impact of an ASP in primary care settings that compared an individual paediatrician's prescribing performance against the performance of all paediatricians in the same primary care network (Gerber et al., 2013[36]). This study led to a 12.5 percentage point decline in broad-spectrum antibiotic prescribing in the intervention group. Another cluster-randomised trial among primary care practices in Boston and Los Angeles compared the antibiotic prescribing performance of clinicians to the top performers defined as prescribers with the lowest rates of inappropriate prescription rates (Meeker et al., 2016[37]). This intervention resulted in a 16.3 percentage point decline in the inappropriate prescription of antibiotics for acute respiratory tract infections. Another study from Norway demonstrated that feedback interventions can yield beneficial results even in settings with low AMR (Høgli et al., 2016[38]).

Importantly, feedback interventions can promote greater compliance with existing ASP guidelines by easing concerns over provider autonomy. One recent systematic review pointed out that several studies on ASPs raised concerns over the potentially adverse effects of restrictive strategies in service provision (Davey et al., 2017[14]). These potentially adverse effects include changes in professional culture due to difficulties that may arise from a breakdown in communication and trust between infection specialists and clinical teams (Davey et al., 2017[14]). In line with this review, available evidence suggests that if prescribers perceive ASPs as encroaching on their autonomy as providers, compliance with ASP guidelines may be lowered (Zetts et al., 2020[39]). This was the case in one 2015 study in the Lorraine region in France, which found that 68% of family physicians disfavoured restrictive interventions, which would require physicians to provide a justification for why the antibiotic that they prescribed complied with the existing ASP guidelines (Giry et al., 2016[40]). In recognition, some feedback interventions explicitly involve strategies to address concerns over provider autonomy. For instance, in the Netherlands, one hospital-based feedback intervention was designed specifically to preserve provider autonomy in an ASP by designating one provider in each department as the lead for good antibiotic policies, rather than requiring pre-authorisation for antibiotics prescribed (Sikkens et al., 2017[41]). Physicians could, then, consult with their designated colleagues before they prescribed antibiotics (Sikkens et al., 2017[41]). This intervention resulted in significant increases in the appropriate use of antibiotics but the overall volume of antibiotic consumption remained the same.

Electronic prescribing (e-prescribing)

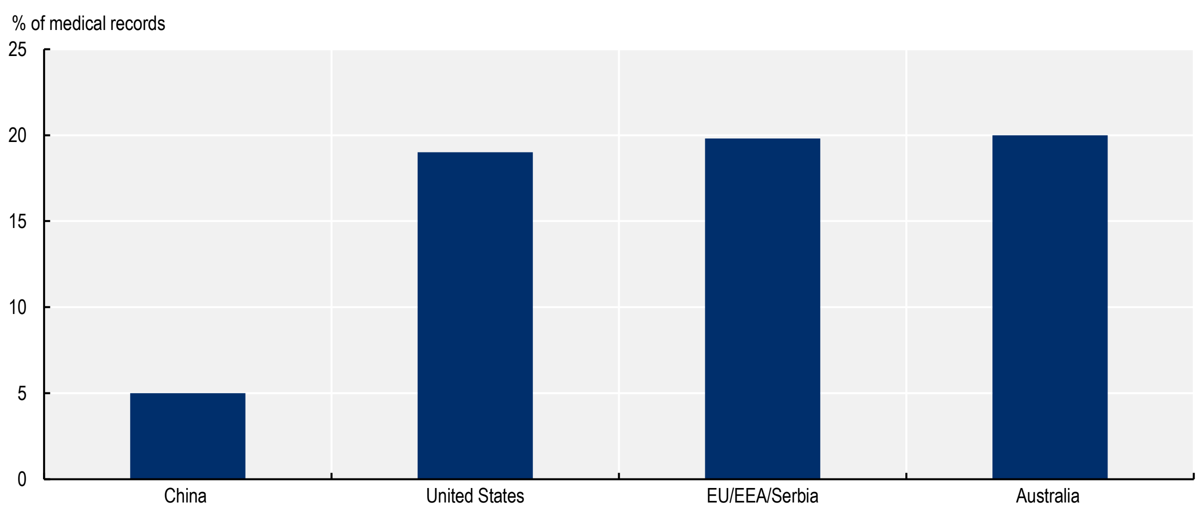
Ensuring high-quality medical record keeping is crucial for ensuring interventions that support the decision making of prescribers are built on accurate data. Despite this, keeping high-quality medical records remains a challenge in many countries (Figure 5.2). For instance, one recent EU point prevalence survey found that nearly 20% of medical records aggregated from 28 EU/EEA countries and Serbia did not provide any explanations for prescribing an antimicrobial (Plachouras et al., 2018[42]). In Australia, an analysis of the 2015 National Antimicrobial Prescribing Survey found that about 20% of antimicrobials lacked documented indication (NCAS/ACSQHC, 2016[43]). A subsequent study from Australia further showed that the share of prescriptions that lacked indication was lower among public hospitals that used e-prescribing

(8.4%) compared to hospitals that used paper-based systems (18.3%) (ACSQHC, 2021[44]). Another study from the United States documented that nearly 18% of all antibiotic prescriptions recorded in the 2015 National Medical Care Survey did not include a rationale for the prescription (Ray et al., 2019[45]).

Importantly, the quality of medical record keeping is linked with the type of antibiotics prescribed. One study from primary care settings in the United Kingdom found that the quality of documentation was the highest for frequently used first-line antibiotics and the poorest for infrequently used antibiotics (Dolk et al., 2018[46]). Another study from the United States showed that the likelihood of antibiotic prescriptions with incomplete information was the lowest for penicillin (Ray et al., 2019[45]). This study also showed that the likelihood of incomplete antibiotic prescription was the lowest for penicillin. A similar variation in antibiotic documentation quality was highlighted in a recent review of 27 lower-middle-income countries (LMICs) (Sulis et al., 2020[47]).

E-prescribing enhances the quality of medical record keeping and supports efforts to monitor antibiotic use in health facilities. Earlier systematic reviews found that e-prescribing is associated with reductions in medication errors and the risk of adverse drug events (Ammenwerth et al., 2008[48]). In line with these findings, a subsequent recent meta-analysis concluded that e-prescribing interventions were associated with a 76% reduction in medical errors (Relative risk = 0.24 [95% CI 0.13, 0.46]), dosing errors (Relative risk = 0.17 [95% CI 0.08, 0.38]) and adverse drug events (Relative risk = 0.52 [95% CI 0.40, 0.68]), though no statistically significant effects were observed for length of hospital stay or for mortality (Roumeliotis et al., 2019[49]). However, these findings should be interpreted with caution because the quality of evidence used in these analyses was determined to be very low (Roumeliotis et al., 2019[49]).

Figure 5.2. Share of medical records with no clear documentation of indication for antimicrobial prescription, various years



Source: China: nationally representative database (Beijing Data Centre for Rational Use of Drugs) covering the years 2014-18 as published in Zhao, H. et al. (2021[50]), "Appropriateness of antibiotic prescriptions in ambulatory care in China: A nationwide descriptive database study", https://doi.org/10.1016/s1473-3099(20)30596-x; United States: taken from 2015 National Ambulatory Medical Care Survey as published in Ray, M. et al. (2019[45]), "Antibiotic prescribing without documented indication in ambulatory care clinics: National cross sectional study", https://doi.org/10.1136/bmj.l6461; 28 EU/EEA countries and Serbia: data aggregated and extracted from the 2016-17 second point prevalence survey (PPP) of healthcare-associated infections as reported in Plachouras, D. et al. (2018[42]), "Antimicrobial use in European acute care hospitals: Results from the second point prevalence survey (PPS) of healthcare-associated infections and antimicrobial use, 2016 to 2017", https://doi.org/10.2807/1560-7917.es.23.46.1800393; Australia: extracted from the 2015 National Antimicrobial Prescribing Survey as published in NCAS/ACSQHC (2016[43]), *Antimicrobial Prescribing Practices in Australian Hospitals: Results of the 2015 Hospital National Antibiotic Prescribing Survey*, National Centre for Antimicrobial Stewardship and Australian Commission on Safety and Quality in Health Care.

Moreover, e-prescribing systems are shown to contribute to ongoing ASP interventions by providing facility-level data that can be used for monitoring and improving antibiotic use. A potential benefit of e-prescribing is that information on antimicrobial use is recorded regularly in these systems, which can serve as novel data sources to assess and monitor antimicrobial use in health facilities and inform the design of interventions to improve antibiotic prescribing behaviours.

One recent systematic review found that the use of e-prescribing systems for quantitative data analysis remains limited, though in some OECD countries, efforts are being made to incorporate data generated from e-prescribing systems into the existing ASPs (Micallef et al., 2017[51]). For instance, several studies from Australia used e-prescribing data to support auditing and feedback interventions focusing on antimicrobial prescribing behaviours of doctors (Micallef et al., 2017[51]). In the United States, data from e-prescribing systems that track antimicrobial dispensing volumes, course durations and doses have been utilised to evaluate the impact of AMR policies. Other studies from Germany, South Korea and the United States use these data for quality improvements (Micallef et al., 2017[51]).

Pharmaceutical policies

Policy interventions

- Promoting the use of forgotten antibiotics.
- Separating antibiotic prescribing from dispensing.

Key messages

- Removing economic and regulatory barriers to the market registration of forgotten antibiotics can help enhance access to these antibiotics.
- Addressing the shortages in medicines can ensure adequate access to forgotten antibiotics.
- Promoting local and global collaborations can help accelerate access to forgotten antibiotics.
- Separate prescription and dispensing of antibiotics can lower the overall volume of antibiotic prescription.

Promoting the use of forgotten antibiotics

One pharmaceutical intervention that can help curb the unnecessary use of antibiotics is promoting the use of forgotten antibiotics. Forgotten antibiotics refer to a class of older antibiotics that can be used in treating patients even though they became available decades earlier. Despite their potential benefits, many OECD countries, EU/EEA and G20 countries do not frequently rely on delayed antibiotic prescribing, with only around a quarter of action plans to tackle AMR making any references to these antibiotics.

Reducing economic and regulatory barriers to market registration is key to improving access to forgotten antibiotics. Many older antibiotics reflect the quality standards in clinical trials and requirements for regulatory documentation at the time of entry into the pharmaceutical market. This can act as a barrier against the increased use of forgotten antibiotics because registering these antibiotics will entail renewed data collection efforts and additional expenses for drug registration, whereas pharmaceutical companies may not always have incentives for registering these antibiotics in new markets (Cox et al., 2015[52]; WHO, 2018[53]). Easing the economic and regulatory barriers to their market registration is one option to increase access to forgotten antibiotics (Pulcini et al., 2017[54]).

In recent years, several laudable examples of co-operation and collaboration across national and international agencies, academic institutions and pharmaceutical have emerged to accelerate market authorisation of new drugs for treating multidrug-resistant tuberculosis (Box 5.5). Lessons learnt from these examples can be applied to ease the regulatory barriers that hinder the entry of forgotten antibiotics into the pharmaceutical market (Cox et al., 2015[52]; Pulcini et al., 2017[54]; WHO, 2018[53]).

Box 5.5. Accelerating access to new drugs for treating multidrug-resistant tuberculosis

One recent example of international efforts to accelerate the introduction of new drugs into the pharmaceutical markets involves antibiotics used for treating multidrug-resistant tuberculosis: bedaquiline and delamanid. These two drugs are currently used for treating tuberculosis patients with bacteria resistant to multiple drugs including rifampicin and isoniazid – two crucial drugs used in the treatment of tuberculosis (WHO, n.d.[55]). Prior to the advent of these drugs, the last time a new drug was developed specifically to treat tuberculosis was when rifampicin was rolled out in the 1960s (WHO, n.d.[55]). In recent years, resistance to rifampicin has been reported across the globe (WHO, 2017[56]).

In recognition of growing concerns over the emergence of multidrug-resistant tuberculosis, the market approval of these two drugs was accelerated. In 2012, the US Food and Drug Administration provided conditional market approval for the use of bedaquiline (WHO, 2017[56]). Following this approval, the WHO published interim guidance in 2013 for its use for patients suffering from multidrug-resistant tuberculosis (WHO, 2013[57]). The following year, in 2014, delamanid received conditional market authorisation from the European Medicine Agency Committee for Medicinal Products for Human Use. Subsequently, the WHO published interim guidance to assist countries in their efforts to ensure that the treatment regimens are taken up in a safe and effective manner (WHO, 2017[56]).

Source: WHO (n.d.[55]), *Frequently Asked Questions on Bedaquiline*; WHO (2013[57]), *The Use of Bedaquiline in the Treatment of Multidrug-resistant Tuberculosis*. https://apps.who.int/iris/handle/10665/84879; WHO (2017[56]), "WHO best-practice statement on the off-label use of bedaquiline and delamanid for the treatment of multidrug-resistant tuberculosis, https://apps.who.int/iris/handle/10665/258941.

In addition to easing market access for these antibiotics, addressing the shortages in existing medicines is another strategy that can help alleviate the challenges in access to forgotten antibiotics. Many forgotten antibiotics are categorised as Access antibiotics in accordance with WHO AwARE groupings (see Chapter 3) that can be used for treating common infections (WHO, 2021[58]). The WHO guidance indicates that Access antibiotics should be accessible at affordable prices and in a quality-assured manner. Despite this, many OECD countries are reporting antibiotic shortages. For example, nearly all pharmacists (95%) that participated in a 2019 pan-European survey from 39 countries indicated that the shortage of medicines was a major problem in the hospital where they worked, a marked rise from about 86% in 2014 (EAHP, 2019[59]). An earlier wave of this survey reported that the average duration of a typical medicine shortage was around 2.2 months in 2018, suggesting that these shortages can result in delays and cancellations in needed care or therapy and receiving a suboptimal course of care. A closer look at the 2019 survey shows that antimicrobial agents are the leading cause of shortages in medicines since 2014. In 2019, about 63% of pharmacists indicated that they experienced shortages in antimicrobial agents, a significant increase compared to 57% in 2014 (EAHP, 2019[59]). While the precise impact of these shortages on patient outcomes is largely unknown, it is recognised that these shortages are a global health priority and a barrier to tackling AMR.

Separating prescription and dispensing of drugs

In most OECD countries, antibiotics are prescribed by health workers and dispensed separately from pharmacies, with no financial links between the prescriber and the dispensing pharmacy. But certain exceptions exist. For instance, in the United Kingdom, nearly 13% of practices in the National Health Service primary care have an inhouse dispensary (Goldacre et al., 2019[60]). These types of dispensing practices are primarily located in rural areas with a lower density of pharmacies, thus providing necessary access to patients residing in these areas (Goldacre et al., 2019[60]). In Switzerland, drug dispensing is regulated by each state, referred to as *cantons*. While some cantons apply a strict separation between prescribing and dispensing of drugs, others either have no separation or a mixed system (Trottmann et al., 2016[61]).

Evidence from countries where health workers are allowed to dispense the antibiotics that they prescribed to their own patients suggests that there are linkages between physicians' dispensing responsibilities and prescribing behaviours. For instance, in the United Kingdom, dispensing primary care practices were more likely to prefer drugs with higher costs across all classes (Goldacre et al., 2019[60]). In Switzerland, one study found that the likelihood of per capita antibiotic consumption was around 1.3 times higher in areas where more than half of the practitioners dispensed drugs directly to their patients (Filippini, Heimsch and Masiero, 2014[62]). Another study from Switzerland found that physician dispensing was associated with a switch towards generic drugs over brands (Trottmann et al., 2016[61]). This study further showed that the greater reliance on generic drugs led to lower pharmaceutical spending for each patient, which was offset by increased use of physician services. Conversely, in Australia, one earlier study found that physician dispensing was associated with fewer drug prescriptions, which was partly explained by perceived expectations from their peers about their prescribing behaviours and preference to generate less administrative paperwork (Lim et al., 2011[63]).

Experiences from countries that implemented separation policies suggest that these interventions can be effective in spurring declines in overall antibiotic prescription and improvements in prudent use. One relatively well-documented example of a separation policy comes from South Korea. In 2002, South Korea put in place a new separation policy, which outlawed prescribing doctors from dispensing drugs and pharmacists from prescribing (Park et al., 2005[64]). A recent evaluation found that this policy was associated with reductions in antibiotic prescriptions for patients with viral illnesses (Relative risk = 0.89, [95%CI: 0.86, 0.91) and to a smaller extent for patients with bacterial illness (Relative risk = 0.98, [0.97, 0.99]) (Park et al., 2005[64]). This study further concluded that the separation policy resulted in the decline of inappropriate antibiotic prescriptions for viral illnesses.

Country experiences suggest that separating the prescription and dispensing of drugs may have unintended consequences. For instance, a recent study suggested Korea's separation policy may have contributed to increases in medical expenditures, partly because the reform led to substantial increases in service fees for providers to offset the potential loss of income and resulted in shifts in prescribing patterns that favoured brand-name or imported drugs (Kim and Ruger, 2008[65]).

Information-based strategies

Policy interventions

- AMR awareness campaigns.
- Improving health literacy.

Key messages

- AMR awareness campaigns should ensure to have clear public health messaging to dispel confusion and misconceptions about antibiotic use.
- Improving the health literacy of the general population promotes more prudent use of antibiotics.

AMR awareness campaigns

As discussed in Chapter 4, many OECD, EU/EEA and G20 countries often rely on mass media campaigns to raise awareness around AMR in the general public but available evidence suggests that these efforts have yielded modest effects. This finding should be interpreted with care, however, as the majority of evidence is generated through studies with weak methodologies. To date, several studies examined the effectiveness of AMR awareness campaigns targeting the general public. In Italy, one AMR awareness campaign aimed at improving the antibiotic behaviours of patients, specifically for antibiotics to treat upper respiratory infections. One study that evaluated the impact of this campaign through a non-randomised trial found that antibiotic prescribing was reduced by 4.3% in the intervention area in comparison to the control area (Formoso et al., 2013[66]). In the United Kingdom, one study recently examined the impact of a regional mass media campaign that was implemented for two consecutive years using editorial coverage from local newspapers, television and radio stations. This study found that there was a 5.8% reduction in antibiotic prescription in the intervention area in comparison to the control area (Lambert, Masters and Brent, 2007[67]). In the United States, one community-wide intervention in the state of Tennessee targeted healthcare providers that routinely provided healthcare services for children, parents of young children and the general public. Parent education activities consisted of the distribution of pamphlets and public education activities included the distribution of pamphlets and dissemination of information on television, radio stations, newspapers and public service announcements. The majority of the educational materials were developed by the CDC (Perz, 2002[68]). This intervention was associated with an 11% decline in antibiotic prescription for young children compared to the control communities that did not roll out similar awareness campaigns in the study period.

One potential explanation for the observed modest effects is that confusion and misconception about antibiotics may impede behaviour change in settings where antibiotic knowledge is already relatively high. A recent WHO survey of 12 LMICs across all 6 WHO regions showed that most respondents (64%) understood that AMR was a significant challenge with consequences for themselves and their families (WHO, 2015[69]). But most respondents lacked an understanding of the potential channels through which AMR affects their own lives and what they could personally do to address it. Confusion around illness types that can be treated with antibiotics was also common. Similar misconceptions and confusion around resistant pathogens and transmission channels have also been documented in high-income settings, such as Australia (Bakhit et al., 2019[70]), Italy (Prigitano et al., 2018[71]) and the United States (CIDRAP, 2019[72]).

To tackle confusion and misconceptions, AMR awareness campaigns should rely on clear public health messaging. A recent review of large-scale antibiotic awareness campaigns from 93 countries since 2010 concluded that the effectiveness of these efforts is often hindered by unclear public health messages around AMR (Huttner et al., 2019[73]). Moreover, this study suggested that AMR awareness campaigns should update their key messages regularly and involve experts with backgrounds in healthcare, health communication and social marketing to strengthen their implementation. This was the case in Italy, where the AMR awareness campaign discussed earlier tailored the key messages of the campaign based on consultations with physicians from various health districts in an attempt to understand the unique contextual factors in the area of their practice that may shape the attitudes and expectations of patients around antibiotics (Formoso et al., 2013[66]).

Improving health literacy

Individuals with greater levels of health literacy may have better access to health information, as well as a greater ability to process and act on this information in a way that promotes prudent antibiotic use. For instance, in Germany, one study found that people with sufficient health literacy, measured through a 16-point scale, were almost half as likely to have a recent history of antibiotic use than those with insufficient health literacy (Salm et al., 2018[74]).

Despite increasing recognition of its importance, health literacy remains low in many OECD countries. One recent survey found that only about half (52.5%) of participants from eight European countries had sufficient or excellent health literacy scores (Sørensen et al., 2015[75]). This study also concluded that people with low socio-economic status and educational attainment and older adults faced greater deficits in health literacy. More recently, one OECD working paper also found that a considerable proportion of respondents experienced difficulty in evaluating the reliability of the information provided in the media (47%), weighting the advantages and disadvantages of different treatment options (41%) and deciding whether they need vaccines (31%) (Moreira, 2018[76]). The OECD members use a wide range of policies to improve the health literacy of their populations, including: the promotion of health literacy skills among adults and children; counselling and training activities in community settings; guidelines aimed at enhancing health professionals' communication skills; and easing access to health information (Moreira, 2018[76]).

Policies to prevent or reduce the emergence of resistant infections

IPC programmes at the national and health facility levels

The WHO IPC guidelines indicate that IPC programmes are most effective when they combine strategies that: i) promote the right mix of health professionals with adequate IPC training; ii) improve staff workload, bed capacity and physical attributes of health facilities; iii) enhance the accessibility of equipment and supplies; and iv) promote a work culture that enables effective IPC practices (WHO, 2016[77]). Importantly, these efforts are meant to be complemented by IPC surveillance, monitoring and feedback practices at the local and national levels. In recent years, many technical tools have been developed in support of the 2016 WHO IPC guidelines (Storr et al., 2017[78]; WHO, 2018[79]).

Policy interventions

- Integrating AMR in healthcare-associated infection (HAI) surveillance.
- IPC monitoring, evaluation and feedback.
- Dedicated IPC leadership in health facilities.
- Optimising organisation of healthcare delivery.

Key messages

- Integrating AMR in HAI surveillance facilitates systematic data collection and analysis.
- Building dedicated IPC teams helps monitor ongoing IPC practices, educate health workers and promote a work environment that enables the best IPC practices.
- Scaling up IPC monitoring, regular audits, evaluation and feedback interventions can promote greater compliance with IPC guidelines among health workers.
- Addressing high rates of bed occupancy and overcrowding in health facilities can help reduce the likelihood of healthcare-acquired resistant infections.

Integrating AMR in HAI surveillance

HAI surveillance can facilitate standardisation in the collection and analysis of data over time. For instance, one recent review of 42 HAI surveillance systems across 20 European countries and 4 transnational systems showed that about 64.2% of these surveillance systems track the percentage of resistant isolates to specific drugs (Núñez-Núñez et al., 2018[80]).

AMR surveillance facilitates the identification of patterns of AMR pathogens in healthcare settings. One study from an Italian teaching hospital used data from a prospective HAI surveillance programme for a period of years (Bianco et al., 2018[81]). This study concluded that the most common resistant pathogens were Gram-negative bacteria, including *Klebsiella pneumoniae* (*K. pneumoniae*), *Acinetobacter baumannii*, *Escherichia coli* (*E. coli*) and *Pseudomonas aeruginosa* (*P. aeruginosa*). In Canada, one study used a 4-year time series of surveillance data collected from 70 sentinel hospitals that participated in the Canadian Nosocomial Infection Surveillance Program (CNISP/Public Health Agency of Canada, 2020[82]). This study found that infection rates for MRSA and vancomycin-resistant enterococci bloodstream infections increased by 59% and 143% respectively. In contrast, *Clostridioides difficile* (*C. difficile*) infection rates declined by 12.5% from 2015 to 2018.

The effectiveness of HAI surveillance can be enhanced by adopting automated surveillance systems that track a comprehensive range of infections. Manual review of patient charts can be labour-intensive and lack standardisation (Streefkerk et al., 2020[83]). In recognition, many countries are increasingly using automated surveillance systems either to support the existing manual surveillance strategies (i.e. semi-automated surveillance) or replace them altogether (van Mourik et al., 2017[84]). Automated surveillance systems can target a specific set of infections (e.g. infections observed in intensive care units, surgical site infections and device-associated infections) or they can be used for comprehensive surveillance (Streefkerk et al., 2020[83]). However, evidence suggests that targeted surveillance can also miss important HAIs, as is demonstrated by one study from the United States which quantified that targeted surveillance can miss up to half of all HAIs (Weber et al., 2012[85]).

IPC monitoring, evaluation and feedback

Regular IPC audits and feedback significantly improves compliance with IPC guidelines. For instance, one cluster-randomised experiment showed that using daily audits with regular feedback and a checklist that clearly identified the priority process indicators was associated with increased compliance with recommended IPC guidelines (Charrier et al., 2008[86]). Alternatively, peer assessments with anonymous feedback were also shown effective in improving compliance with handwashing guidelines (Storr et al., 2017[78]). Another study from England and Wales (United Kingdom) demonstrated that personalised feedback with explicit goal-setting exercises was associated with a 10-13% increase in compliance with hand hygiene guidelines in acute care for the elderly and 13-18% in intensive care units (Fuller et al., 2012[87]).

Automated auditing techniques offer a promising avenue for improving compliance with IPC guidelines. In many settings, audit- and feedback practices rely on direct observation of behaviours but emerging evidence suggests direct observation can spur inaccuracies in data collection and create tension among health workers (Livorsi et al., 2018[88]). Automated auditing techniques can offer an alternative solution. For instance, one recent study showed that automatic video auditing with feedback led to a 15.7% to 46% increase in compliance with the WHO's handwashing guidelines (Lacey et al., 2020[89]). Another study that used remote video surveillance with real-time group feedback led to similar increases in compliance with hand hygiene guidelines in an intensive care unit (Armellino et al., 2011[90]).

Dedicated IPC leadership at health facilities

Creating dedicated IPC teams and leaders in health facilities is crucial to promote best practices. Dedicated IPC teams can: monitor the ongoing IPC practices; educate and train other health professionals; and foster a work environment that promotes best practices. While the exact composition of the IPC teams will differ depending on the context of care, multidisciplinary teams comprised of nursing staff, a dedicated physician with training in infection control and other health personnel that can provide microbiological and data management support are preferred.

Dedicated IPC leadership should encourage and support the provision of IPC training and education, particularly in the context of health emergencies. The beneficial impact of IPC training and education is well-documented (Zingg et al., 2015[91]; Storr et al., 2017[78]). In recent years, a growing body of evidence shows that simulation-based IPC training is associated with reductions in HAIs (Wang et al., 2019[92]), including central line-associated bloodstream infections (Allen et al., 2014[93]; Gerolemou et al., 2014[94]). Moreover, in the context of health emergencies, these benefits may be pronounced. One recent systematic review showed that the provision of IPC training and education was consistently linked to reduced risk of infections among health workers, not only in the context of the ongoing pandemic but also during SARS-CoV-1 and MERS-CoV outbreaks (Chou et al., 2020[12]).

IPC teams and leaders in acute care facilities should also support clear communication of IPC guidelines and promote a work environment that promotes the best IPC practices. The recent Cochrane review provided evidence that beliefs and attitudes among health professionals towards IPC practices shape the professional culture and practices in health facilities (Houghton et al., 2020[95]). This review further showed that health professionals had difficulty complying with local IPC guidelines when these guidelines were lengthy and offered confusing explanations of the recommended code of IPC practice (Houghton et al., 2020[95]). Moreover, inconsistencies across local, national and international IPC guidelines and frequent updates further undermined the likelihood of compliance. Combined, evidence suggests that dedicated IPC teams can support efforts to clearly communicate IPC guidelines through education and training activities. To date, available evidence showed that IPC training and education programmes yielded improvements in provider knowledge of IPC practices, led to gains in provider competency and enhanced compliance with existing IPC guidelines as much as 27.5% (Storr et al., 2017[78]; Wang et al., 2019[92]).

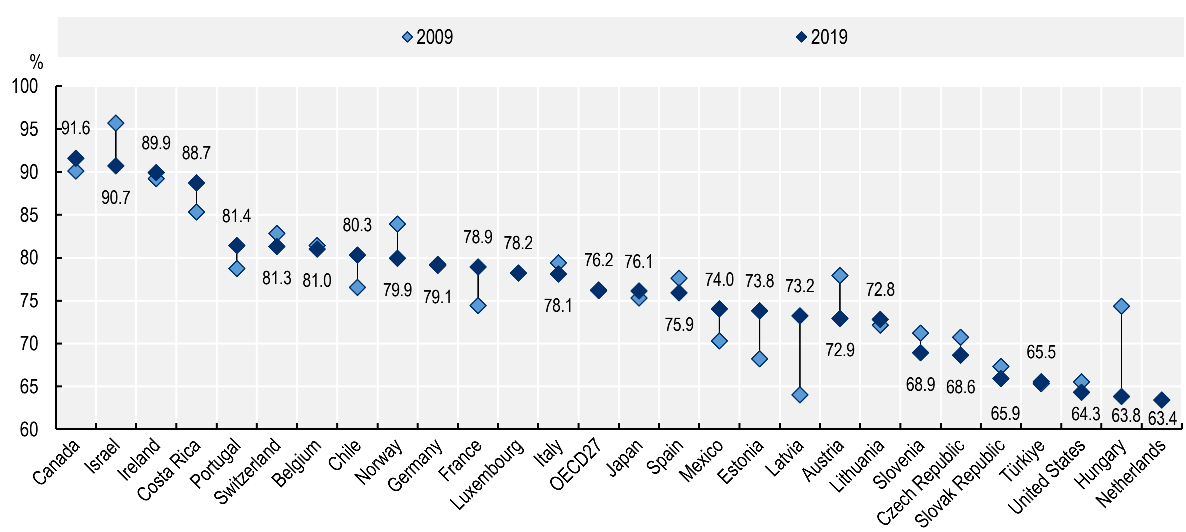
Optimising the organisation of care

Keeping the workload of health workers at acceptable levels is key to avoiding increases in the likelihood of healthcare-acquired AMR even in settings where IPC guidelines are in place and compliance is high. One cohort study from Portugal concluded that the quality of antimicrobial prescriptions was inversely related to the workload of the prescribing physician (Teixeira Rodrigues et al., 2016[96]). Similarly, a more recent study from China showed that reductions in the workload of prescribing physicians were inversely associated with the rate of carbapenem-resistant *Pseudomonas aeruginosa* (Han and Zhang, 2020[97]).

Addressing high rates of bed occupancy and overcrowding is another important intervention to reduce the risk of resistant HAIs. Several recent studies demonstrated that high rates of bed occupancy and overcrowding contribute to the spread of MRSA by: decreasing compliance with IPC guidelines (e.g. hand hygiene); increasing movement of patients and healthcare staff between different wards within health facilities; decreasing levels of cohorts; and overburdening available resources for screening and isolation (Andersen et al., 2002[98]; Clements et al., 2008[99]). Similarly, a recent study from the United States showed that a 1% increase in private patient rooms as a proportion of all inpatient rooms was associated with an 0.8% decline in MRSA infections effect (Park et al., 2020[100]).

Among OECD members, the curative care bed occupancy rate remained relatively stable over the last decade, averaging at about 76% in 2019 (Figure 5.3). However, substantial variation exists across countries in the occupancy rates: in Canada, almost 92% of acute care beds were used in 2019 compared to 63.4% in the Netherlands. In addition to bed occupancy and overcrowding, certain attributes of the physical infrastructure (e.g. the lack of isolation rooms, shower facilities and difficulties in access to handwashing facilities, poor water, sanitation and waste management) and inadequate access to equipment and materials have been reported to hinder good IPC practices (Storr et al., 2017[78]).

Figure 5.3. Occupancy rate of curative (acute) care beds, 2000 and 2019 (or nearest year)



Source: *OECD Health Statistics 2021*, https://doi.org/10.1787/health-data-en.

StatLink https://stat.link/nti1kc

Policies to improve vaccination coverage

Policy interventions

- Addressing hesitancy towards vaccines.

Key messages

- A wide range of communication and dialogue-based interventions can be used to build and sustain public confidence vaccines among different stakeholders.
- Behavioural interventions are showing promising results in nudging people to take up vaccines.

While it is paramount to support R&D efforts for developing new antibiotics and promote the use of forgotten ones, reliance on antibiotics will not suffice to mitigate the AMR threat. In contrast to antibiotics, vaccines are currently undergoing a remarkable phase of development and technological advances, offering new avenues for tackling AMR (Box 5.6). In recognition of the importance of vaccines for tackling AMR, the WHO Global Action Plan on Antimicrobial Resistance (GAP AMR) explicitly urges the global community to make an economic case for improved investments in vaccines.

Improving vaccination coverage is considered a public health priority in many countries. Building on long-standing efforts to improve vaccination coverage, in 2012, all members of the WHO endorsed the Global Vaccine Action Plan 2011-20. This plan sets out a 90% coverage target for all vaccines globally by 2020, with each country achieving at least 80% of coverage within all of their subnational administrative units (WHO, 2012[101]). Since then, many countries have seen marked increases in the coverage of different vaccines, though this progress differs by country groupings. As of 2019, the *Haemophilus influenzae* type B (Hib) vaccine has been incorporated into routine immunisation programmes in 192 countries (IVAC, 2019[102]). In contrast, only less than half of all infants (47%) residing in 144 countries have access to pneumococcal conjugate vaccines (PCVs). In 2018, the PCV coverage was the highest in the WHO's Americas and Europe regions: respectively, 82% and 78% of infants at 1 year of age received 3 doses of PCV in 2018 (WHO, 2019[103]). In the same year, the PCV coverage rates averaged 13% in the WHO Western Pacific region and 17% in the South-East Asia region (WHO, 2019[103]).

Box 5.6. New developments in new vaccine candidates to tackle AMR

In recent years, important strides have been made in the development of new vaccine candidates that can help reduce AMR. Developing a new vaccine can be a prolonged process, with only a few vaccine candidates eventually completing the clinical trial phase. Nevertheless, recent developments in vaccine research yielded promising results. For instance, a glycoconjugate vaccine that can protect against infections from *P. aeruginosa* and *K. pneumoniae* is currently in pre-clinical development, with early evidence demonstrating promising results (Hegerle et al., 2018[104]). Both of these bacteria are catalogued as a priority by the WHO and have been increasingly shown to complicate existing strategies for treatment.

Another pathogen that has recently been shown to develop a multidrug-resistant strain, particularly in community settings, is hypervirulent *K. pneumoniae*. Recent pre-clinical trials with a novel bioconjugate vaccine targeting hypervirulent *K. pneumoniae* have shown promising results in pre-clinical studies (Feldman et al., 2019[105]). In addition to these efforts, a number of vaccine candidates are currently in different stages of clinical development, including those that target *C. difficile,* group B *Streptococcus, Mycobacterium tuberculosis, Staphylococcus aureus* (*S. aureus),* carbapenem-resistant and extra intestinal *E. coli* and respiratory syncytial virus (Buchy et al., 2020[106]).

A growing body of literature highlights the need for incorporating the potential benefits of vaccines for AMR to reflect their full value (Bloom et al., 2017[107]). For instance, one recent review of the mathematical models that inform the implementation of vaccination programmes concluded that only a handful of studies in the existing literature quantified the impact of a vaccine on antibiotic transmission within a human population (Atkins et al., 2018[108]).

Source: Hegerle, N. et al. (2018[104]), "Development of a broad spectrum glycoconjugate vaccine to prevent wound and disseminated infections with Klebsiella pneumoniae and Pseudomonas aeruginosa", https://doi.org/10.1371/journal.pone.0203143; Feldman, M. et al. (2019[105]), "A promising bioconjugate vaccine against hypervirulentKlebsiella pneumoniae", https://doi.org/10.1073/pnas.1907833116; Buchy, P. et al. (2020[106]), "Impact of vaccines on antimicrobial resistance", https://doi.org/10.1016/j.ijid.2019.10.005; Bloom, D. et al. (2017[107]), "Moving beyond traditional valuation of vaccination: Needs and opportunities", https://doi.org/10.1016/j.vaccine.2016.12.001; Atkins, K. et al. (2018[108]), "Use of mathematical modelling to assess the impact of vaccines on antibiotic resistance", https://doi.org/10.1016/s1473-3099(17)30478-4.

In general, vaccination coverage among OECD members remains relatively high, but some countries are experiencing challenges in maintaining performance. On average, nearly 95% of children residing in OECD countries receive the recommended diphtheria, tetanus and pertussis (DTP) and measles vaccines, and around 91% receive a vaccine for hepatitis B (OECD, 2019[109]). Despite this, some OECD countries have seen reductions in the coverage of DTP vaccines by as much as 4 or more percentage points (e.g. Canada, Chile, Iceland, Lithuania, Mexico, Poland, Slovenia and Spain), while others experienced smaller declines (Estonia, Iceland, Lithuania, the Netherlands, Poland, the Slovak Republic and Slovenia) (OECD, 2019[109]). Today, nearly half of OECD countries do not meet the minimum immunisation thresholds (95%) recommended by the WHO to prevent the spread of measles and 15% fall short of meeting a similar target for DPT (OECD, 2019[109]). Taken together, these findings suggest that even countries with a long-standing track record of high vaccination coverage can face challenges in maintaining performance.

Addressing hesitancy towards vaccines

The remainder of this section focuses on barriers that may hinder the performance of vaccination programmes, with an emphasis on hesitations around vaccines. This approach was taken as a recognition of the growing concerns around hesitation towards the vaccines available among OECD members, despite generally high levels of vaccination coverage (Box 5.7).

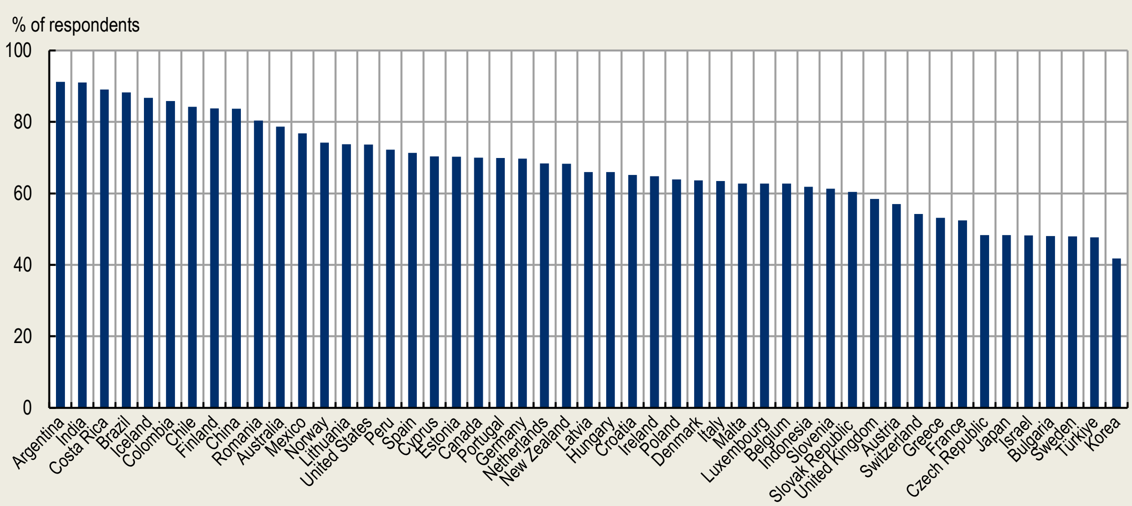
Box 5.7. Vaccine hesitancy in OECD countries

Vaccine hesitancy can significantly threaten the progress made in tackling vaccine-preventable diseases. Broadly, the WHO defines vaccine hesitancy as the reluctance and/or refusal to the vaccine, even though the vaccines are available. The WHO calls out vaccine hesitancy among the top ten gravest threats to global health. Vaccine hesitancy is a complex public health challenge due to its context-specific drivers that vary across time and different vaccine types (Díaz Crescitelli et al., 2020[110]; Larson et al., 2014[111]). Available evidence suggests that refusal of vaccines is on the rise among some OECD members, with the refusal rates for the measles-mumps-rubella (MMR) vaccine in 9 EU countries increasing over the last two decades (Larson et al., 2018[112]).

Waning public confidence in vaccines is among the most important factors that exacerbate hesitancy towards vaccines. In recent years, EU countries are diverging in terms of general public confidence in vaccines with some countries experiencing improvements (e.g. France, Italy and Slovenia), while others are seeing declines (e.g. the Czech Republic, Finland and Sweden) (Larson et al., 2018[112]). Importantly, vaccine confidence among health professionals also varies. For instance, in the Czech Republic, 36% of general practitioners indicated that they disagreed with the statement that the MMR vaccine was safe (Larson et al., 2018[112]).

Public confidence in vaccines is highly correlated with trust in the importance, safety and effectiveness of vaccines. One recent study that collated data across 149 countries found that, in 2020, among OECD countries and key partners, EU/EEA and G20 countries, the proportion of study participants that strongly believed that vaccines were important to child health stood around 67% (Figure 5.4) (de Figueiredo et al., 2020[113]). Importantly, considerable variation across countries exists in the beliefs about the importance of vaccines, ranging above 80% in Argentina, Brazil, China, Colombia, Costa Rica, Finland, Iceland, India and Romania, below 50% in Bulgaria, the Czech Republic, Israel, Japan, Korea, Sweden and Türkiye.

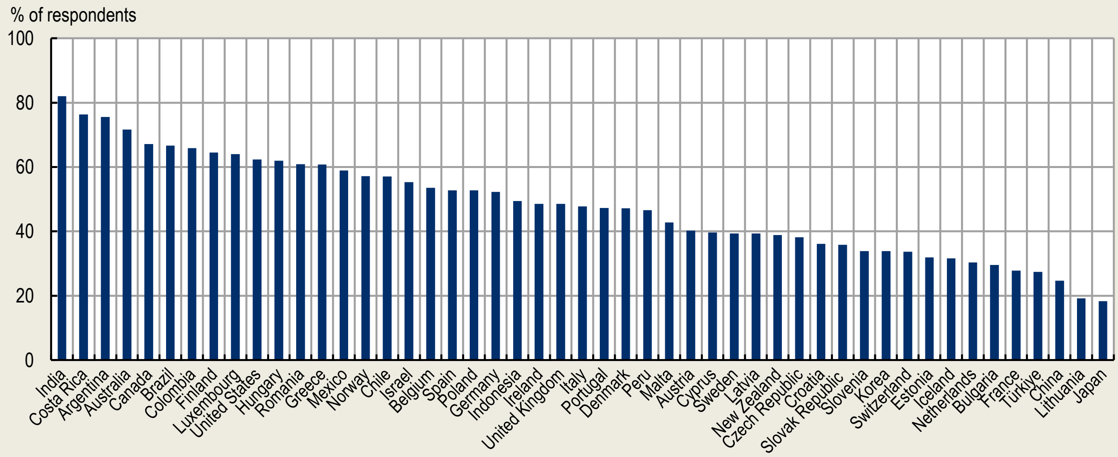
Figure 5.4. Beliefs about the importance of vaccines among OECD countries, 2020



Source: The graph presents the mean model-based estimates of the proportion of respondents who strongly agreed that vaccines are important for children for the year 2020 as published in de Figueiredo, A. et al. (2020[113]), "Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: A large-scale retrospective temporal modelling study", https://doi.org/10.1016/s0140-6736(20)31558-0, which generated estimates based on data from 290 surveys carried out from September 2015 to December 2019 across 149 countries.

Beliefs about the safety of vaccines also vary among G7 countries, OECD members and key partners (Figure 5.5). De Figueiredo et al. (2020[113]) also showed that, in 2020, only about 48% of study participants from OECD countries and key partners, EU/EEA and G20 countries considered vaccines to be safe. Beliefs about the safety of vaccines vary substantially, with a fraction of study participants indicating that they strongly agree with the statement that vaccines are important standing at the lowest levels for those Japan (18%) and Lithuania (19%), and the highest for those study participants from India (82%), Costa Rica (76%) and Argentina (76%). Similar variation in the beliefs about the effectiveness of vaccines was observed among G7 countries, OECD countries and key partners.

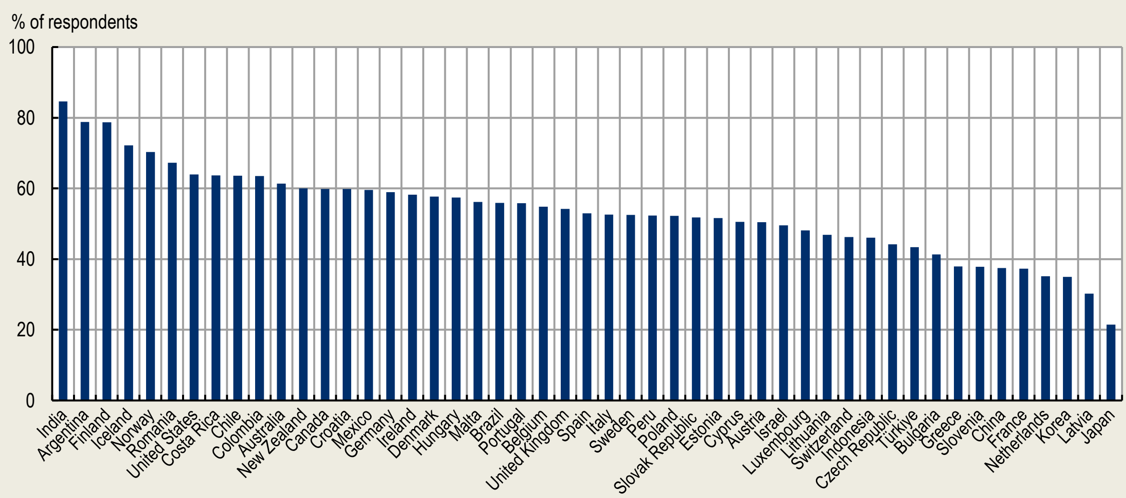
Figure 5.5. Beliefs about the safety of vaccines among OECD countries, 2020



Source: The graph presents the mean model-based estimates of the proportion of respondents who strongly agreed that vaccines are safe for children for the year 2020 as published in de Figueiredo, A. et al. (2020[113]), "Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: A large-scale retrospective temporal modelling study", https://doi.org/10.1016/s0140-6736(20)31558-0, which generated estimates based on data from 290 surveys carried out from September 2015 to December 2019 across 149 countries.

With respect to the beliefs about the effectiveness of vaccines (Figure 5.6), there is also substantial cross-country variation. It is estimated that, for the year 2020, about half of respondents (54%) in OECD countries and key partners, EU/EEA and G20 countries strongly agreed with the statement that vaccines are effective for children, with Japan having the lowest level of agreement (22%) and India having the highest level of agreement (85%) with this statement.

Figure 5.6. Beliefs about the effectiveness of vaccines among OECD countries, 2020



Source (box): Díaz Crescitelli, M. et al. (2020[110]), "A meta-synthesis study of the key elements involved in childhood vaccine hesitancy", https://doi.org/10.1016/j.puhe.2019.10.027; Larson, H. et al. (2014[111]), "Understanding vaccine hesitancy around vaccines and vaccination from a global perspective: A systematic review of published literature, 2007-12", https://doi.org/10.1016/j.vaccine.2014.01.081; Larson, H. et al. (2018[112]), *State of Vaccine Confidence in the EU*, https://doi.org/10.2875/241099; de Figueiredo, A. et al. (2020[113]), "Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: A large-scale retrospective temporal modelling study", https://doi.org/10.1016/s0140-6736(20)31558-0.

Increasingly, several international bodies are publishing analytical products to guide country efforts to address vaccine hesitancy, which underscores the need to build and sustain public confidence in vaccines among different stakeholders. Recently, the WHO also made available best practice guidelines that aim to provide basic principles for promoting vaccines in public discussions (WHO/Europe, 2017[114]). In 2017, the European Centre for Disease Prevention and Control (ECDC) published a catalogue of individual- and community-level strategies to alleviate vaccine hesitancy (2017[115]). In accordance with emerging evidence, the majority of the strategies highlighted by the ECDC rely on communication and dialogue techniques to address the information-related drivers of vaccine hesitancy, including those that relate to lack of information, misinformation and mistrust (Díaz Crescitelli et al., 2020[110]). Further, they highlight the need for developing strategies that target the complex driver of vaccine hesitancy across a wide array of stakeholders, including parents, health professionals and community gatekeepers as shown in Table 5.3.

Table 5.3. Selected individual- and community-level interventions highlighted by the ECDC to address vaccine hesitancy

Target stakeholder	Example interventions
Individual-level interventions focusing on parents	• Behavioural interventions to increase vaccine acceptability • Educational tools (e.g. brochures, vaccine information pamphlets and short videos addressing common concerns about vaccination, individually tailored education tools) • Referrals to specialised immunisation clinics • Vaccine risk communication messages • Countering anti-vaccination attitudes (e.g. expose information on the consequences of not vaccinating)
Individual-level interventions focusing on improving healthcare workers' confidence and communication skills to respond to hesitant patients	• Specialised physician training on vaccine communication (e.g. communicating with vaccine-hesitant parents in three different steps: ask, acknowledge and advise) • Becoming a vaccine champion to improve vaccination uptake in the general population by focusing on vaccine-hesitant parents • Improve communication between physicians and parents using the Corroborate, About me, Science and Explain/advise (C.A.S.E.) approach • Electronic medical records linked clinical decision support for clinicians • Motivational interview methods in nurseries to promote vaccination
Community-level interventions	• Interactive social media tools for parents with concerns about vaccines, web-based decision aids • Messages with corrective information against influenza vaccination myths • Household visits in communities with high rates of vaccine hesitancy • ECDC communication guide, WHO *Best Practice Guidance: How to Respond to Vocal Vaccine Deniers in Public*

Source: Adapted from ECDC (2017[115]), *Catalogue of Interventions Addressing Vaccine Hesitancy*, https://doi.org/10.2900/654210.

In addition to these interventions, behavioural approaches that aim to nudge the uptake of vaccines have recently gained prominence in improving vaccination uptake. For instance, one recent randomised controlled trial from Kenya demonstrated that in settings where the baseline vaccination coverage is already high, the use of mobile phone-delivered reminders coupled with financial incentives can lead to important improvements in the uptake of vaccines for young children (Gibson et al., 2017[116]). Another field experiment from Sierra Leone that was implemented in the course of almost 2 years in 120 public clinics found that public health interventions that rely on principles grounded in behavioural economics like social signalling among community members can substantially increase vaccination uptake (Karing, 2018[117]).

Policies to tackle AMR outside the human health sector

Policies to tackle AMR in animal health

Globally, food consumption is rising faster than its production, exerting pressure on producers to resort to intensive, antibiotic-dependent agricultural practices in livestock and crop production. Many antibiotics used in food-producing animals are considered to be medically important for human medicine (Box 5.8). Plant production is another potentially important driver of antimicrobial use in agriculture, though relatively little is documented on the use of antibiotics in plants.

Box 5.8. WHO guidelines on the use of medically important antimicrobials in food-producing animals

Broadly, antibiotics are administered to animal populations for four main purposes:

- Therapeutic use refers to instances when veterinary antimicrobials are administered in the presence of a clinically diagnosed infectious disease (WHO, 2017[118]).
- Metaphylactic and prophylactic use occurs in the absence of a clinically diagnosed infectious disease. According to the WHO, metaphylactic use refers to treating animals that were exposed to animals with a clinical diagnosis of an infectious disease. Under these circumstances, antibiotic use is considered warranted, because the exposed animal may have been infected without presenting any symptoms (WHO, 2017[118]). In comparison, the WHO defined prophylactic use (i.e. disease prevention use) as the use of antimicrobials in healthy animals that are suspected to have a high risk of infection prior to the clinical onset of an infectious disease.
- Growth promotion refers to antibiotic use in otherwise healthy animals to accelerate weight gain and improve the efficiency of feed utilisation (WHO, 2017[118]).

Recognising that many antimicrobials used in food-producing animals are either the same or closely related to those used in human medicine, in 2005, the WHO developed a systematic classification of medically important antimicrobials: important, highly important or critically important for human medicine (WHO, 2017[118]). These classifications provide the basis for the WHO List of Critically Important Antimicrobials for Human Medicines and guidance on veterinary antimicrobial use as follows (WHO, 2017[118]):

- A complete restriction is recommended for the use of all medically important antimicrobials in food-producing animals for growth promotion purposes.
- In the absence of disease, a complete restriction is recommended for the use of all classes of medically important antimicrobials in food-producing animals for the prevention of infectious diseases that have not yet been clinically diagnosed.
- In the presence of disease, it is recommended that antimicrobials classified as critically important for human medicine should not be used to control the dissemination of a critically diagnosed infectious disease identified within a group of food-producing animals.
- It is recommended that antimicrobials that are classified as the highest priority and critically important for human medicine should not be used for treating food-producing animals with clinically diagnosed infectious diseases.

Source: WHO (2017[118]), *WHO Guidelines on Use of Medically Important Antimicrobials in Food-producing Animals*, https://apps.who.int/iris/handle/10665/258970.

Over-reliance on veterinary antimicrobials can contribute to the growing AMR burden. Earlier reviews demonstrated the linkages between the use of veterinary antimicrobials and AMR in humans (Review on Antimicrobial Resistance, 2015[119]). One subsequent meta-analysis quantified that reductions in veterinary antimicrobial use may contribute to a 10-15% reduction in resistance in animals and a 24% reduction in humans (WHO, 2017[118]). In farm settings, contact with animals has been suggested to be a particularly important factor in AMR transmission (Hoelzer et al., 2017[120]), with evidence pointing to an increased risk of transmission of livestock-associated MRSA between animal species, from animals to humans (e.g. farmers in contact with animals) and to the environment (Klous et al., 2016[121]). In recognition of these complexities, one recent OECD publication examined the economic benefits and costs of the use of veterinary antimicrobials and provided five recommendations, three of which are particularly relevant for this publication that mainly focuses on human health aspects (Box 5.9). The rest of this section covers evidence associated with selected recommendations.

Box 5.9. OECD analysis of economic benefits and costs of antimicrobial use in food production animals

Recent OECD analysis sheds light on the economic benefits and costs associated with the use of veterinary antimicrobials in food-producing animals and provides five key recommendations (Ryan, 2019[122]). Three recommendations are particularly relevant for this publication that mainly focuses on human health:

1. Provide flexible regulations and a step-by-step approach to facilitate adjustment at the farm level. A regulatory approach that is likely to optimise prudent use may consist of various dimensions, including: i) quality veterinary services and clear legislation on the use of antimicrobials in animal production; and ii) good co-operation and understanding of the regulations by all stakeholders supported by appropriate enforcement, adequate expertise and a well-functioning surveillance system. Abolishing the use of veterinary antimicrobials for growth promotion should be prioritised.
2. Optimise a mix of management and biosecurity measures on the farm by: i) adopting good internal and external biosecurity; ii) increasing the natural immunity of the animals by improving breeding, housing, nutrition and stocking density on the farm; and iii) improving overall management on the farm.
3. Take an inter-sectoral or One Health approach to combat the negative externalities arising from AMR.

The two recommendations below are also crucial but relatively less evidence is available in terms of their effectiveness for human health:

1. Enhance information availability on economic benefits and costs of antibiotics in food-producing animals through: i) specific training and providing better information on the economic impact of antimicrobials to key stakeholders, especially farmers and veterinarians; ii) examples of "best practice" in terms of the optimal level of antimicrobial use on animal farms based on research in other countries and other animal enterprises; and iii) improvements in the diagnostic tests of animal diseases in order to optimise the use of preventive and affordable veterinary medication, as well as information on the antimicrobial classes best suited to treat and control the disease.
2. Improve the availability of information and knowledge on interventions alternative to antimicrobials and the relative costs and benefits associated with these interventions. It is also crucial to ensure adequate access to alternative interventions at affordable prices.

Source: Ryan, M. (2019[122]), "Evaluating the economic benefits and costs of antimicrobial use in food-producing animals", https://doi.org/10.1787/f859f644-en.

Policies to promote prudent use of antimicrobials in animals

Policy interventions

- Regulations concerning access to and use of veterinary antimicrobials.

Key messages

- Regulations that restrict the use of veterinary antibiotics can result in reductions in AMR but the precise magnitude of the effectiveness of each type of regulation varies by setting.
- Flexible regulations and a step-by-strategies that enable adjustments at the farm level are preferable to blanket bans that outlaw the use of antimicrobials for all purposes.
- While considering regulatory options, priority should be given to regulations that limit antimicrobial use for growth promotion purposes.
- The effectiveness of regulatory measures may be enhanced through the use of market mechanisms, voluntary initiatives, improving the availability of options alternative to antimicrobials and financial incentives for producers.

Regulations to optimise the prudent use of antimicrobials in animal populations

Regulations that seek to promote the prudent use of veterinary antimicrobials can be grouped in accordance with the degree to which they impose restrictions on access to and use of these antimicrobials. To date, some countries chose to outlaw the use of all veterinary antibiotics, while others imposed limits on a single antibiotic class or a single antibiotic for all indications of use (Tang et al., 2019[123]). Other countries restrict antimicrobial use for all non-therapeutic indications (e.g. limiting antimicrobial use for prophylaxis or growth promotion purposes). In recent years, some countries also started to incorporate multi-sectoral considerations in the rules and regulations around veterinary antimicrobials in line with the One Health framework (Box 5.10).

Box 5.10. Germany’s environmental checklist for the use of veterinary medicinal products

In 2017, the German Environment Agency published a checklist for veterinary medicine and animal husbandry, which delineates a list of environmental issues when using veterinary medicines (Umwelt Bundesamt, 2018[124]). A translation of these issues encompasses (OECD, 2019[125]):

Veterinary medicine

- Carrying out sufficient levels of diagnostics and confirmation of a medical indication.
- Possibility of avoiding a drug treatment, with consideration to input of pharmaceuticals to the environment, and to reducing resistance formation.
- Informing the animal owner regarding the accurate administration of prescribed medicines, as well as correct storage and disposal.

Livestock farming

- Considering the necessity of preventive measures, such as vaccinations.
- Ensuring that alternative treatment methods are considered by veterinarians and farmers.
- Complying with veterinary instructions for administrating the correct dosage, duration and frequency of medicine.
- Avoiding unnecessary treatment and entry of pharmaceutical residues into the environment by keeping records of veterinary medicines.
- Ensuring proper disposal of used medicines, leftovers, and packaging.
- Ensuring a rest period of several months before the spreading of manure, which may contain traces of veterinary medicinal products.
- Assessing what prevention measures could be taken at the farm scale to avoid or reduce future drug treatments.

Source: Umwelt Bundesamt (2018[124]), *Umweltaspekte bei Verabreichung von Tierarzneimitteln*, https://www.umweltbundesamt.de/umweltaspekte-bei-verabreichung-von#Landwirtschaft (accessed on 16 January 2021); OECD (2019[125]), *Pharmaceutical Residues in Freshwater: Hazards and Policy Responses*, https://doi.org/10.1787/c936f42d-en.

Most OECD countries have regulations in place that restrict access to veterinary antimicrobials (e.g. purchases only through authorised pharmacies, veterinarians and wholesalers and based on prescription). For instance, EU members started implementing new regulations in 2022 (i.e. Regulations (EU) 2019/6 and 2019/4), which outlawed the use of veterinary antimicrobials for prophylaxis purposes with certain exceptions and in medicated feed, and enforcing new restrictions concerning metaphylactic use. Moreover, the EU standards started covering imports from third parties outside the EU area (e.g. compliance with EU regulations that outlaw the use of veterinary antimicrobials as growth promoters). In comparison, in many LMICs, over-the-counter purchase of veterinary antimicrobials without the need for a prescription remains the norm and access to veterinary antimicrobials is largely unchecked given the existing regulatory gaps and difficulties around enforcing existing regulations (Sulis et al., 2020[47]).

Available evidence suggests that regulating access to veterinary antimicrobials can result in reductions in AMR. One recent meta-analysis quantified that a complete ban on antimicrobial use was associated with a 15% reduction in AMR (Tang et al., 2019[123]). However, a blanket ban on veterinary antimicrobials for all purposes may not be necessary. In their review, Tang et al. (2019[123]) suggested that regulations that allowed antimicrobial use for therapeutic purposes achieved similar levels of reduction in AMR, compared to regulations that outlawed all types of antimicrobial use. Among less restrictive regulations, those with narrower targets (e.g. targeting a specific antibiotic or an antibiotic class) were less effective than those that imposed broader limitations (Tang et al., 2019[123]). However, these findings should be interpreted with caution, as many of the studies that provide the basis for these results suffer from important methodological weaknesses. Nonetheless, in congruence with these findings, previous OECD analysis recommends flexible regulations and a step-by-strategies that enable adjustments at the farm level (Ryan, 2019[122]).

While considering regulatory options to optimise the prudent use of veterinary antimicrobials, limiting use for growth promotion purposes should be prioritised. This type of usage presents an alarming public health challenge because it entails exposing bacteria to antimicrobials in low doses over prolonged periods of time, which, in turn, elevated the risk of developing resistance. One meta-analysis calculated that a 30% reduction in the proportion of antibiotic-resistant isolates may be achieved by restricting the use of antimicrobials for growth promotion, suggesting that such restrictions can offer a highly successful strategy for tackling AMR (Tang et al., 2019[123]).

Countries follow different regulatory paths while restricting the use of antimicrobials for growth promotion in their own setting. In 2017, the United States embarked on a regulatory process focusing on medically important antimicrobial drugs used in the feed or drinking water of food-producing animals (FDA, 2020[126]). With the introduction of new regulations, veterinary oversight has become a requirement for the purchase of medically important antimicrobial drugs and the use of these drugs' growth promotion was outlawed (FDA, 2020[126]). China, another important agricultural producer, followed a different path in restricting antimicrobial use for growth promotion. In 2016, the country rolled out new restrictions, which entailed a ban on the use of Colistin for growth promotion – an antibiotic categorised as the highest priority and critically important for human medicine used as a last resort for treating multidrug-resistant Gram-negative infections (WHO, 2019[127]). These regulations were followed by new restrictions that were rolled out in 2019 that made it illegal to use medicated feed additives for growth promotion, except for traditional Chinese medicine (Hu and Cowling, 2020[128]).

While regulations are key to promoting the prudent use of veterinary antimicrobials, countries also make use of market mechanisms to limit the use of antimicrobials as growth promoters. Interestingly, one recent World Organisation for Animal Health (WOAH) survey revealed that 50 countries were able to enforce bans on antimicrobial use for growth promotion in their settings without an explicit regulatory framework (2020[129]). Instead, some of these countries restricted market access to these molecules altogether, while others relied on strategies like bans on the imports of selected molecules and scaling up monitoring of manufacturing companies to ensure antimicrobials were used only in veterinary medicine. These strategies were complemented with efforts that provided pig and poultry farmers alternatives to antimicrobials while highlighting the need for improved sanitation and hygiene practices in agricultural production (WOAH, 2020[129]).

In settings where regulatory frameworks are already in place to promote the prudent use of veterinary antimicrobials, voluntary initiatives can be considered to enhance the effectiveness of these regulations. For instance, in 2005, a public health programme from Quebec, Canada, promoted voluntary withdrawal of Ceftiofur consumption in hatcheries, a broad-spectrum, third-generation cephalosporin. This programme was associated with remarkable reductions in the prevalence of Ceftiofur resistance in *Salmonella* Heidelberg isolates from 2004 to 2006: from 62% to 7% in retail chicken and 36% to 8% in humans (Dutil et al., 2010[130]). Conversely, a brief re-introduction of Ceftiofur in 2007 was associated with spikes in the prevalence of resistant bacteria in retail chicken and humans. In Japan, the voluntary withdrawal of off-label use of Ceftiofur in chicken hatcheries was linked to significant declines in resistance to broad-spectrum cephalosporin in *E. coli* in healthy broilers from 16.4% in 2010 to 4.6% in 2013 (Hiki et al., 2015[131]), suggesting that the beneficial effects of voluntary initiatives may be reaped in a relatively short period.

Improving the availability of interventions that are alternative to antimicrobials offers another important strategy to strengthen the effectiveness of regulatory approaches without exacerbating the burden of animal diseases. For instance, one randomised controlled trial from the states of Michigan and New York in the United States investigated the impact of antibiotic-free feeding practices in dairy calves, where farmers started using non-medicated milk replacers instead of those that contained broad-spectrum antibiotics like oxytetracycline and neomycin (Kaneene et al., 2008[132]). This switch towards antibiotic-free feeding was associated with increased susceptibility to tetracycline in *Salmonella* and *Campylobacter* spp. and *E. coli* in dairy calves over a 12-month period (Kaneene et al., 2008[132]). Importantly, no measurable increases were observed in cattle diseases in the study period.

Additionally, offering financial incentives for producers in agricultural and aquaculture industries can help improve the effectiveness of regulatory approaches. The FAO estimates that, globally, 1.3 billion people rely on livestock production for their livelihood, which accounts for nearly 40% of total agricultural output in developed countries and about 20% in developing nations (FAO, 2020[133]). Interventions that restrict the use of veterinary antimicrobials may have economic implications that vary across industry types (Box 5.11). In recognition, one potentially successful strategy is to consider financial incentives that can help assuage financial concerns among producers over the potential loss of farm productivity.

Box 5.11. Health and economic impacts of the termination of growth promoters in Denmark

Denmark is among the pioneering countries that terminated the use of antimicrobials as growth promoters through a combination of regulatory and voluntary action. In 1995, Denmark discontinued the use of avoparcin for non-therapeutic purposes, which was followed by a similar limitation on virginiamycin use in broilers, cattle and finishing pigs in 1998 (FAO/DMOEF, 2019[134]). The same year, Danish producers volunteered to discontinue the use of all antimicrobials for growth promotion in finishing pigs. In 1999, the use of all antimicrobial growth promoters was outlawed for all food-producing animals. Today, veterinary antimicrobials can only be used for therapeutic or metaphylactic purposes, as prophylactic use is no longer permitted (FAO/DMOEF, 2019[134]).

Building on these efforts, Denmark introduced the Yellow Card scheme in 2010, with the aim of reducing the overall consumption of antimicrobials in pig production (Jensen and Hayes, 2014[135]). Rather than targeting all pig farmers, this intervention focuses on farmers that consume the highest levels of antimicrobials. At the outset, the programme identified a threshold for veterinary antimicrobial use (FAO/DMOEF, 2019[134]). Farmers that exceed this threshold receive a yellow card that is meant to serve as a warning. Upon receiving a yellow card, farmers and veterinarians work together to lower antibiotic consumption on the farm within a nine-month time frame (FAO/DMOEF, 2019[134]). If a farmer fails to achieve the target reductions in antimicrobial consumption in this time frame, they receive a red card, which brings about mandatory reductions in the stocking density of animals on the farm (FAO/DMOEF, 2019[134]).

The Danish Ie underscores the complexities in regulating the use of antimicrobials in animals. Available evidence shows that the Danish efforts to terminate the use of antimicrobial growth promoters in the 1990s were associated with declines in the total volume of antimicrobials used in animals (Jensen and Hayes, 2014[135]). In the months following the initial ban on antimicrobial growth promoters, some increases in therapeutic use were observed in pig production but this surge was substantially lower than the overall reduction in the total volume of antibiotics used (FAO/DMOEF, 2019[134]). Similarly, available evidence suggests that the Yellow Card initiative was associated with declines in antimicrobial consumption, with the country achieving the target of a 10% decline in antimicrobial use for food-producing animals by 2013 (FAO/DMOEF, 2019[134]).

In terms of the economic impact of the termination of antimicrobial growth promoters, the overall losses in farm productivity varied by industry type. For instance, in pig production, productivity losses were estimated to average around EUR 1.04 per pig produced, which was partly driven by excess mortality and increased medication use (WHO, 2002[136]). This corresponds to approximately a 1% increase in overall production costs. In comparison, in poultry production, additional costs associated with the observed reductions in feed efficiency were almost entirely offset by savings from reduced antimicrobial use (WHO, 2002[136]).

Available evidence on the Yellow Card initiative suggests that there was a 1% decline in profits among farms that remained above the programme target threshold (FAO/DMOEF, 2019[134]). The decline in profits was largely attributable to the additional farm-level investments that were needed to lower antimicrobial use in line with the programme threshold (FAO/DMOEF, 2019[134]). These investments included additional expenses to cover animal vaccines, higher-quality feed and veterinary consultations, suggesting that the programme may have contributed to a shift in the emphasis on farming management practices that relied on antimicrobial use for disease prevention in these farms.

Source: FAO/DMOEF (2019[134]), "Tackling antimicrobial use and resistance in pig production: Lessons learned from Denmark", Food and Agriculture Organization of the United Nations; Jensen, H. and D. Hayes (2014[135]), "Impact of Denmark's ban on antimicrobials for growth promotion", https://doi.org/10.1016/j.mib.2014.05.020; WHO (2002[136]), *Impact of Antimicrobial Growth Promoter Termination in Denmark: The WHO International Review Panel's Evaluation of the Termination of the Use of Antimicrobial Growth Promoters in Denmark*, https://apps.who.int/iris/handle/10665/68357.

Policy interventions

- Optimising farm management and biosecurity measures
- Increase the coverage of animal vaccines.

Key messages

- Investing in farm management, biosecurity and animal vaccines contribute to reductions in the likelihood of the emergence and spread of resistant pathogens in farm settings.
- Additional expenses incurred due to investing in farm management and biosecurity measures can be offset by savings achieved from reducing reliance on antibiotics.

Optimising farm management and biosecurity measures

The spread of infection among animals living in the same population may increase the likelihood of veterinary antimicrobial use while leading to reductions in farm productivity and increases in costs (Dewulf, 2019[137]). As discussed earlier in Chapter 4, an important strategy to prevent the spread of infection in animal populations relates to better farm management practices and enhanced external and internal biosecurity measures. Improving the existing farm management practices can boost the natural immunity in animal populations (e.g. improvements in breeding, housing, nutrition and stocking density on the farm) (Ryan, 2019[122]), while biosecurity measures can help reduce the likelihood of emergence and spread of pathogens environments (Alarcón, Alberto and Mateu, 2021[138]). In recent years, many OECD countries adopted holistic approaches to reducing the spread of infection among animals (Box 5.12).

Box 5.12. Sweden's holistic approach to livestock production

Today, Sweden has the lowest use of antimicrobials in livestock production among the EU countries, thanks to a holistic approach that prioritises preventive health strategies, coupled with restrictions on the use of veterinary antimicrobials. As the first European country that banned the use of antimicrobial growth promoters in 1986, Sweden applies a national regulatory framework that sets the rules and guidelines for access to veterinary antibiotics. The Swedish Veterinary Association provides specific guidelines on antibiotic use, which emphasises the importance of preventive and biosecurity measures.

In general, antibiotics are considered a last resort and their use is meant to be supported by a number of factors including bacteriological diagnosis and susceptibility tests, food safety and environmental and economic concerns. Since 2013, a national list of antibiotics is being used, which clearly delineates antibiotics that can be used only in human medicine (FAO, 2020[139]). Access to antimicrobials is closely regulated, whereby the Medical Products Agency requires prescribed antibiotics to be purchased only from pharmacies and not from veterinarians, with some exceptions for acute treatment (FAO, 2020[139]).

A key component of the Swedish approach is close stakeholder collaboration. Veterinarians and farmers work closely to optimise animal health. Many farmers are assigned to specific veterinarians, who typically carry out either extension or clinical work. At the point of care, veterinarians examine animals and animal groups before antibiotics can be dispensed and these examinations are required to involve AMR risk assessments. Veterinarians also give advice on biosecurity measures, which are tailored to each farm. Farmers can also make use of several advisory tools for biosecurity (e.g. checklists for infection control on farms). In addition, administrative boards in counties are responsible for providing authorisation before any new animal housing can be constructed.

The Swedish approach underlines the importance of monitoring and surveillance of animal health. During routine farm visits, veterinarians collect data on the health status of herds, which provide the basis for herd-specific recommendations. Data collected during each visit are recorded in the Swedish Board of Agriculture database, which offers summaries on disease incidence and treatment within the herd (FAO, 2020[139]). Data collated from farms are then used for surveillance, benchmarking and goal setting. An additional database for post-mortem disease registration is also operational and it aids decisions regarding breeding practices and culling strategies. Since 2013, Sweden requires the monitoring of certain resistant bacteria, including *S aureus,* methicillin-resistant *Staphylococcus pseudintermedius,* other methicillin-resistant coagulase-positive *Staphylococci* and carbapenemase-producing *Enterobacteriaceae* (FAO, 2020[139]). When a laboratory suspects that samples collected by a veterinarian include any of these agents, the local country administrative board and the Swedish Board of Agriculture are notified.

Source: FAO (2020[139]), *Tackling Antimicrobial Use and Resistance in Dairy Cattle*, https://doi.org/10.4060/cb2201en.

Improvements in farm management and biosecurity measures reduce reliance on veterinary antimicrobials and AMR in animals. A recent study from 38 Japanese pig farms rolled out a strict application of an all-in and all-out system that disallowed the mixing of different animal groups (Isomura, Matsuda and Sugiura, 2018[140]). This intervention was associated with reductions in the circulation of pathogens, as well as reductions in the amount and variety of antibiotics used. Another study in Belgium rolled out a complex intervention in 61 Flemish pig herds, which combined new herd management methods, biosecurity measures (including animal vaccines) and anthelmintic therapy and recommendations for farmers on prudent use of animal antibiotics (Postma et al., 2016[141]). This intervention was associated with significant reductions in the use of antimicrobials considered to be critically important for human medicine, as well as a 52% reduction of AMR in pigs from birth to slaughter and 32% in breeding animals. In other settings, biosecurity measures yielded preventive returns for multiple diseases at the same time, while reducing the probability of transmission within the intervention sites (Manyi-Loh et al., 2018[142]).

A particular set of biosecurity measures that work well in one setting may not necessarily be suitable in others, underscoring the importance of collaboration across different stakeholders like veterinarians and farmers to optimise biosecurity strategies that best fit local needs. Previous OECD analysis suggested that carrying out biosecurity assessments in regular intervals may help decide which biosecurity strategies should be prioritised in a given setting while facilitating regular assessments of the changes in farm biosecurity over time and performance benchmarking (Ryan, 2019[122]).

An important debate around the implementation of farm management and biosecurity measures relates to concerns about costs and potential changes in farm productivity. Available evidence suggests that additional expenses may be offset by savings due to reductions in antimicrobial consumption. For instance, one recent study from Flemish pig herds showed that improvements in biosecurity measures were linked to increases in the number of weaned piglets per sow per year (+1.1), daily weight gain (+5.9 g/day) and reductions in mortality in the finisher period (−0.6%) (Postma et al., 2016[141]). Similarly, another study from 117 farrow-to-finish pig farms in Belgium found that biosecurity measures were cost-effective (Rojo-Gimeno et al., 2016[143]). This study found that costs associated with the rollout of new biosecurity measures (median +EUR 3.96/sow/year) were lower than the net cost reduction associated with reduced antibiotic use (median −EUR 7.68/sow/year). Importantly, cost reductions were driven primarily by the declines in antibiotic use for prophylactic treatment. This study further pointed to reductions in mortality in finishers (-1.1%).

Animal vaccines

Similar to humans, increasing vaccination coverage in animal populations offers an important strategy to prevent infections and reduce the need for antibiotic use. A well-documented example comes from aquaculture practices in Norway, the world’s largest salmon producer. To tackle the rising burden of furunculosis, a bacterial fish disease that is present in wild salmon, Norway embarked on a large-scale vaccination initiative in the late 1980s in the fish farming sector. This initiative was complemented with additional measures like zoning and spatial re-arrangement of marine production sites to limit the spread of infections. Today, all domestic produce in Norway is vaccinated, with only about 0.03% of salmon estimated to receive at least one course of antimicrobial drugs (Midtlyng, Grave and Horsberg, 2011[144]). This corresponds to less than one tonne of antibiotics used per year. In comparison, Chile, the second largest salmon producer globally, uses about 300 tonnes of antibiotics each year (FAO, 2020[133]), though the Chilean salmon industry recently pledged a 50% reduction in veterinary antibiotic use by 2025.

The uptake and scale-up of animal vaccines can reduce the need for antibiotic use without adversely impacting farm productivity. In Norway, efforts to scale up vaccination coverage in salmon populations coincided with the doubling of domestic salmon production between 2003 and 2014, suggesting that the reductions in antibiotic use were unlikely to hinder the expansion of production capacity (Midtlyng, Grave and Horsberg, 2011[144]). In Hungary, oral vaccination and medication against *Lawsonia intracellularis* (*L intracellularis*) for finishing pigs were associated with significant reductions in the prevalence of porcine proliferative enteropathy and concurrent improvements in average daily weight, a commonly used measure of farm productivity (Thaker, 2006[145]). Animal vaccines can also yield important gains even in settings where veterinary antibiotic use is already relatively low. For instance, in Denmark, vaccination against *L intracellularis* in pig herds led to a 79% reduction in the use of oxytetracycline (Bak and Rathkjen, 2009[146]). This vaccination effort was also associated with gains in average daily weight and carcass weight and reductions in the fattening period by eight days.

Policies to tackle AMR in plant health

Policy interventions

- Regulations to promote the prudent use of antimicrobials in plant population.
- Enhancing farm biosecurity measures and strengthening integrated pest management (IPM).

Key messages

- Regulations to limit the use of antimicrobials that may impart resistance against critically important drugs for animal and human health in plant populations may help lower AMR transmission but important gaps exist in the existing regulatory arrangements across G7 countries, OECD members and key partners.
- Mechanisms are lacking for monitoring pesticide use in plant production.
- Improving farm biosecurity and strengthening integrated pest management approaches can help reduce the likelihood of the emergence and spread of diseases in plants.

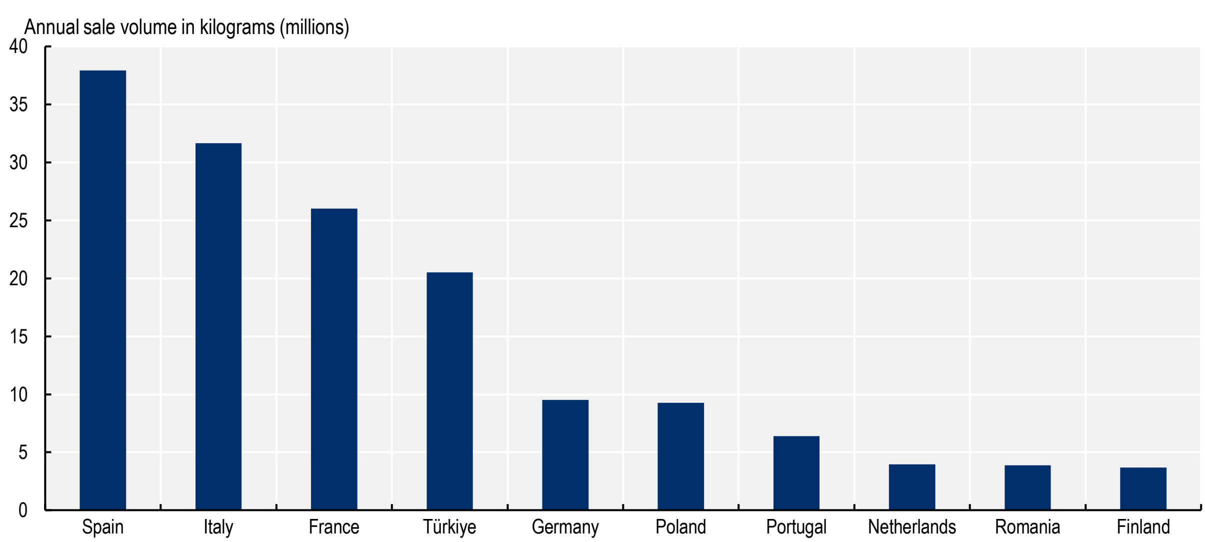
Antimicrobials are used in plant populations to treat bacterial and fungal diseases, though important knowledge gaps need to be addressed to inform the development of effective AMR policies. Limited evidence suggests that antimicrobial use during plant production can potentially contribute to AMR by exerting selective pressure on pathogens in the environment, particularly those that thrive in the surrounding soil and water bodies (FAO/WOAH/WHO, 2019[147]). No systematically collected sources of data are available on a global scale to shed light on the volume of antimicrobials used as pesticides. While the dearth of data makes it difficult to quantify the precise magnitude of the challenge (Lomazzi et al., 2019[148]), the FAO estimates that, globally, the amount of antibiotics used in plant products constitutes around 0.2-0.4% of total agricultural antibiotic consumption each year (FAO, 2020[133]).

Policies to promote prudent use of antimicrobials in plants

Regulatory frameworks for antimicrobial use in plant production

Limited data suggest that countries are diverging in their reliance on pesticides. Today, pesticide use in Argentina, China and the United States constitute around 70% of the global use, with China accounting for about half of global consumption (Pretty and Bharucha, 2015[149]). Over the last two decades, the use of pesticides in China grew fourfold, while it remained relatively stable in Germany and the United States. In addition, welcome reductions were observed in Denmark, France, Italy, Japan and the United Kingdom (Pretty and Bharucha, 2015[149]). Some of the observed reductions in country-level sales of pesticides across EU countries may be partly explained by the scale-up of regulatory frameworks that relate to pesticide use in plant production, including the EU law on sustainable use of pesticides (Article 15 of Directive 2009/128/EC) (European Commission, 2009[150]), as well as increased use of IPM techniques, technological advancements in spray applications and formulations, and enhancements in disease forecasting models. As shown in, Figure 5.7, in 2020, the annual sales volume of fungicides and bactericides remained the highest in 2020 in France across those countries that report information to Eurostat (2022[151]).

Figure 5.7. Top 10 countries that report the highest annual sales volume of fungicides and bactericides to Eurostat, 2020



Source: Fungicide and bactericide sales data extracted from Eurostat (2022[151]), *Pesticide Sales*, https://ec.europa.eu/eurostat/databrowser/view/AEI_FM_SALPEST09/bookmark/table?lang=en&bookmarkId=53792fd3-191d-4201-aab5-c01c67fd927c (accessed on 26 October 2022).

Globally, there are important gaps in regulatory frameworks concerning antimicrobial use in plant production. In 2020-21-20, about 80% (124/155) of countries, globally, had some form of national policy or legislative framework in place to address quality safety and efficacy of pesticides, including antimicrobial pesticides (e.g. bactericides, fungicides), as well as their distribution, sale or use (WHO/FAO/WOAH, 2022[152]). The welcome news is that across G7 countries, OECD members and key partners, the availability of these regulatory frameworks were higher than the global averages, standing at around 90% (46/51). However, only 16% (8/51) of G7 countries, OECD members and key partners reported having enforcement and control mechanisms in place to ensure compliance with these frameworks in 2019-20 (WHO/FAO/WOAH, 2022[152]).

In addition to gaps in regulatory frameworks, mechanisms are lacking monitoring of antimicrobial use in plant production. In 2020-21, about 45% (23/51) of G20 countries, OECD members and key partners reported having some form of a national plan or mechanism in place to collect data and report the amount of pesticides sold/used at the national level, including antimicrobial pesticides, in order to respond to bacterial or fungal diseases (WHO/FAO/WOAH, 2022[152]). Relatedly, the existing guidelines concerning antimicrobial use in plants vary considerably across geographic regions. Globally, streptomycin is the most commonly recommended antibiotic for use in plants, followed by tetracycline and kasugamycin (Taylor and Reeder, 2020[153]). But notable geographic variations exist in current antibiotic guidance. For instance, tetracycline and streptomycin are most frequently recommended in the South-East Asia region, whereas producers in the Americas and Western Pacific regions rely more frequently on oxytetracycline and gentamicin (Taylor and Reeder, 2020[153]). This variation in antibiotic recommendations may be partly due to differences in prices, regulatory frameworks, product availability, cropping regimes, knowledge of agronomic advisors and the nature of pathogens that are of concern (Taylor and Reeder, 2020[153]).

Policies to prevent the emergence and spread of diseases in plants

Farm biosecurity, infection prevention and control, investing in IPM

It is crucial to implement AMR-relevant policies that can help prevent the emergence and spread of diseases in plant populations. Specifically, the FAO, WHO and WOAH guidance highlights the importance of enhancing farm biosecurity, and infection control measures (e.g. good hygiene practices and measures to prevent contamination) (FAO, 2020[154]), as well as the centrality of investing in IPM (FAO/WHO, 2019[155]). While the effects of these interventions in crop production on AMR transmission are largely unknown, they are expected to yield largely positive impacts for AMR by reducing the need for antimicrobial use in plant production.

The FAO further recommends the uptake and scale-up of IPM approaches to supplement other efforts that aim to support healthy crop production. The FAO defines IPM as an approach to crop production and protection that brings together strategies to grow healthy crops (FAO, 2020[154]). By emphasising healthy crop production, IPM aims to minimise economic losses for crops while minimising risks for people and the environment caused by using pesticides (FAO/WHO, 2019[155]). Though limited, available evidence is in accordance with the FAO guidance. For instance, one recent study evaluated IPM systems across 24 countries in African and Asian regions over two decades and found that the IPM projects were associated with a nearly 41% increase in the yield of crops and an accompanying 31% decline in pesticide use (Pretty and Bharucha, 2015[149]).

Policies to tackle AMR in agri-food systems

Policy interventions

- Building robust food safety compliance systems.
- Scaling up integrated AMR surveillance.

Key messages

- The Hazard Analysis and Critical Control Point (HACCP) system, a popular food safety compliance approach, can help reduce the burden of foodborne illness including food-related AMR, by supporting the focused implementation of food hygiene standards.
- Evidence from OECD countries demonstrates that the introduction and robust enforcement of regulations that are aligned with international food hygiene and safety standards can help enhance the effectiveness of HACCP systems.
- National AMR surveillance can help systematically monitor antimicrobial residues in foodstuffs.

Food plays an increasingly important role in the spread of AMR worldwide. It is estimated that almost 1 in 10 people globally fall ill after eating contaminated food, and roughly 420 000 deaths are attributed to foodborne diseases (FBDs) every year (Havelaar et al., 2015[156]). An important cause of concern is that the most common microbial agents causing FBD outbreaks are becoming drug-resistant, including norovirus, *Campylobacter* spp. and *Enterobacteriaceae*, a Gram-negative bacteria family composed of *E. coli, Klebsiella, Salmonella* or *Shigella* (Smith and Fratamico, 2016[157]). In recognition, the Codex Alimentarius Commission, the lead in setting reference food standards worldwide, sets out a wide range of standards, guidance and codes of practice that, collectively, aim to prevent the emergence of AMR and minimise its transmission in the food supply chain (FAO, n.d.[158]).

Food-producing animals and crops that carry resistant pathogens may eventually contaminate the food supply at any point in the farm-to-fork chain. In recognition, the AMR policies discussed earlier in relation to animal and plant health are instrumental in reducing AMR transmission in agricultural production. Supplementing these policies, it is crucial to build and scale up food safety compliance systems, which have been shown effective in interrupting AMR transmission in the food supply chain.

Scaling up food safety compliance systems

The introduction and scale-up of food safety compliance systems is an important strategy to halt AMR transmission in the food supply chain. One commonly deployed preventive approach to food safety is the HACCP management system. The HACCP system entails identifying specific hazards associated with all stages of food production and implementing measures to address them to ensure food safety (FAO, 1997[159]). By intervening in all stages of food production, the HACCP system aims to prioritise the prevention of foodborne disease while reducing over-reliance on end-product testing (FAO, 1997[159]). It considers several inter-governmental codes of practice put forward by different international organisations, including the World Trade Organization (WTO), the WOAH and the Codex Alimentarius Commission.

Typically, the introduction of the HACCP system entails the application of seven essential principles pertaining to food handling including (FAO, 1997[159]):

1. Conduct a hazard analysis to identify the potential sources of hazards across all stages of food production.
2. Identify the critical control points and procedures to eliminate or minimise the likelihood of occurrence of hazards that have been identified.
3. Establish critical limits to ensure targets concerning critical control points are met.
4. Establish a monitoring system to track performance with respect to critical control points.
5. Establish corrective actions, which would be pursued if the critical control point targets are not met.
6. Establish verification procedures to ensure the HACCP system is working as intended (e.g. supplementary tests).
7. Establish record-keeping procedures to ensure proper documentation of the agreed procedures and their application.

In recent years, some OECD countries started incorporating the implementation of the HACCP system in their AMR national action plans (Box 5.13).

Box 5.13. Japan's mandatory HACCP system in its food industry

In 2016, Japan reported a HACCP coverage rate of 30% in small- and medium-sized food business operators (FBOs), in comparison to the full coverage rate in France, the United Kingdom and the United States (MUFG, 2016[160]). The same year, the Japanese Ministry of Health, Labour and Welfare announced the nationwide introduction of the HACCP system covering the entire food chain adapted to Japan's unique needs.

The introduction of Japan's mandatory HACCP legislation came at a time when public concerns were rising over the risks of foodborne diseases (MHLW, 2016[161]). At this time, an analysis of the state of food safety in Japan identified that most cases of food contamination in the country could be attributed to the lack of proper implementation of good hygiene practices (e.g. maintenance and sanitation of establishments/equipment). In recognition, the Japanese Government proposed a new set of regulations that were more aligned with international food hygiene and safety standards (MHLW, 2016[161]). Today, this initiative is regarded as an important demonstration of Japan's willingness to achieve high standards of food safety, as well as its inclination to expand its exports of foodstuffs.

A notable aspect of Japan's food safety reform relates to the role of HACCP in Japan's 2016-20 National Action Plan on AMR. Unlike many other settings, Japan explicitly embedded the reinforcement of the implementation of HACCP in food processing and distribution establishments as a way to reduce occurrences of food poisoning and contamination of foodstuffs with antimicrobial-resistant organisms is explicitly embedded in its AMR mitigation strategy (Government of Japan, 2016[162]).

Source: MUFG (2016[160]), "The imminent mandatory implementation of HACCP in Japan", https://www.murc.jp/english/report/quarterly_journal/qj1604_07/ (accessed on 21 January 2021); MHLW (2016[161]), *Summary of the Final Report on the Implementation of Mandatory HACCP Program in Food Industry Adopted by the Ad Hoc Panel on International Standardization of Food Hygiene Control*, https://www.mhlw.go.jp/english/topics/foodsafety/consideration/dl/summary_of_the_final_report.pdf; Government of Japan (2016[162]), *National Action Plan on Antimicrobial Resistance (2016-2020)*, https://www.mhlw.go.jp/file/06-Seisakujouhou-10900000-Kenkoukyoku/0000138942.pdf.

Though limited, available evidence suggests that HACCP systems are effective in interrupting AMR transmission in the food supply chain. Several earlier studies demonstrated that microbial contamination on kitchen surfaces and in food products was significantly reduced following the implementation of HACCP-based systems in food service establishments (Roy et al., 2016[163]; Soares et al., 2013[164]; Cenci-Goga et al., 2005[165]). Evidence emerging from other settings also shows similar improvements. For instance, one recent study showed that, in Thailand, slaughterhouses that implemented a HACCP food management system achieved reductions in *Salmonella* occurrence, as well as serotype numbers and serotype diversity (Wu et al., 2019[166]). Another study from the United States found that the publication of a pathogen reduction and HACCP rule in 1996 by the Food Safety and Inspection Service proceeded with an overall reduction in *Salmonella* occurrence on meat and poultry products between 2000 and 2018, though the study was unable to quantify the level of reduction in *Salmonella* occurrence attributable to the introduction of this rule (Williams et al., 2020[167]).

Scaling up integrated AMR surveillance

Integrated AMR surveillance can help systematically monitor antimicrobial residues in foodstuffs. Data generated through integrated surveillance can help facilitate the development and implementation of evidence-based policies and inform decisions around resource allocation to activities that curb the spread of AMR through the food chain. These surveillance systems must collate data using clearly defined and harmonised methodologies that can facilitate the comparison of results not only within each country but also across countries.

There are several good practice examples from OECD countries that established integrated AMR surveillance systems including the food chain. For example, in Denmark, the Danish Integrated Antimicrobial Resistance Monitoring and Research Programme (DANMAP) also collects data not only from humans and animals but also from food products. Regional veterinary and food control authorities gather food samples from wholesale and retail outlets during their routine inspections for monitoring *Salmonella* and *Campylobacter* spp. or at the request of DANMAP to monitor enterococci and *E. coli* (Hammerum et al., 2007[168]). Importantly, information gathered through various resources are made available to the public through annual reports (DANMAP, 2020[169]). In the United States, the National Antimicrobial Resistance Monitoring System (NARMS) for enteric bacteria is the public health surveillance system that monitors AMR among enteric bacteria through data collected from humans, retail meats and food animals (CDC, 2022[170]) by multiple partners that play complementary roles, including the CDC, the U.S. Food and Drug Administration and the U.S. Department of Agriculture, among others. Specifically, each month, *Salmonella, Campylobacter, Enterococcus* and *E. coli* isolates are sent by health departments and universities in 19 states that participate in the sampling of retail meats to the Food and Drug Administration NARMS for serotyping, antimicrobial susceptibility testing and genetic analysis (CDC, 2022[170]).

Policies to tackle AMR in the environment

Policy interventions

- Implementing measures to safely dispose of and remove antibiotics from the environment.
- Upgrading municipal wastewater treatment facilities.
- Improving wastewater management in pharmaceutical manufacturing facilities.

- Improving waste management in agricultural production.
- Improving waste collection and management in healthcare settings.
- Encouraging proper pharmaceutical waste disposal in households.

Key messages

- Upgrading technologies used in municipal wastewater treatment facilities can help reduce AMR transmission in the environment but none of these technologies can completely eliminate resistant bacteria and genes in their entirety.
- In agricultural production, investing in integrated waste and manure management in the continuum of production can help reduce the likelihood of AMR transmission in the environment.
- In healthcare settings, waste management, coupled with antimicrobial inventory control measures and environmental risk assessments offer a promising avenue for interrupting AMR transmission.
- Drug take-back programmes can help curb the inappropriate disposal of antimicrobials in households.

The environment can contribute to AMR through several pathways, though important gaps in knowledge exist. The environment can act as a transmission route for resistance by the way of water and soil systems (e.g. sewage systems, faecal contamination of water and pollutants that exert selective pressure for developing resistance) (Keen and Montforts, 2011[171]). The environment can also serve as a reservoir of resistant pathogens because many resistant genes have their origins in bacteria that live in the environment (Keen and Montforts, 2011[171]; Bengtsson-Palme, Kristiansson and Larsson, 2017[172]). In addition, horizontal gene transfers are another prominent resistance mechanism in the environment, particularly for most Gram-negative bacteria (Keen and Montforts, 2011[171]). However, relatively little is known about these biological processes, both in terms of transmission and evolution of resistance (Larsson et al., 2018[173]). Mirroring this, evidence is limited in terms of the effectiveness of technological, social, economic and behavioural interventions that can curb the emergence and spread of AMR through environmental channels (Larsson et al., 2018[173]).

The role of the environment as a contributing factor to AMR is increasingly acknowledged. In recent years, global and regional bodies are putting a spotlight on the role of environmental systems on AMR in line with the One Health approach. For instance, the 2017 United Nations Environmental Program (UNEP) Frontiers report noted that AMR is among the leading emerging issues of environmental concern with global implications (UNEP, 2017[174]). More recently, OECD analysis explored the role of pharmaceuticals, including antibiotics, in the environment and provided policy recommendations (Box 5.14). The rest of this section looks at available evidence in line with these recommendations.

Box 5.14. OECD Studies on Water *Pharmaceutical Residues in Freshwater: Hazards and Policy Responses*

Previous OECD analysis proposed four strategies to manage pharmaceuticals in the environment, including antimicrobials (OECD, 2019[125]). Specifically, the OECD analysis concluded that preventive measures that intervene early in a pharmaceutical's life cycle may yield the greatest long-term societal return. Specifically, the OECD analysis highlights the importance of the following:

1. Improvements in monitoring and reporting on the occurrence, fate, toxicity, and human health and ecological risks of pharmaceutical residues in order to lay the ground for pollution reduction policies. This approach also entails considering the inclusion of environmental risks in the risk-benefit analysis of the authorisation of new pharmaceuticals, and risk intervention and mitigation approach for pharmaceuticals with high environmental risk.
2. Implementing source-directed approaches, such as the sustainable design and procurement of pharmaceuticals, to prevent the release of pharmaceutical residues into water bodies.
3. Introducing use-orientated approaches, such as disease prevention, improved diagnostics and restrictions on pharmaceuticals with high environmental risk, to reduce inappropriate and excessive consumption of pharmaceuticals.
4. Implementing end-of-pipe measures, such as advanced wastewater treatment, public collection schemes for unused pharmaceuticals and education campaigns, to safely dispose of and remove pharmaceutical residues.

Source: OECD (2019[125]), *Pharmaceutical Residues in Freshwater: Hazards and Policy Responses*, https://doi.org/10.1787/c936f42d-en.

Upgrading municipal wastewater treatment plants

Wastewater is one prominent pathway through which antimicrobials are disseminated into the environment. Aquatic environments are amongst the most important reservoirs of antimicrobial-resistant agents and bacteria. Specifically, wastewater is a particular concern. Globally, only about 20% of wastewater that is directly discharged into the environment is treated (FAO, 2018[175]). Wastewater also plays an important role in agricultural production across the world, with at least one in ten people consuming food from plants that are irrigated with wastewater (WHO/WOAH/FAO, 2018[176]). Samples collected from wastewater from influent and effluent in municipal wastewater treatment plants (WWTPs), industrial and agricultural production sites and health facilities point to elevated levels of antibiotic-resistant bacteria (e.g. *E. coli*, *Klebsiella* spp., *Shigella* spp., *Salmonella* spp., *Vibrio* spp., *Acinetobacter* spp. and *Enterococcus* spp.) and genes (Fouz et al., 2020[177]). The final effluent discharged into the environment from these sites can contaminate the receiving water bodies if antimicrobial-resistant agents and bacteria are not removed completely (OECD, 2019[125]).

Upgrading WWTPs can help interrupt the transmission of AMR in the environment but available technologies offer different levels of removal efficiencies (OECD, 2019[125]; Shekhawat, Kulshreshtha and Gupta, 2020[178]). For instance, one study from England (United Kingdom) collected data from 20 WWTPs and found that terminal ultraviolet (UV) light treatment technology was the most effective option to reduce the levels of E. coli, while secondary and tertiary treatment yielded lower levels of reduction (Raven et al., 2019[179]). Importantly, this study concluded that even the most stringent treatment options such as tertiary treatment including UV light fell short of eradicating extended-spectrum B-lactamase producing *E. coli* (ESBL-EC) from most wastewater effluent samples. Another study from 16 urban WWTPs in 10 European countries found that lower levels of antibiotic-resistant genes were released into the environment in WWTPs that were equipped with secondary clarifiers (Cacace et al., 2019[180]).

WTTPs provide a readily accessible avenue for AMR surveillance and monitoring. With the advent of new sequencing technologies, samples from WWTP outflows have been suggested as another avenue for monitoring the detection of new and circulating antibiotic resistance genes (Raven et al., 2019[179]; Larsson et al., 2018[173]). For instance, one study used metagenomic analyses and ribosomal ribonucleic acid (rRNA) sequencing on samples from 32 WWTPs influents in 17 major Chinese cities and detected 381 different genes that were resistant to almost all antibiotics (Su et al., 2017[181]). Importantly, these genes were shared extensively across cities with no apparent geographic clustering. Another study in Norway deployed whole-genome sequencing to demonstrate that the same ESBL-EC type was shared in recreational waters, wastewater in close proximity to a WWTP and urine samples collected from humans residing in the same area (Jørgensen et al., 2017[182]).

Wastewater management in pharmaceutical manufacturing facilities

In countries with large antibiotic production capacity, a particular concern for AMR transmission relates to the release of the compounds generated during the manufacturing process into the environment. One well-documented example comes from India – one of the world's leading manufacturers of antibiotics. In the city of Hyderabad, one of India's most populous cities, alarmingly high levels of ciprofloxacin were detected in the effluent samples collected from a WWTP that served 90 bulk pharmaceutical manufacturers (Larsson, de Pedro and Paxeus, 2007[183]). Notably, all of the bacteria detected in this WWTP were multidrug resistant and high levels of resistant genes were detected in the surface water in downstream rivers up to 17 km from the WWTP site (Kristiansson et al., 2011[184]). Samples from the groundwater and drinking water in nearby villages were shown to contain a variety of pharmaceuticals (Fick et al., 2009[185]). In response, the Indian Government announced in 2020 a new bill that consisted of restrictions on the level of residue from 121 common antibiotics that can be disseminated into the environment from pharmaceutical manufacturers (EPR, 2020[186]).

Even in settings where regulatory frameworks are in place, wastewater management in pharmaceutical manufacturing sites remains a concern. For instance, one recent study in the United States collected samples from 20 WWTPs and found that the concentration of 33 pharmaceuticals was significantly greater in WWTPs linked to pharmaceutical production sites, compared to those that were not connected to similar facilities (Scott et al., 2018[187]). In Europe, the European Medicines Agency considers environmental risk assessment of new pharmaceuticals before the required authorisations can be complicated before entry into the market (OECD, 2019[125]). Yet, antibiotic-resistant microorganisms have been observed in European water bodies that receive a discharge from pharmaceutical production sites (Nappier et al., 2020[188]).

In the face of these challenges, it is paramount to promote co-operation and collaboration across different stakeholders to develop industry standards for the management of waste/wastewater in manufacturing facilities and to achieve high rates of compliance among manufacturers. To this end, in 2020, the WHO published practical guidelines for pharmaceutical manufacturers, inspectors and national regulatory bodies for handling antimicrobial waste and/or process effluents from pharmaceutical processes (WHO, 2020[189]). Concurrently, many pharmaceutical companies are making efforts to develop and implement industry standards for the environmental management of the manufacturing process of antibiotics (Box 5.15).

Box 5.15. AMR Industry Alliance framework for assessing the environmental impact of manufacturing

In recent years, a number of private sector coalitions proliferated to scale up efforts to tackle AMR in manufacturing sites. One of these coalitions is the AMR Industry Alliance, a broad consortium of companies and associations. Members of the AMR Industry Alliance are estimated to represent about one-third of the global antibiotic supply and almost half of the AMR-relevant products currently under clinical development. The AMR Industry Alliance commits its members to an industry roadmap (Tell et al., 2019[190]), which promotes:

- Reducing the environmental impact of the production of antibiotics.
- Helping ensure antibiotics are used only by patients who need them.
- Improving access to current and future antibiotics, vaccines and diagnostics.
- Exploring new opportunities for open collaborations between industry and the public sector.

In 2018, the members of the AMR Industry Alliance published a framework for managing antibiotic discharge in manufacturing sites, with the aim of minimising the environmental impact of manufacturing. This framework delineates minimum requirements to carry out risk evaluation, lays out a methodology for evaluating risks as well as risk-based targets for antibiotic discharge from manufacturing sites of about 120 antibiotics (AMR Industry Alliance, 2020[191]). These targets are meant to be used by all antibiotic manufacturing companies, as they establish their own targets for antibiotic residue in wastewater from their plants. By 2020, about 80% of AMR Industry Alliance members have reportedly assessed risks in their manufacturing sites against the new industry targets and 82% indicated that they either met or partially met the minimum requirements (AMR Industry Alliance, 2020[191]).

Moving forward, the most recent progress report of the AMR Industry Alliance makes recommendations towards accelerating efforts to make surveillance data publicly available, which includes information on infection rates, AMR patterns and antibiotic use, supports local health system and laboratory capabilities for the diagnosis and treatment of drug-resistant infections and fosters partnerships with other stakeholders (AMR Industry Alliance, 2020[191]).

Source: Tell, J. et al. (2019[190]), "Science-based targets for antibiotics in receiving waters from pharmaceutical manufacturing operations", https://doi.org/10.1002/ieam.414; AMR Industry Alliance (2020[191]), *2020 Progress Report*, https://www.amrindustryalliance.org/wp-content/uploads/2020/01/AMR-2020-Progress-Report.pdf.

Waste management in agricultural production

Agricultural production has important consequences for AMR transmission in the environment, with impacts in magnitudes comparable to WWTPs and healthcare facilities. In farm settings, veterinary antibiotics are disposed into the environment through animal waste, animal excrete re-used as manure and runoff from animal waste storage and disposal tanks (FAO, 2018[175]; Nappier et al., 2020[188]; Hoelzer et al., 2017[120]). Additionally, wastewater from livestock production is widely utilised in the form of organic fertilisers and soil conditioners. These pathways through which veterinary antibiotics enter the environment have important implications for AMR transmission. For instance, one study that collected samples from wastewater across 96 countries showed that the abundance of antimicrobial-resistant genes from swine and poultry farms was three to five times that of the magnitude observed in hospital and municipal wastewater (He et al., 2020[192]). This study also showed that wastewater samples collected from cattle and fish farms had similar levels of antimicrobial-resistant genes compared to those collected from hospitals and WWTPs.

In recognition, several livestock waste treatment technologies can be considered to mitigate the role of livestock waste in environmental contamination, including anaerobic digestion, thermophilic or mesophilic composting, biological treatment process and constructed wetlands (He et al., 2020[192]). Similar to the technologies used in WWTPs, each livestock waste treatment technology comes with a different set of advantages and caveats, and their efficiency may depend on the local operating conditions and manure type. Importantly, none of them guarantees that antibiotic-resistant bacteria and genes are eliminated from livestock waste in their entirety.

Importantly, investments in waste management technologies should be made in accordance with local needs and conditions. In their multi-country study, He et al. (2020[192]) suggested that the level of abundance may be correlated with the intensity with which antibiotics are used in agricultural production, as well as the resulting concentration of residual antibiotics. For instance, this study showed that the highest absolute abundance of antimicrobial-resistant bacteria was observed in samples collected from livestock waste in China, the largest producer and consumer of antibiotics in the world. However, this study found that country-level aggregate data on antibiotic use may mask important realities at the farm-level antibiotic use. For instance, He et al. (2020[192]) also compared *tet* in swine wastewater in Shandong, China, and the state of Colorado in the United States, two countries with comparable levels of country-aggregated antibiotic use. This study concluded that the abundances of antimicrobial-resistant genes were higher in Shandong than in Colorado, suggesting that it is important to keep in mind the site-specific chemical and physical conditions that contribute to differences in the growth of antimicrobial-resistant bacteria and the propagation and attenuation of antimicrobial-resistant genes.

The WHO, WOAH and FAO promote integrated manure management practices in the continuum of manure use, from collection to storage and treatment before re-application as fertiliser or disposal. In many farms, animal excrete is re-used as manure as a way to support food and feed production in farms (WHO/WOAH/FAO, 2018[176]). However, the application of manure is associated with significant increases in the diversity and abundance of antimicrobial-resistant genes in the soil, with abundance in manured soil is estimated to reach up to 28 000 times that of the abundance in un-manured soil (He et al., 2020[192]). While the contribution of manure to total fertiliser use has been on a decline, manure remains a key input into agricultural production in many LMICs, particularly in Africa (84%) and Latin America (73%) regions (FAO, 2018[175]). In recognition, the WHO, WOAH and FAO provide guidance for countries to aid efforts to optimise manure management practices in their own settings by improving the ways in which manure is stored, treated, handled and disposed of (WHO/WOAH/FAO, 2018[176]).

Waste collection and management in healthcare settings

According to WHO estimates, about 15% of healthcare waste is considered hazardous, which may contribute to spreading drug-resistant microorganisms in the environment (WHO, 2017[193]). Despite this, globally, 40% of health facilities lack systems that can ensure the safe disposal of healthcare waste where antibiotic-resistant microorganisms may be present (WHO/WOAH/FAO, 2018[176]).

Even so, available evidence on the role of healthcare settings in AMR transmission in the environment remains mixed. To date, elevated levels of antimicrobial-resistant agents and genes have been reported in hospital effluent wastewater samples and water bodies receiving untreated hospital waste (Hocquet, Muller and Bertrand, 2016[194]; Fouz et al., 2020[177]). In contrast, one recent study from ten European countries found that effluent from hospitals represented only around 0.2-2% of the total wastewater in urban settings and that the number of hospitals and hospitalised patients did not correlate with the amount of antibiotic-resistant genes released from WWTPs in urban areas (Cacace et al., 2019[180]). Similarly, another study from 20 WWTPs across the East of England (United Kingdom) region showed that there were no statistically significant differences in ESBL-EC counts between samples taken from WWTPs that directly received waste from acute care hospitals and those that did not (Raven et al., 2019[179]). Taken together, these findings suggest that the role of healthcare facilities in AMR transmission into the environment may be closely related to the unique circumstances in each setting.

The selection of optimal wastewater management strategies in healthcare settings depends largely on whether these facilities are connected to a WWTP system. The WHO recommends that in cases where antimicrobial waste from a healthcare facility goes directly into a WWTP, decentralised wastewater treatment at that health facility may not be necessary (WHO/WOAH/FAO, 2018[176]). In line with this recommendation, one study from Switzerland showed that the introduction of early separation and onsite treatment of wastewater in hospitals led to lower levels of emission of contaminants of emerging concern to the environment, including pharmaceuticals (EAWAG, 2007[195]). However, this study also found that the annual operational cost of this decentralised wastewater system was considered high and that this strategy fell short of offering a more cost-effective option than upgrading centralised municipal WWTP. In comparison, the WHO recommends that if wastewater from a health facility does not go to a central WWTP, then pre-treatment at the health facility is needed to ensure reductions in pathogens and AMR (WHO/WOAH/FAO, 2018[176]). In these cases, the WHO indicates that the choice of wastewater treatment technology should optimise for minimising AMR release and not rely on conventional waste treatment technologies.

Efforts to optimise waste management in healthcare settings can be bolstered by antimicrobial inventory control measures. The WHO recommends that antimicrobial waste should be kept separate from other waste, encapsulated, buried, incinerated or returned to manufacturers (WHO/WOAH/FAO, 2018[176]). Waste minimisation techniques can also be considered, whereby inventories for high-use pharmaceuticals, including antimicrobials, can be maintained, and antimicrobials with short expiration dates may be redistributed to other health facilities in the area where there may be a need. In recent years, OECD countries are introducing novel approaches to integrating environmental considerations into other aspects of efforts to minimise the role of the health sector in the AMR burden (Box 5.16).

Box 5.16. Integrating environmental considerations to the promote prudent use of antibiotics in Sweden

In 1996, Sweden introduced a new regulation that stipulated that each healthcare region in the country should establish at least one Drug and Therapeutics Committee that is responsible for developing guidelines and recommendations that promote the prudent use of antibiotics. In 2000, the Stockholm Healthcare Region published the "Wise List" which provides recommendations for the use of 212 essential medicines that are used across different levels of care in the public and private sectors including primary care and hospitals spanning 24 therapeutic areas (Regional Drug Expert Consortium, 2011[196]). The list also includes non-pharmacological advice for certain therapeutic areas and recommendations tailored to reflect case severity and comorbidities. Starting from 2008, adherence to Wise List recommendations was linked to provider payment for prescribers in primary care (Eriksen et al., 2017[197]).

A novel aspect of the Wise List is that it classifies pharmaceuticals in line with their potential impact on the environment. This approach explicitly recognises that pharmaceuticals can remain in the environment long after their initial use, especially in water resources. In doing so, Wise List recommendations aim at minimising environmental risks attributable to the use of pharmaceuticals in healthcare settings. For each pharmaceutical substance, the environmental risks are examined both in terms: i) environmental hazard, defined as the capacity to cause damage to the environment (i.e. persistence, bioaccumulation and toxicity); and ii) environmental risks, referred to as the risks of toxicity to the aquatic environment (Eriksen et al., 2017[197]).

Evidence suggests that adherence to Wise List recommendations for prescribers in the Stockholm Healthcare Region increased from 75% to 84% between 2000 and 2015, with variation across different practice types (e.g. primary care versus hospitals) narrowing over time (Eriksen et al., 2017[197]). One explanation for this finding relates to the highly transparent process through which Wise List recommendations have been developed. This process involved input from various stakeholders including clinicians, clinical pharmacologists, pharmacists and nurses based on a review of existing scientific evidence (Eriksen et al., 2017[197]). Compounding the beneficial impact of this process was the use of evidence-based guidelines in combination with an effective communication strategy and continuous medical education opportunities.

Source: Regional Drug Expert Consortium (2011[196]), "The 'Wise List'- A comprehensive concept to select, communicate and achieve adherence to recommendations of essential drugs in ambulatory care in Stockholm", https://doi.org/10.1111/j.1742-7843.2011.00682.x; Eriksen, J. et al. (2017[197]), "High adherence to the 'Wise List' treatment recommendations in Stockholm: A 15-year retrospective review of a multifaceted approach promoting rational use of medicines", https://doi.org/10.1136/bmjopen-2016-014345.

Pharmaceutical waste disposal in households

Inappropriate disposal of antimicrobials in households remains an important pathway through which antibiotics are disseminated into the environment. While quantifying the precise magnitude of this challenge is difficult, recent estimates suggest that about 10-50% of medicines are disposed of by households through sinks and bathrooms (OECD, 2019[125]). When not properly discarded or eliminated during wastewater treatment, antibiotics can enter aquatic environments and promote resistance even in small doses (Tong, Peake and Braund, 2011[198]).

In response, many OECD countries are rolling out drug take-back programmes but the evidence is lacking in terms of their effectiveness for curbing AMR. For instance, all EU members are obligated to implement medicine collection and disposal schemes for unused medicines in their countries (HCWH-Europe, 2013[199]). But the ways in which drug take-back programmes are implemented in each EU country vary. In Sweden, the Swedish Pharmaceutical Society spearheads a government-funded, national programme for the safe disposal and destruction of unused medications, in conjunction with wholesalers and community pharmacies (Persson, Sabelström and Gunnarsson, 2009[200]). In other countries like Belgium, Canada, France and Spain, collection schemes are funded in accordance with the Extended Producer Responsibility principle, whereby pharmaceutical companies are required to collect and destroy unused medicines that they produce (OECD, 2019[125]). The scope of medicines covered by these schemes also differs across countries. While most drug take-back programmes focus only on pharmaceuticals used in human medicine, others, like Portugal's national collection system, have extended their scope to include veterinary medicines (HCWH-Europe, 2013[199]).

Emerging lessons

This chapter presented an overview of the current state of evidence on AMR in line with the One Health framework. Looking across countries and policies to address AMR, several important lessons emerge:

- **In human and animal health, flexible AMR policies that aim to create an enabling work environment that promotes prudent use of antimicrobials achieve similar levels of improvements in antibiotic prescribing behaviours compared to restrictive policies that limit the opportunities for using antibiotics**. In human health, the WHO guidance indicates that restrictive interventions that limit the opportunities for antimicrobial prescriptions may result in relatively quick gains in prudent antibiotic prescribing behaviours. But, over time, these interventions achieve similar levels of improvement in prescribing behaviours compared to interventions that deploy persuasive strategies (e.g. education and feedback interventions) that aim to induce behavioural change by enabling a professional environment that promotes prudent prescribing behaviours (WHO, 2019[20]). Importantly, supporting restrictive interventions with persuasive ones was shown to improve the effectiveness of restrictive policies. In animal health, available evidence suggests that regulations that allow the use of antibiotics for therapeutic purposes may be just as effective as bans on all types of antibiotics used in food-producing animals (Tang et al., 2019[123]). Similarly, limitations on antimicrobial growth promoters should be prioritised, as these restrictions have been shown to yield substantial reductions in AMR burden. This is in line with the previous OECD analysis that recommends flexible regulations and stepwise adjustments at the farm level.

- **Getting input and buy-in from key stakeholders (e.g. healthcare providers, veterinarians, farmers) in the design and implementation of AMR policies improves the effectiveness of these policies**. The process of designing and implementing AMR policies entails interactions across stakeholders from multiple sectors with diverse interests, influences and positions towards each policy option (e.g. healthcare providers, veterinarians, farmers and pharmaceutical manufacturers, local and national regulatory bodies). Getting buy-in from these stakeholders can help improve the likelihood that the policy objectives will be achieved. In human health, the chapter found evidence that embedding provider feedback interventions in persuasive ASP strategies yielded greater compliance with ASP guidelines. In animal health, the chapter highlighted evidence from Denmark and Sweden, which demonstrated that co-operation across farmers, veterinarians and local and national regulatory bodies were paramount to successfully eradicating the use of antimicrobial growth promoters. Concerning AMR transmission in the environment, the chapter showed that the involvement of pharmaceutical manufacturers has played an important role in supporting national and international efforts to develop industry standards to curtail the adverse effects of industrial production on AMR transmission.
- **The effectiveness of AMR policies may change over time, necessitating modifications in the design and implementation of these policies to address evolving needs in a given setting**. The chapter showed that, in countries with long-standing vaccination programmes, the beneficial effects of high rates of vaccination coverage have been shown to accrue over time. Conversely, the chapter found evidence that the removal of an effective AMR intervention may threaten gains achieved over time. This was the case in Canada where a temporary re-introduction of Ceftiofus in 2007 was followed by a rise in the prevalence of resistant bacteria in animals and humans. Relatedly, even when an intervention is effective at the outset, the beneficial effects may be attenuated over time. These changes in the effectiveness of AMR policies highlight the importance of tracking the performance of these policies over time and introducing modifications in their design and implementation to reflect the evolving health needs in a given context.
- **Even when AMR interventions are effective, unintended consequences may occur**. For instance, in the United Kingdom, the rollout of a mobile application that aimed to improve access to antibiotic guidelines was associated with improvements in the fraction of antibiotic prescriptions in compliance with the existing guidelines, while also leading to declines in the completeness of documentation of prescriptions (Charani et al., 2017[32]). In South Korea, the launch of a national programme that separated dispensing from prescribing of antimicrobials led to improvements in the appropriate prescription of antibiotics but this programme also prompted a rise in medical expenditures, partly due to increases in provider fees (Park et al., 2005[64]). Taken together, these findings suggest that it may be beneficial to consider the potential effects of AMR policies before they are rolled out – including potential effects that may not necessarily be the main intent of the intervention – and attempt to pre-empt negative consequences.
- **Improving the availability and accessibility of information from novel data sources offers an important avenue for supporting rigorous evaluations of AMR policies in line with the One Health framework**. Welcome news is that the analytical basis that evaluates the impact of

AMR interventions has grown since the previous OECD analysis. Despite this, many systematic reviews and meta-analyses underline the urgent need for higher-quality studies. One important factor that hinders rigorous policy evaluations relates to the dearth of systematically collected data. In recognition, data collected from global AMR surveillance networks (e.g. the Global Antimicrobial Resistance and Use Surveillance System) offer a valuable avenue for systematic data collection. In addition, other novel data sources can be considered, including: data collated from HAI surveillance networks; data gathered through computerised decision support systems and e-prescribing tools; data collected during veterinary visits to farms; and samples collected from WWTPs. Combined, these data sources can help support efforts to design and implement effective policies to stem the AMR tide.

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6 Cost-effectiveness of interventions relevant to tackling antimicrobial resistance

This chapter reports findings from modelling the health and economic impact of scaling up 11 policy interventions to tackle antimicrobial resistance (AMR) consistent with the One Health approach. The selected interventions aim to optimise the use of antibiotics in human health, to promote AMR awareness and understanding and to reduce the incidence of infections in healthcare settings, farms and food establishments. In addition, the chapter reports the impact of three policy packages designed to address the most pressing policy gaps on AMR. The results are presented for 34 countries, including 29 European Union (EU)/European Economic Area (EEA) countries and Japan, Switzerland, Türkiye, the United Kingdom and the United States. The chapter concludes by discussing the implications of the findings.

Key findings

Policies to tackle AMR reduces deaths and the burden of diseases

- The OECD model shows that healthcare-based interventions, including antimicrobial stewardship programmes (ASPs), improving hand hygiene and enhancing environmental hygiene are expected to yield the greatest health gains, producing, on average, 71 000-153 000 life years (LYs) gained each year if resistant infections were eliminated across the 34 countries included in the analysis.
- ASPs are estimated to result in the greatest gains in terms of the number of averted AMR-related deaths. On average, this intervention is estimated to prevent more than 10 000 deaths per year across the 34 countries included in the analysis if resistant infections were eliminated and more than 3 200 deaths if resistant infections were replaced by susceptible ones. This is equivalent to preventing around 10-30% of deaths due to tuberculosis (TB), influenza and human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) in 2020 (or the nearest year for which this information is available).

Policies to tackle AMR can reduce pressure on hospital resources, generate substantial savings in health expenditure and produce gains in workforce productivity

- All of the modelled interventions promise to have a significant impact on the use of hospital resources. ASPs promise the greatest reduction in the extra days spent in hospitals, with the estimated reduction ranging from more than 3.7 million fewer days annually if resistant pathogens were to be eliminated and 822 000 fewer hospital days if resistant infections were replaced by susceptible infections. This would be equivalent to freeing up the entire acute bed capacity in Ireland in 2020 for nearly 1 year by eliminating resistant infections and around 2 months if resistant infections were replaced by susceptible infections.
- All modelled interventions are expected to result in savings in health expenditure. Across the 34 countries included in the analysis, enhancing environmental hygiene is estimated to yield the greatest amount of savings in health expenditure amounting to more than USD 7.1 billion per year adjusting for purchasing power parity (PPP) by eliminating both resistant and susceptible infections. Following this intervention, improving hand hygiene and scaling up ASPs are associated with expected reductions in health expenditure exceeding USD PPP 6 billion and USD PPP 3.9 billion per year respectively.
- Enhancing environmental hygiene practices can generate almost USD PPP 6.4 billion annually in productivity gains, which measures the combined effect of changes in the participation in the workforce and workforce productivity. Improving hand hygiene and scaling up ASPs can potentially yield more than USD PPP 5.2 billion and USD PPP 3.9 billion respectively.

Benefits of implementing policies to tackle AMR as part of a package more than make up for their implementation costs

- Countries can achieve greater return on their investments by combining single interventions into a package of interventions. Investing in a hospital-based package can produce an average gain of more than 511 000 LYs and 618 000 disability-adjusted life-years (DALYs) per year across the 34 countries included in the scope of the analysis. Every year, savings in health expenditure by scaling up this package is estimated to be around USD PPP 11 billion across the countries included in the analysis. These estimated savings in health expenditure is roughly equivalent to half of all health spending in the Czech Republic in 2020. The estimated gains in productivity can exceed USD PPP 14.9 billion if the hospital package was scaled up to desired levels.

- A mixed package that combines policy interventions in human health and food sectors also promises health and economic gains. A mixed package is expected to result in a gain of more than 466 000 LYs and 556 000 DALYs every year across all countries included in the analysis. This package will potentially lead to USD PPP 9.4 billion in savings in health expenditure and USD PPP 13.8 billion in productivity gains.
- A community-based package is estimated to produce relatively smaller but crucial health and economic benefits. This package is predicted to produce more than 262 000 LYs and 308 000 DALYs annually, save countries more than USD PPP 5.3 billion in health expenditure and result in USD PPP 8.4 billion in productivity gains.
- Benefits that can be accrued by upscaling each policy package substantially exceed their implementation costs. The average cost of implementation of the mixed package is around 5 times lower than the estimated benefits accrued through reductions in health expenditure and gains in productivity combined. The cost of the hospital-based package is around 4.7 times lower than its potential benefits, whereas the benefits associated with the scale-up of the community-based package are 2.5 times that of the cost of scaling up this intervention.

It is vitally important to continue to shore up effective policies in line with the One Health approach

Evidence presented in Chapters 3 and 4 underlines the vital importance of continued action to stem AMR. Chapter 3 demonstrated that AMR continues to pose significant health and economic burden across the OECD and EU/EEA countries included in the analysis. This chapter showed that infections caused by resistant organisms could claim around 79 000 lives each year across the 34 countries included in the analysis. Further, it showed that without new policy action, AMR can cost around USD PPP 28.9 billion annually to health systems across the OECD and EU/EEA countries included in the analysis. Subsequently, Chapter 4 found that important progress has been made in recent years in scaling up policies to effectively tackle AMR. Though important gaps remain in the implementation of AMR policies, particularly those aiming to optimise the use of antibiotics, policies to reduce the incidence of infections in various settings including healthcare facilities, farms and food establishments and increase AMR awareness and understanding in the general public and among health professionals. Even in countries where the AMR agenda is more advanced, the design of the AMR policies often does not reflect the best practices and international standards and the implementation is limited to select localities. Exacerbating these challenges, the existing enforcement mechanisms do not always guarantee a high degree of compliance. Combined, findings emerging from earlier chapters suggest that it is paramount to continue to invest in policies to tackle AMR through multi-sectoral action.

Considering these findings, it is important to assess the effectiveness and cost-effectiveness of scaling 11 interventions that can be implemented in the human health and non-human sectors up to the desired levels of health and economic outcomes (Box 6.1). The chapter also quantifies the return on investing in these policies. While the majority of interventions that were selected to be modelled for the purposes of this chapter target the human health sector, the cost-effectiveness of interventions in food safety and agriculture was also examined. The interventions modelled in the scope of this chapter were selected using three criteria:

- Consistency with the interventions whose implementation is recommended by the World Health Organization (WHO) Global Action Plan on AMR (2015[1]) and prioritised by OECD and EU/EEA countries in their action plans.
- Difference between the current and desired level of implementation of each intervention across OECD and EU/EEA countries.
- Availability of high-quality quantitative evidence on the effectiveness of each intervention at the individual level that could be used as inputs to the OECD Strategic Public Health Planning for AMR (SPHeP-AMR) model.

The chapter starts by summarising the design features of the 11 modelled interventions. Next, it presents results that show the estimated health and economic impact of scaling up each intervention when implemented first separately and then as part of a package in which multiple interventions are scaled up at the same time. The chapter concludes by discussing the implications of the key findings.

Box 6.1. Quantifying the return on investment of policy interventions to tackle AMR using the OECD SPHeP-AMR model

The effectiveness and cost-effectiveness estimates of policy interventions modelled in this chapter were generated by deploying the OECD SPHeP-AMR model described in Box 3.1 in Chapter 3. The OECD SPHeP-AMR model recognises whether a policy intervention will work in a given setting and the magnitude of its potential effectiveness is highly sensitive to contextual factors such as the demographic and epidemiological profile of each country, local treatment costs and cost of implementation. When quantifying the potential effectiveness of each policy intervention, the OECD model integrates these factors into its framework by modelling interventions across four key parameters:

- **Intervention effectiveness at the individual level:** Parameter values are extracted based on systematic reviews and meta-analyses in the existent literature whenever possible. In cases where evidence is taken from single studies, randomised controlled trials were prioritised over observational studies.
- **Intervention effectiveness over time:** A growing body of literature on AMR-relevant policies suggests that the effectiveness of public health interventions may change over time, with some interventions having larger observable effects in the earlier phase of implementation and waning effects over time. In the OECD analysis, it is assumed that the modelled interventions continue to receive investments over time (e.g. repeated training, regular updates to mass media campaigns, etc.) to ensure that their effectiveness remains constant over the simulation period.
- **Intervention coverage:** This parameter involves identifying population groups that are eligible to be covered by the modelled intervention and the level of exposure to the intervention at the outset. For the modelled interventions that have not yet been implemented in the countries included in the analysis, the coverage in the business-as-usual scenario was set to zero. For other interventions that have already been implemented in some capacity, the coverage in the business-as-usual scenario was selected based on information extracted from studies that use data from the 2020-21 Tripartite AMR Country Self-Assessment Survey (WHO/FAO/OIE, 2021[2]), as well as the 2019 Hand Hygiene Self-Assessment Framework (de Kraker et al., 2022[3]) and the 2019 Infection Prevention and Control (IPC) Assessment Framework survey (Tomczyk et al., 2022[4]) conducted by the WHO. These surveys were selected to calculate intervention coverage in line with the beginning of the projection period.
- **Implementation costs:** Implementation costs combine: i) programme-level costs associated with administration, training, and other activities; and ii) patient-level costs are associated with individual-level expenditures. Costs were derived using a standardised ingredients-based approach using the WHO Choosing Interventions that are Cost-Effective (WHO-CHOICE) framework (2003[5]) as well as forthcoming OECD publications on infectious diseases that focused on promoting hand hygiene and enhanced environmental hygiene in healthcare services. All costs are expressed in 2020 USD PPP to account for the differences in purchasing power. All costs are calculated from a governmental and healthcare perspective. In effect, this means refers to the assumption that the interventions would be delivered by social health insurance schemes or by hospitals regardless of their ownership status. Costs covered by other agents are excluded from the analysis (e.g. costs for the purchase of personal protective equipment [PPE] bought by farmers in the improved farm hygiene intervention).

Gauging population-level effectiveness and return on investment

The model gauges the population-level effectiveness of the modelled interventions through comparisons against a business-as-usual scenario over time. For the majority of countries, the simulation period is from 2021 to 2050. For a handful of countries, the first year of the simulation ranges between 2015 and 2020 depending on the availability of historical data. Under the business-as-usual scenario, it is assumed that no new AMR-relevant interventions are rolled out throughout the simulation period except for those already in place and the provision of preventive and health services is assumed to remain unchanged. A comparison between the business-as-usual and intervention scenarios yields the impact of an intervention, measured through the differences in health and economic outcomes. The uncertainty around the effectiveness of an intervention is assessed through sensitivity analyses. Combined, results from these analyses are used to quantify the return on investment.

Assessing the effectiveness of modelled interventions using different scenarios

The OECD model recognises that some of the modelled interventions can interrupt the transmission of both susceptible and resistant infections while others are assumed to reduce only the incidence of resistant infections (see below). For interventions that are assumed to target only the resistant infections, results are presented using two scenarios: i) the elimination scenario in which the scale-up of the modelled is assumed to eliminate resistant infections while the burden of susceptible infections remains unchanged; and ii) the replacement scenario whereby resistant infections are assumed to be replaced by susceptible infections.

Note: A detailed description of the OECD SPHeP-AMR model is accessible here: http://oecdpublichealthexplorer.org/sphep-amr-doc/.
Source: WHO/FAO/OIE (2021[2]), *Tripartite AMR Country Self-Assessment Survey (TrACSS) 2020-21*, https://www.who.int/publications/m/item/tripartite-amr-country-self-assessment-survey-(tracss)-2020-2021; WHO (2003[5]), *Making Choices in Health: WHO Guide to Cost-Effectiveness Analysis*, https://apps.who.int/iris/handle/10665/42699; Tomczyk, S. et al. (2022[4]). "The first WHO global survey on infection prevention and control in health-care facilities", https://www.doi.org/10.1016/s1473-3099(21)00809-4.

A host of multi-sectoral policies offers an important means to tackling AMR in line with the One Health approach

Consistent with the Global Action Plan on AMR (WHO, 2015[1]), the OECD analysis groups the modelled interventions into four domains:

1. Policies to optimise the use of antibiotics in human health.
2. Policies in human health to reduce the incidence of infections.
3. Policies to promote AMR awareness and understanding.
4. Policies outside of human health sector to reduce the incidence of infections.

The next section summarises the design features of the modelled interventions and Table 6.1 denotes the key model parameters associated with each intervention (detailed descriptions of the selected interventions are available in Annex 6.A).

Policies to optimise the use of antibiotics in human health

The modelled interventions in this category can be implemented in hospitals and community settings. All of these interventions are built under the assumption that efforts that aim to optimise the use of antibiotics will reduce AMR in the short term, reflecting the evidence emerging from the literature (Lee et al., 2013[6]). It is also assumed that there exists a perfectly elastic relationship between the consumption of antibiotics in human health and AMR in the short term. In effect, this means a 10% improvement in the use of antibiotics can result in a 10% reduction in AMR in the short term. This assertion is based on a handful of studies that quantify the relationship between antibiotic consumption in human health and AMR (Kaier, Frank and Meyer, 2011[7]; FiRe Network, 2004[8]).

- **Strengthening antimicrobial stewardship programmes (ASPs) in human health:** This intervention entails the scale-up of a hospital-based stewardship programme to promote the prudent use of antimicrobials. It involves building multi-disciplinary teams that provide guidance on antimicrobial prescription, coupled with scaling up the monitoring of antimicrobial use and AMR burden in healthcare facilities.

- **Introducing delayed antimicrobial prescribing:** This is a community-based initiative to promote prudent antibiotic prescription. It involves developing or updating clinical guidelines that consider delayed prescribing practices, provider training and education to improve awareness and understanding around best practices in delayed antibiotic prescribing, rollout of a feedback programme to assess prescriber performance over time and the development and distribution of informational materials that serve as best practice reminders.
- **Scaling up the availability of rapid diagnostic tests (RDTs) (C-reactive protein [CRP] testing):** This is a novel community-based programme that aims to increase the use of RDTs by increasing the availability of point-of-care (POC) CRP in ambulatory care settings in line with antibiotic treatment guidelines depending on the CRP levels. In addition, the intervention entails a brief training to disseminate information on the benefits of using POC CRP testing in line with antibiotic prescribing guidelines, dissemination of informational materials for prescribers and monitoring and evaluation of prescribers' adherence to the antibiotic treatment guidelines.
- **Using financial incentives to optimise antimicrobial use:** This is a nationwide pay-for-performance programme with the aim of promoting the prudent use of antimicrobials in community settings. It involves rewarding lump-sum bonus payments corresponding to around 1% of the base salary of prescribers for meeting pre-set prescribing targets. The intervention also includes setting up a monitoring and evaluation mechanism to assess whether the prescribers are meeting their prescribing targets.

Policies in human health to reduce the incidence of infections

Improving hand hygiene and enhancing environmental hygiene practices are considered by the WHO as the Core Components of IPC practices in healthcare settings (WHO, 2022[9]; 2016[10]). Improvements in vaccination coverage have also been increasingly suggested as another crucial strategy to tackle AMR (WHO, 2015[1]). The OECD model assumes that all of these interventions can reduce the incidence of not only resistant infections but also the incidence of susceptible ones.

- **Improving hand hygiene:** This is a hospital-based intervention with multiple components to improve hand hygiene practices in line with the WHO guidelines. It involves ensuring that physical infrastructure (e.g. alcohol dispensers) is accessible throughout health facilities, designating an IPC focal point that is responsible for organising and co-ordinating all educational activities around improving hand hygiene practices, providing training and education opportunities for health workers around best practices in hand hygiene, distributing informational materials and monitoring compliance with hand hygiene practices.
- **Enhancing environmental hygiene practices:** This is a hospital-based multimodal programme to enhance routine cleaning practices. It involves substituting disinfectant products already in use with those that have been shown greater effectiveness in line with the WHO guidance, the introduction of no-touch disinfection methods as part of the terminal cleaning of rooms/areas in between occupying patients, a training programme targeting staff members who are responsible for environmental cleaning in healthcare facilities to teach best practices in environmental cleaning and regular audits of environmental cleaning activities.
- **Increasing coverage of 23-valent pneumococcal polysaccharide vaccines (PVV23):** This is a nationwide community-based campaign of PVV23 targeting 90% coverage across older adults. It involves making sure that there are sufficient stocks of PPV23 in healthcare facilities and disseminating informational materials to ensure high levels of uptake among the target population and setting up a monitoring system to assess the level of vaccine uptake over time.

Policies to promote AMR awareness and understanding

The interventions grouped in this category can be implemented in community settings under the assumption that increasing AMR awareness and understanding can improve behaviours around antibiotic use among prescribers as well as the general public. These interventions also rely on the perfect elasticity assumption between antibiotic consumption in human health and AMR in the short term.

- **Improving health professional training and education:** This is a routine training programme that can be implemented in community settings. Specifically, the modelled intervention aims to improve the communication skills of prescribers, with a particular emphasis on enhancing their proficiency around methods to examine and modify patients' beliefs and expectations around antibiotic use. The modelled intervention also involves setting up a monitoring mechanism to examine whether the training curriculum yields the intended improvements in the communication skills of prescribers.
- **Scaling up mass media campaigns:** This is a nationwide community-based mass media campaign to enhance AMR awareness and understanding in the general population. The campaign is assumed to be carried out annually during the peak flu season when antibiotic consumption reaches its highest levels. Awareness activities are assumed to include developing communication toolkits and key messages targeting a diverse set of mass media outlets (e.g. television, etc.) and making sure that guidelines and recommendations for prudent antibiotic use developed by public health agencies are accessible on line.

Policies outside the human health sector to reduce the incidence of infections

Adopting a One Health framework is considered to be vital to tackling the complex drivers of AMR that span multiple sectors. In recognition, the OECD model looks at the potential impact of two interventions that can be implemented in farms and food establishments. Similar to the interventions in the human health sector that aim to reduce the incidence of infections, it is assumed that the scale-up of these interventions can reduce the incidence of both resistant and susceptible infections.

- **Enhancing farm hygiene:** This is a novel programme that aims to improve the use of PPE in farm settings in accordance with international guidelines. It involves the introduction of a regulatory framework to facilitate the purchase of PPE (e.g. farm boots, work clothes, etc.) that can be used by farmers and technical visitors (e.g. veterinarians). Informational materials like posters and brochures are assumed to be developed. In addition, a monitoring and evaluation mechanism is assumed to be put in place to increase compliance.
- **Enhanced hygiene in food handling:** This intervention is modelled as a hazard analysis and critical control points (HACCP)-based food safety training programme for food service workers in food establishments. It entails routine training sessions by trainers with expertise in HACCP systems and a focus on personal hygiene, food preparation and storage, and the dissemination of informational materials around food safety to reinforce the key lessons from training sessions and routine inspections of food establishments to assess compliance.

Table 6.1. Inputs used to model the selected policy interventions to tackle AMR

	Policies to optimise the use of antibiotics in human health				Policies in human health to reduce the incidence of infections			Policies to promote AMR awareness and understanding		Policies outside of human health sector to reduce the incidence of infections	
	Strengthen ASPs	Delayed antimicrobial prescribing	Scale up RDTs	Financial incentives	Enhance hand hygiene	Enhance environmental hygiene	Improve vaccination coverage	Enhance health worker training	Scale up mass media campaigns	Improve farm hygiene	Improve food handling practices
Setting	Hospital	Community	Community	Community	Hospital	Hospital	Community	Community	Community	Farms	Food establishments
Target population	Health workers	Health workers	Health workers	Health workers	Health workers	Health workers	General population	Health workers	General population	Farm workers and professional visitors	Food service workers
Intervention effectiveness at the individual level	25% decline in antibiotic use	60% decline in antibiotic prescribing	32% reduction in immediate antibiotic prescribing in adults and 46% in children <18 years of age	8% decline in antibiotic prescribing	33% reduction in risk of infection among people who comply with enhanced hand hygiene practices compared to those who do not	26% reduction in risk of infection among people who are exposed to enhanced environmental hygiene practices compared to those who do not	64% decline in the incidence of all serotypes of invasive pneumococcal disease and pneumococcal pneumonia	39% reduction in antibiotic prescribing in comparison to usual care	7% decline in antibiotic prescription	12% reduction in risk of infection among people who use PPE compared to those who do not	28.6% reduction in microbial count
Intervention effectiveness over time	Observed immediately and sustained over time	Observed immediately and sustained over time	Observed immediately and sustained over time	Observed immediately and sustained over time	Observed immediately and sustained over time	Observed immediately and sustained over time	Observed immediately and sustained over time	Observed immediately and sustained over time	Observed immediately and sustained over time	Observed immediately and sustained over time	Observed immediately and sustained over time

	Policies to optimise the use of antibiotics in human health				Policies in human health to reduce the incidence of infections			Policies to promote AMR awareness and understanding		Policies outside of human health sector to reduce the incidence of infections	
	Strengthen ASPs	Delayed antimicrobial prescribing	Scale up RDTs	Financial incentives	Enhance hand hygiene	Enhance environmental hygiene	Improve vaccination coverage	Enhance health worker training	Scale up mass media campaigns	Improve farm hygiene	Improve food handling practices
Intervention coverage (business-as-usual scenario) (%)	21-43	0	0	0	18-54	21-43	10-74	46-56	0	10-50	10-50
Target coverage (%)	80	40	70	70	70	70	90	70	100	70	70
Implementation cost (per capita USD PPP)	0.53 -6	0.06-1.26	0.53-2.15	0.15-8.01	0.02-1.06	0.71-5.06	0.03-0.57	0.05-0.86	0.40-1.36	0.08-0.78	0.02-0.73

Results

Scaling up policy interventions to tackle AMR can prevent thousands of resistant infections every year

All 11 modelled interventions are estimated to reduce the number of infections each year (Figure 6.1). Scaling up ASPs is expected to yield the greatest reductions in the number of resistant infections whereas increasing the coverage of PVV23 is estimated to produce the smallest reductions. The magnitude of the estimated effectiveness of each intervention varies substantially across countries, reflecting the differences in the incidence of resistant infections, variation in the distribution of the type of resistant infections (i.e. community- vs. healthcare-acquired infections [HAIs]) and healthcare system characteristics.

Hospital-based interventions offer the greatest benefits compared to interventions that can be implemented in other settings. For example, scaling up ASPs is estimated to help avoid, on average, more than 298 000 resistant infections per year across the 34 countries included in the analysis. IPC measures such as enhancing environmental hygiene and improving hand hygiene are also highly effective. On average, enhancing environmental hygiene can prevent more than 123 000 resistant infections each year whereas improving hand hygiene is estimated to prevent more than 113 000 infections. It is important to note that the beneficial impact of these two IPC measures goes beyond preventing only resistant infections. The OECD analysis suggests that, in addition to the impact on resistant infections, an average of more than 461 000 susceptible infections can be eliminated per year by improving environmental hygiene. Similarly, enhancing hand hygiene is expected to avoid more than an additional 392 000 susceptible infections every year.

Boosting the implementation of community-based interventions also leads to reductions in the number of resistant infections. Delayed antibiotic prescription is estimated to prevent, on average, more than 279 000 resistant infections each year. Scaling up mass media campaigns, improving prescriber training and education and financial incentives to optimise antimicrobial use are also effective in reducing resistant infections, with the estimated impact ranging from almost 157 000 to 196 000 resistant infections across these interventions. Countries such as the Czech Republic and Luxembourg that have a relatively higher burden of community-acquired infections (see Chapter 3) are poised to make greater gains from investing in these interventions.

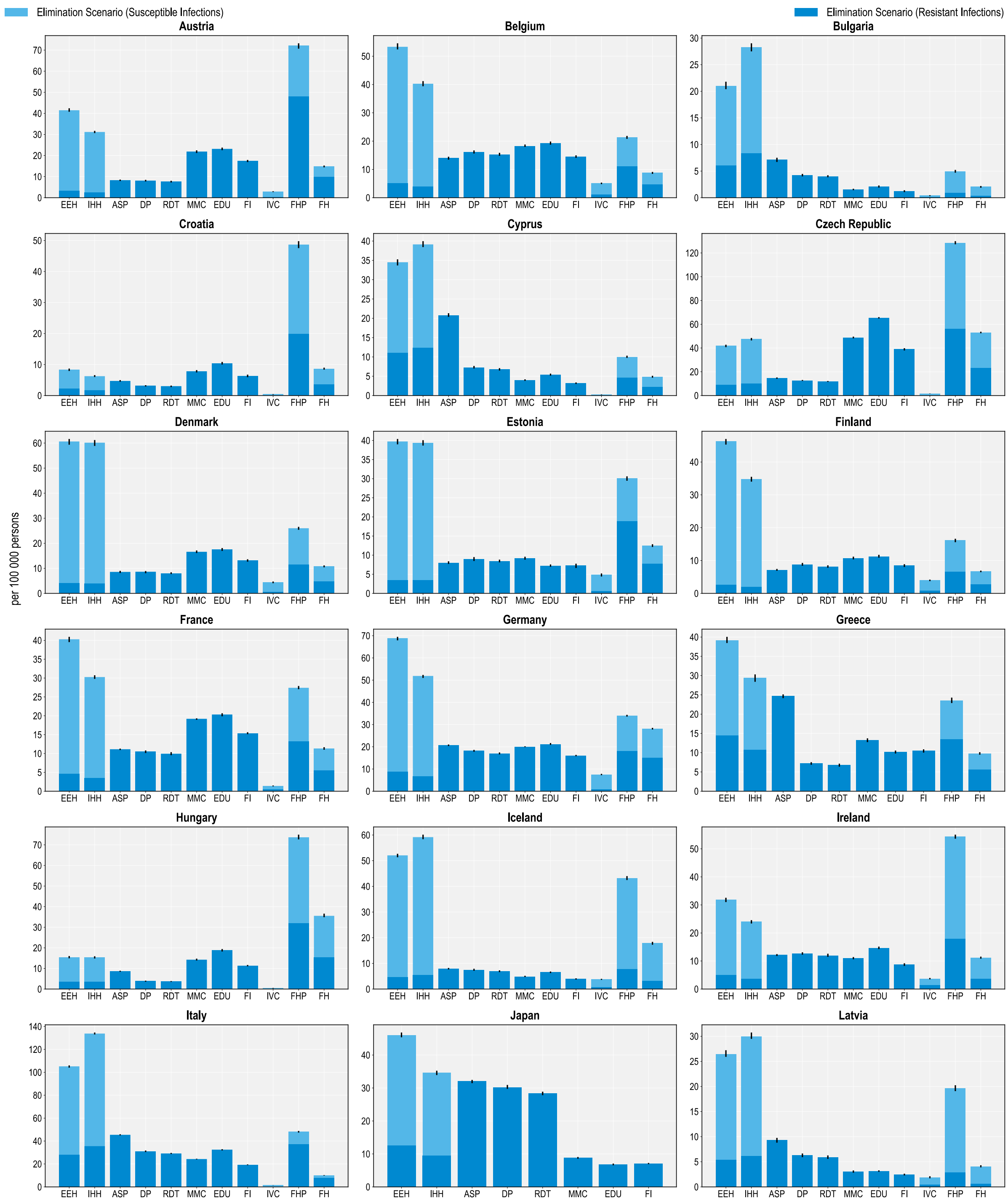
Scaling up the coverage of PVV23 can produce health gains by reducing the number of resistant infections caused by *Streptococcus pneumoniae* (*S. pneumoniae*) among older populations. On average, this intervention is estimated to avert almost 3 000 infections each year across the countries included in the analysis. Importantly, there are notable differences in the effectiveness of PVV23. For instance, Germany stands to make the greatest gains across all of the countries included in the analysis, averting around 7.5 resistant infections per 100 000 persons every year. This corresponds to more than 6 000 resistant infections prevented among the target population reflecting the relatively higher incidence of *S. pneumoniae* compared to the other countries and the low levels of PVV23 coverage among the target population (Bahrs et al., 2021[11]).

The lower impact of PVV23 coverage compared to the other assessed interventions is not surprising given the relatively low incidence of *S. pneumoniae* across the 34 countries included in the analysis (see Chapter 3). While little global evidence reporting the burden of *S. pneumoniae* among the elderly population is sparse, findings from available studies suggest that morbidity and mortality due to *S. pneumoniae* are particularly pressing in non-OECD countries such as those in the WHO African and Eastern Mediterranean Regions (Wahl et al., 2018[12]) and in countries where vaccination coverage against *S. pneumoniae* remains low. Combined, evidence suggests that increasing the coverage of vaccines that target *S. pneumoniae* promises greater benefits in settings with a relatively higher burden of *S. pneumoniae* and lower vaccination rates.

Outside of the human health sector, enhancing food safety and improving farm biosecurity are both associated with reductions in the number of infections, highlighting the importance of the One Health approach. Each year, improving food safety is expected to prevent, on average, more than 424 000 resistant and susceptible infections in humans. Approximately 48% of this attributable reduction would be driven by preventing resistant infections. The Czech Republic and the Slovak Republic stand to achieve the greatest reductions in the number of resistant infections by investing in this intervention, preventing around 139 and 128 resistant infections per 100 000 persons every year. Improving biosecurity in farm settings can also safeguard population health: on average, more than 150 000 infections in humans can be averted through scaling up this intervention, with nearly half of the observed reductions occurring through preventing resistant infections.

Figure 6.1. Antimicrobial stewardship programmes are the most effective modelled policy intervention to avert resistant infections

Number of infections averted per 100 000 persons annually up to 2050



Note: ASP: Antimicrobial stewardship programme; DP: Delayed prescribing; EDU: Education and training of healthcare professionals; EEH: Enhancing environmental hygiene; FH: Farm hygiene; FHP: Food handling practices; FI: Financial incentives; FMS: Improving farm hygiene practice; IHH: Improving hand hygiene; IVC: Increasing vaccine coverage; MMC: Mass media campaigns; RDT: Rapid diagnostic testing capacity.

Source: OECD analysis based on the OECD SPHeP-AMR model.

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Investing in policy interventions to tackle AMR can safeguard population health by preventing thousands of deaths

All 11 modelled interventions are associated with reductions in the number of deaths caused by resistant infections (Figure 6.2). ASPs are estimated to prevent the highest number of deaths. On average, ASPs are estimated to avoid more than 10 000 deaths each year using the elimination scenario and more than 3 200 deaths using the replacement scenario. In other words, scaling up ASPs to the desirable levels across the 34 countries included in the analysis can be equivalent to preventing around 10-30% of deaths due to TB, influenza and HIV/AIDS in 2020 (or the nearest year for which this information is available).

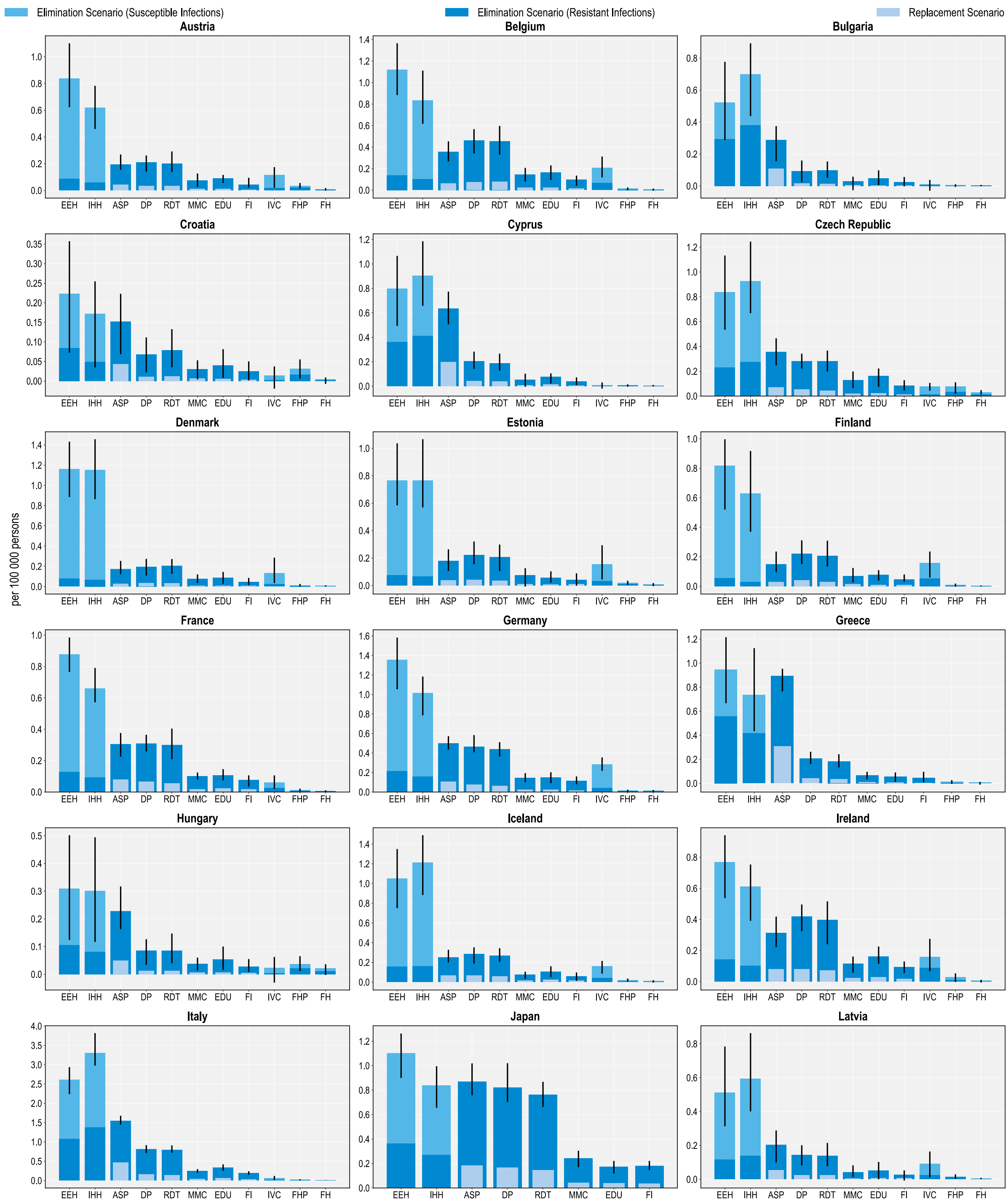
The OECD analysis points to substantial cross-country variation. For example, across the EU/EEA member OECD countries, Italy and Greece can avert, on average, 1.6 and 0.9 deaths per 100 000 persons each year respectively by investing in this intervention, whereas Türkiye can prevent 3.9 deaths per 100 000 persons each year, representing the highest potential gains across non-EU/EEA OECD countries.

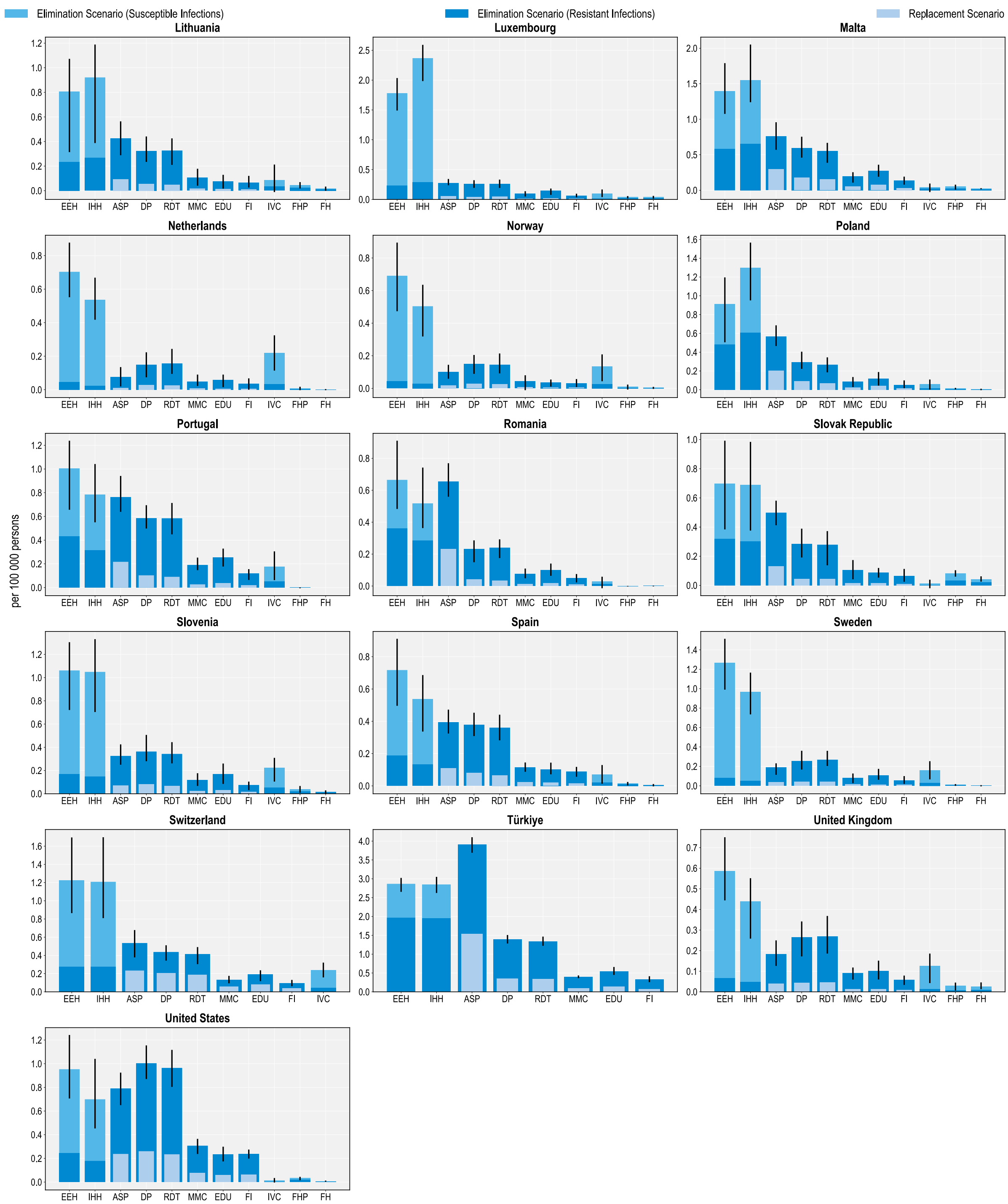
IPC measures are also effective in preventing AMR-related deaths. On average, improving environmental hygiene is estimated to reduce more than 4 800 deaths every year across the 34 countries included in the analysis. Similarly, improving hand hygiene could help avoid more than 4 500 deaths per year. Importantly, improving environmental hygiene and hand hygiene practices can also prevent thousands of deaths each year by eliminating susceptible infections (more than 8 500 and 7 400 deaths respectively). Italy and Luxembourg are the two EU/EEA countries that can avoid the greatest number of deaths due to AMR by investing in these IPC measures. Across the non-EU/EEA member OECD countries, Switzerland and Türkiye are poised to prevent the highest number of AMR-related deaths per 100 000 persons every year by investing in improvements in environmental and hand hygiene practices.

Interventions that can be implemented in community settings also offer a valuable means for reducing AMR-related deaths. Delaying antibiotic prescribing could prevent the greatest number of deaths across all of the community-based interventions. On average, this intervention is estimated to prevent around 7 800 deaths per year under the elimination scenario and nearly 2 000 deaths using the replacement scenario. This is followed by scaling up RDTs, increasing mass media campaigns and improving prescriber education. Increasing vaccination coverage can also help reduce mortality due to AMR. Similar to its relative effectiveness in terms of preventing resistant infections, the impact of this intervention in terms of preventing mortality is estimated to be more modest compared to others in the human health sector due to the relatively low estimated incidence of deaths attributable to *S. pneumoniae* across the countries included in the analysis.

Figure 6.2. All modelled policy interventions can avert deaths due to AMR

Number of deaths due to AMR averted per 100 000 persons annually up to 2050





Note: ASP: Antimicrobial stewardship programme; DP: Delayed prescribing; EDU: Education and training of healthcare professionals; EEH: Enhancing environmental hygiene; FH: Farm hygiene; FHP: Food handling practices; FI: Financial incentives; FMS: Improving farm hygiene practice; IHH: Improving hand hygiene; IVC: Increasing vaccine coverage; MMC: Mass media campaigns; RDT: Rapid diagnostic testing capacity.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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Investing in policies to tackle AMR leads to gain in years of life

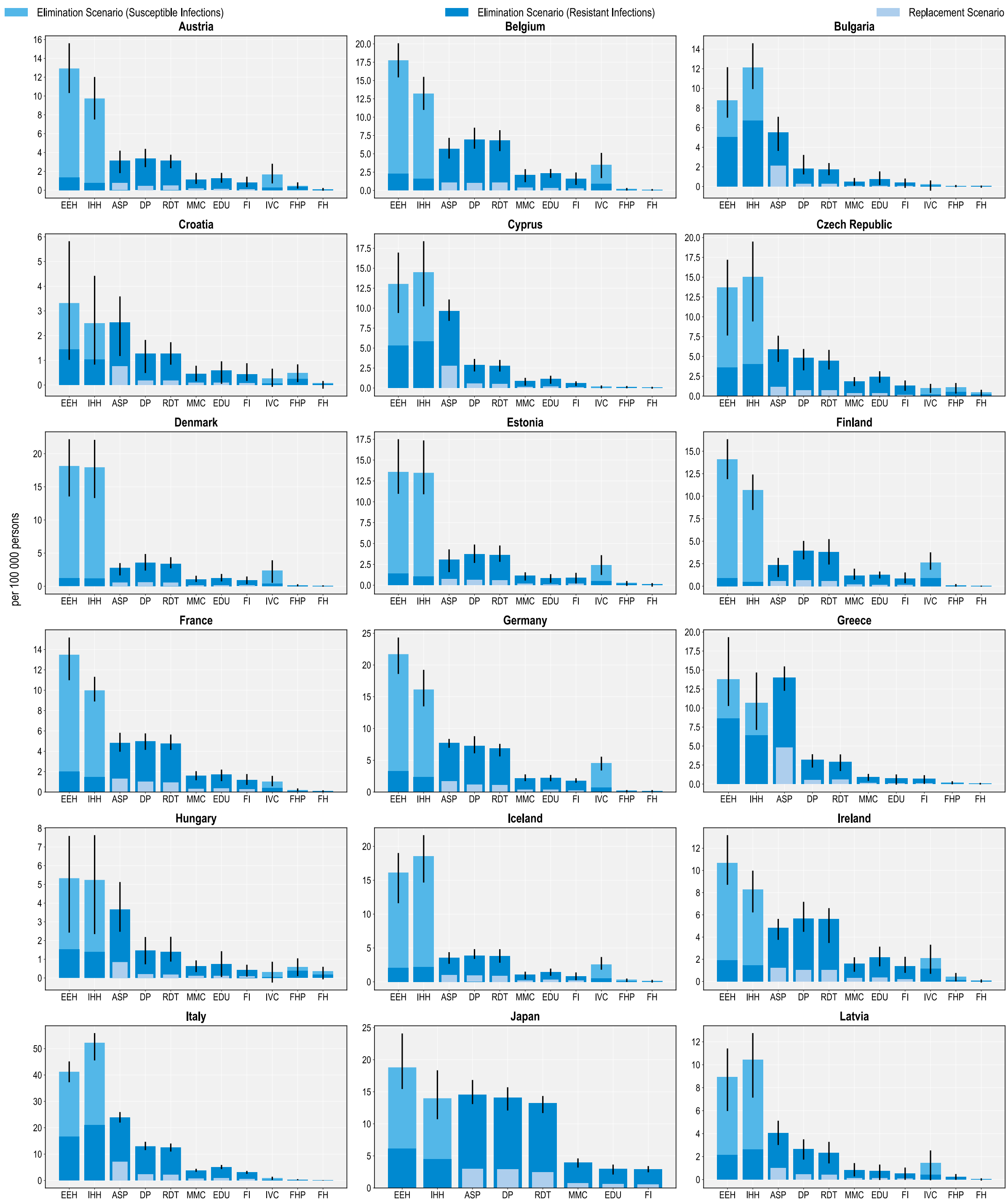
All of the modelled interventions are linked to improvements in the number of LYs lived (Figure 6.3). Similar to their beneficial impact on mortality, interventions to scale up ASPs promise the greatest savings in LYs gained whereas interventions to improve biosecurity practices in farm settings offer the lowest gains. Importantly, the effectiveness of all interventions on morbidity as measured in DALYs surpasses their effectiveness on mortality as measured in LYs gained.

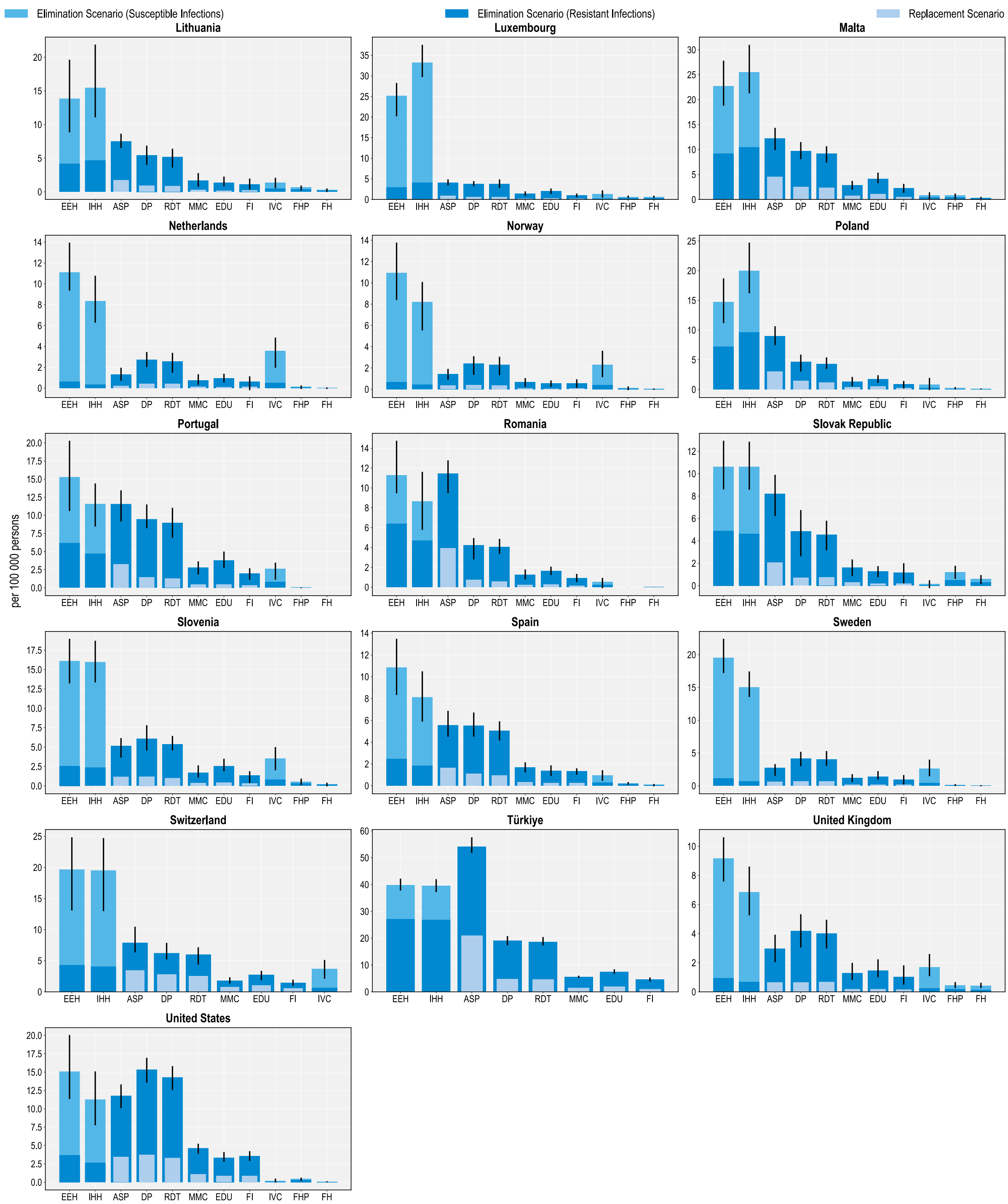
On average, scaling up ASPs is estimated to save more than 153 000 LYs annually using the elimination scenario and more than 47 000 LYs using the replacement scenario. Better environmental hygiene and hand hygiene practices also result in LYs gained by eliminating resistant infections. On average, enhanced environmental hygiene can help save more than 71 000 LYs whereas improved hand hygiene can generate around 67 000 LYs per year. Much like previous health outcomes examined, these interventions can also yield gains in LYs by eliminating susceptible infections.

Delaying antimicrobial prescription is the leading community-based intervention that yields the greatest number of LYs gained. On average, the annual number of LYs gained through this intervention is estimated to exceed more than 121 000 LYs using the elimination scenario and more than 27 000 LYs under the replacement scenario. Scaling up the use of RDTs is the second most impactful intervention in terms of LYs gained. This intervention is associated with more than 114 000 LYs and more than 24 000 LYs gained using the elimination and replacement scenarios respectively. Scaling up mass media campaigns, improving prescriber education and financial incentives also lead to gains in LYs. In comparison, scaling up human vaccination programmes, improving food safety and enhancing biosecurity in farm settings yield the lowest number of LYs gained.

Figure 6.3. All modelled interventions can generate gains in years of life

Number of LYs saved per 100 000 persons annually up to 2050





Note: Countries are sorted in alphabetical order.
ASP: Antimicrobial stewardship programme; DP: Delayed prescribing; EDU: Education and training of healthcare professionals; EEH: Enhancing environmental hygiene; FH: Farm hygiene; FHP: Food handling practices; FI: Financial incentives; FMS: Improving farm hygiene practice; IHH: Improving hand hygiene; IVC: Increasing vaccine coverage; MMC: Mass media campaigns; RDT: Rapid diagnostic testing capacity.
Source: OECD analysis based on the OECD SPHeP-AMR model.

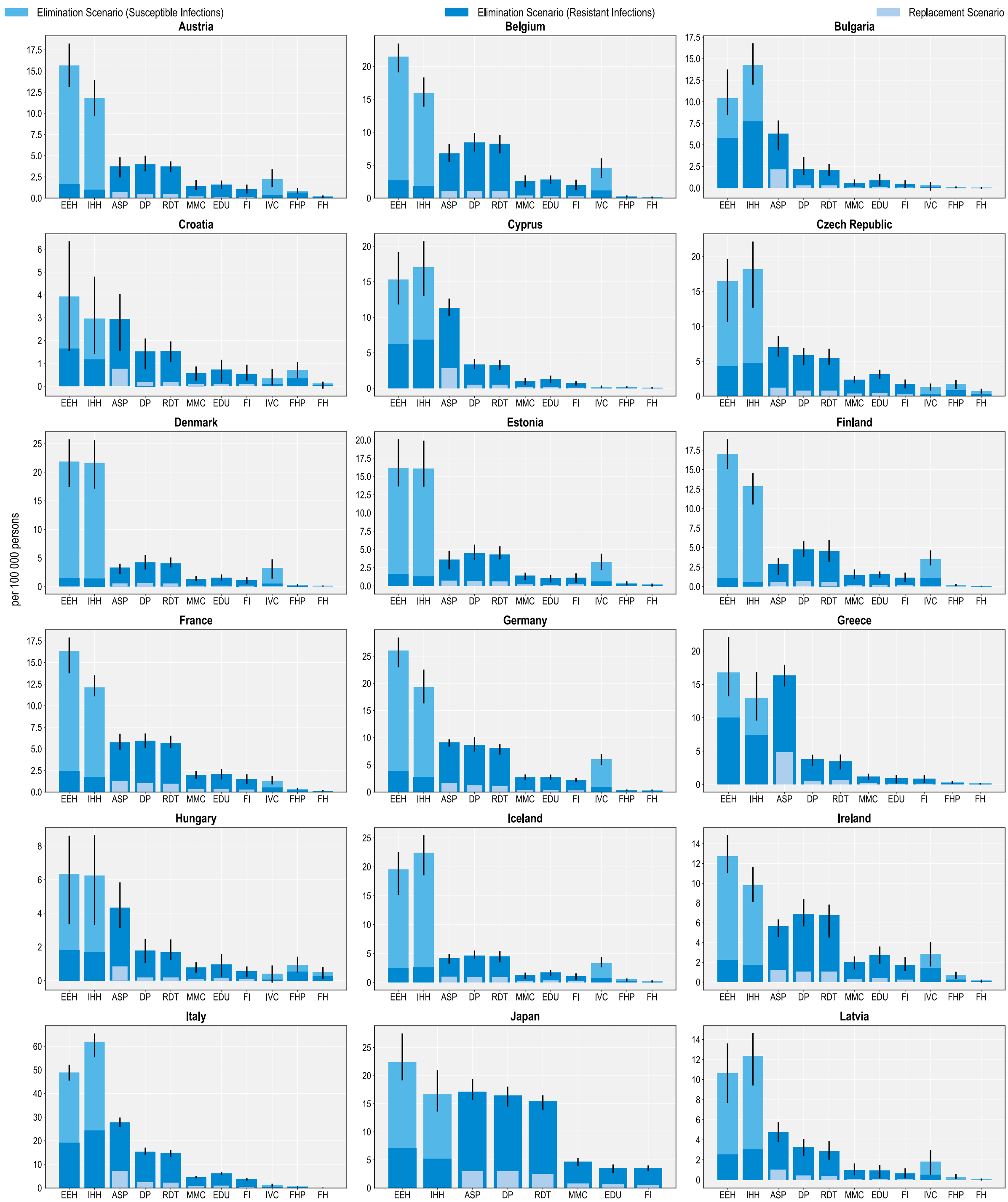
StatLink https://stat.link/c1jkg4

The modelled interventions also yield health benefits as measured in DALYs (Figure 6.4). In a scenario where resistant infections are eliminated, more than 178 000 DALYs would be gained, on average, every year by scaling up ASPs across the countries included in the scope of the analysis. This figure stands at more than 47 000 DALYs if resistant infections were to be replaced by susceptible ones. Improving environmental hygiene and enhancing hand hygiene are also highly effective. For example, improving environmental hygiene promises gains in more than 83 000 DALYs per year by eliminating resistant infections whereas enhancing hand hygiene is estimated to generate more than 78 000 DALYs. Community-based interventions are also associated with estimated health gains, though the magnitude of these gains is smaller than for hospital-based interventions.

These findings suggest that the modelled interventions promise a greater beneficial impact on quality of life than premature mortality. This result is partly due to the finding presented in Chapter 3 that resistant infections pose a greater risk of mortality for the elderly population above 65 years of age than other population groups due to a range of factors such as physiological changes (e.g. weakened immune response) and comorbidities. Even after a successful recovery from a resistant infection, elderly individuals continue being more prone to the competing risks of mortality than younger population groups (e.g. greater risk of HAIs and infections acquired in long-term care settings due to longer time spent in these facilities, etc.) (Nelson et al., 2021[13]).

Figure 6.4. All modelled interventions can yield savings DALYs

Number of DALYs gained per 100 000 persons annually up to 2050



Note: ASP: Antimicrobial stewardship programme; DP: Delayed prescribing; EDU: Education and training of healthcare professionals; EEH: Enhancing environmental hygiene; FH: Farm hygiene; FHP: Food handling practices; FI: Financial incentives; FMS: Improving farm hygiene practice; IHH: Improving hand hygiene; IVC: Increasing vaccine coverage; MMC: Mass media campaigns; RDT: Rapid diagnostic testing capacity.

Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/2yck86

Policy interventions to tackle AMR can reduce the use of hospital resources

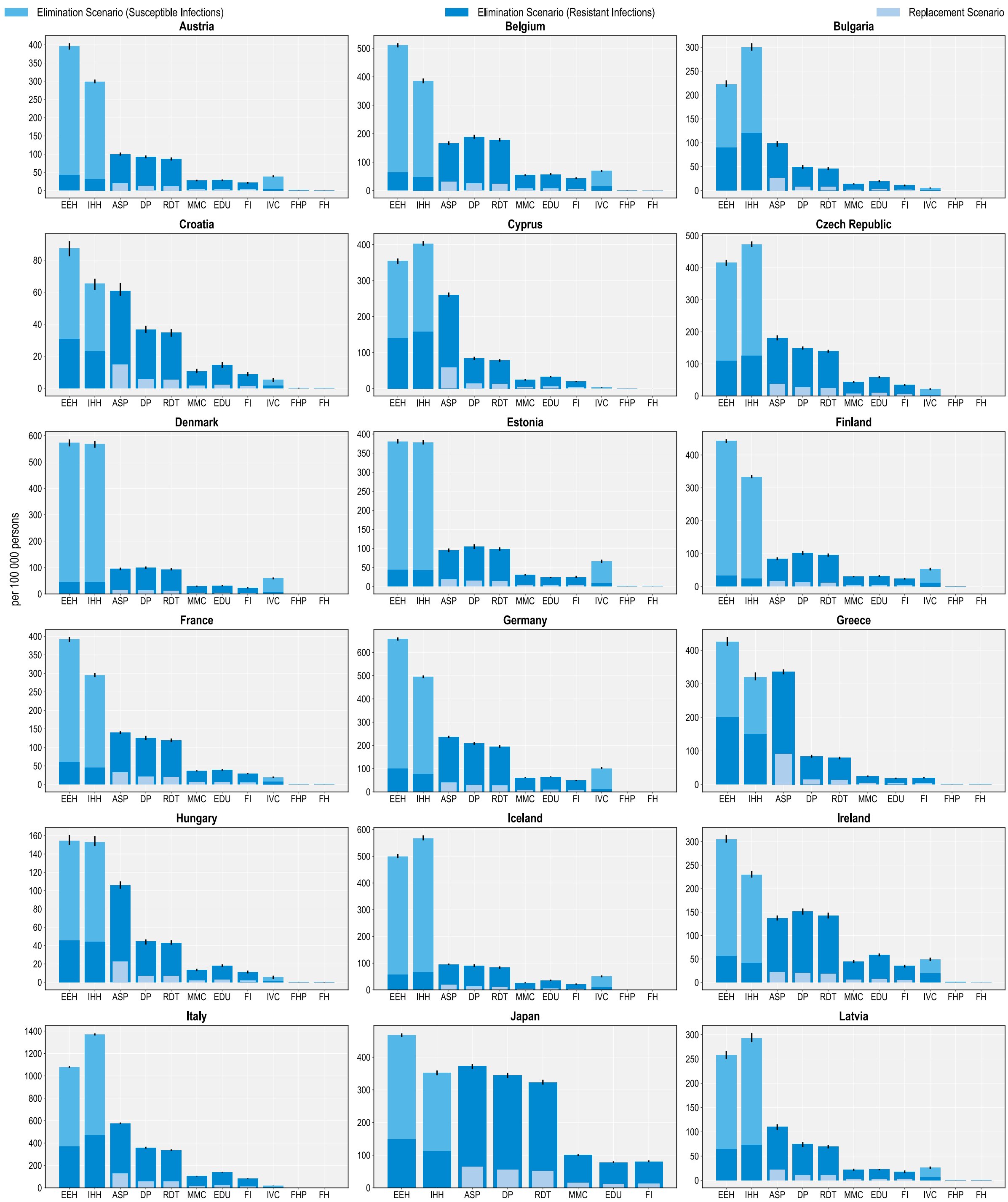
Investing in AMR policies can also help reduce the pressure on hospital resources (Figure 6.5). ASPs promise the greatest number of reductions in the use of hospital resources using both modelling scenarios. On average, this intervention is predicted to result in more than 3.7 million fewer extra days spent in hospital using the elimination scenario and more than 822 000 additional days using the replacement scenario. This would be equivalent to freeing up the entire acute bed capacity in Ireland in 2020 for nearly 1 year by eliminating resistant infections and around 2 months if resistant infections were replaced by susceptible infections.

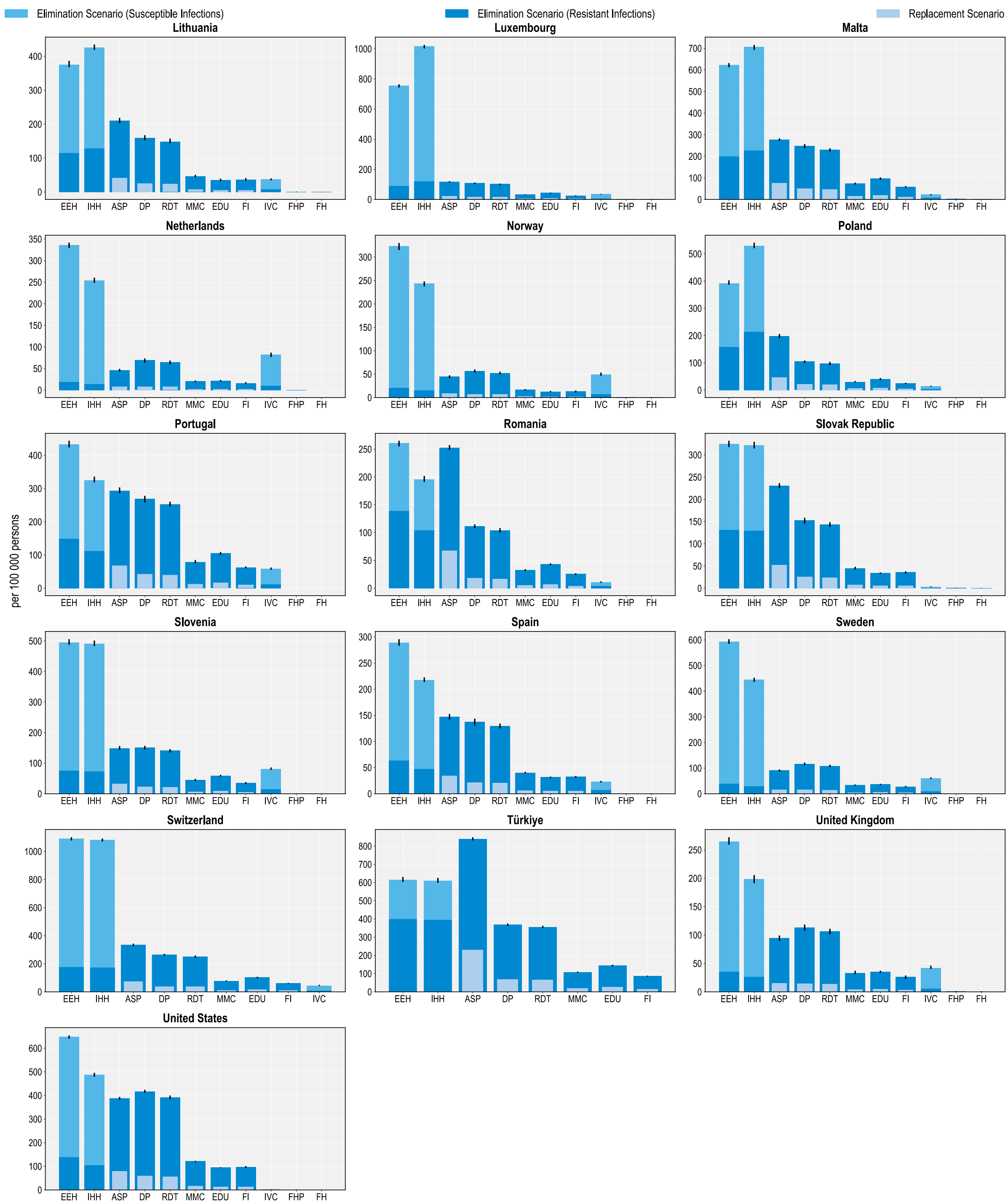
Across EU/EEA member OECD countries, Italy and Portugal are expected to have the largest annual reduction in the number of additional days spent in hospital (576 and 294 additional hospital days avoided per 100 000 persons respectively) whereas Türkiye and the United States can achieve the greatest gains among non-EU/EEA member OECD countries (840 and 388 additional hospital days avoided per 100 000 persons). Investing in better environmental hygiene could prevent nearly 1.7 million additional hospital days by eliminating resistant infections, whereas investing in better hand hygiene would prevent more than 1.5 million extra days spent in hospital due to infections.

Community-based interventions could also contribute to less frequent use of hospital resources. On average, delayed antibiotic prescribing could avert more than 3.1 million additional days spent in hospital if resistant infections are eliminated and avert more than 476 000 additional hospital days if resistant infections were to be replaced by susceptible infections. Following delayed prescribing, greater reliance to RDTs, mass media campaigns, prescriber education and financial incentives also promise non-negligible reductions in the number of extra days spent in hospital due to AMR, with these interventions preventing between nearly 726 000 to more than 2.9 million additional hospital days using the elimination scenario and between more than 111 000 to nearly 450 000 additional hospital days using the replacement scenario.

Figure 6.5. Investing in policies to tackle AMR can reduce additional days spent in hospitals due to treating resistant infections

Number of additional days spent in hospital avoided per 100 000 persons annually up to 2050





Note: ASP: Antimicrobial stewardship programme; DP: Delayed prescribing; EDU: Education and training of healthcare professionals; EEH: Enhancing environmental hygiene; FH: Farm hygiene; FHP: Food handling practices; FI: Financial incentives; FMS: Improving farm hygiene practice; IHH: Improving hand hygiene; IVC: Increasing vaccine coverage; MMC: Mass media campaigns; RDT: Rapid diagnostic testing capacity.

Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/wqz63p

Costs associated with implementing each policy intervention are expected to be offset by reductions in health expenditure and gains in workforce productivity

The OECD analysis demonstrates that implementation costs associated with all of the modelled policy interventions are estimated to be offset by reducing health expenditure while increasing participation in the workforce and improving productivity at work (Figure 6.6). Across the 34 countries included in the analysis, the average implementation annual costs associated with improving hand hygiene are expected to be around 24.6 times lower than the savings generated by estimated reductions in health expenditures and productivity gains made through increased participation in the workforce and productivity at work. Scaling up delayed prescription practices in primary healthcare settings is another highly attractive intervention, with a benefit to cost ratio of around 17. Enhancing food handling practices and improving environmental hygiene practices in healthcare settings are also promising investments. The average annual cost of scaling up each of these interventions across all countries included in the analysis is around five times lower than the expected savings from reducing health expenditure and productivity gains.

As shown in Figure 6.6, using financial incentives to optimise antimicrobial use and ASPs have the highest estimated annual implementation cost per capita (USD PPP 2.6 and 2.3 respectively), followed by enhancing environmental hygiene (USD PPP 2.2) and increasing the use of RDTs (USD PPP 1.3). The costs associated with implementing other interventions each average below USD PPP 1 per capita. There are notable cross-country differences in the cost of policy implementation. For example, across 29 EU/EEA countries, the estimated cost of implementing financial incentives is the highest in Iceland and Luxembourg. Across the non-EU/EEA member OECD countries, the estimated per capita costs associated with financial incentives are the highest in the United States.

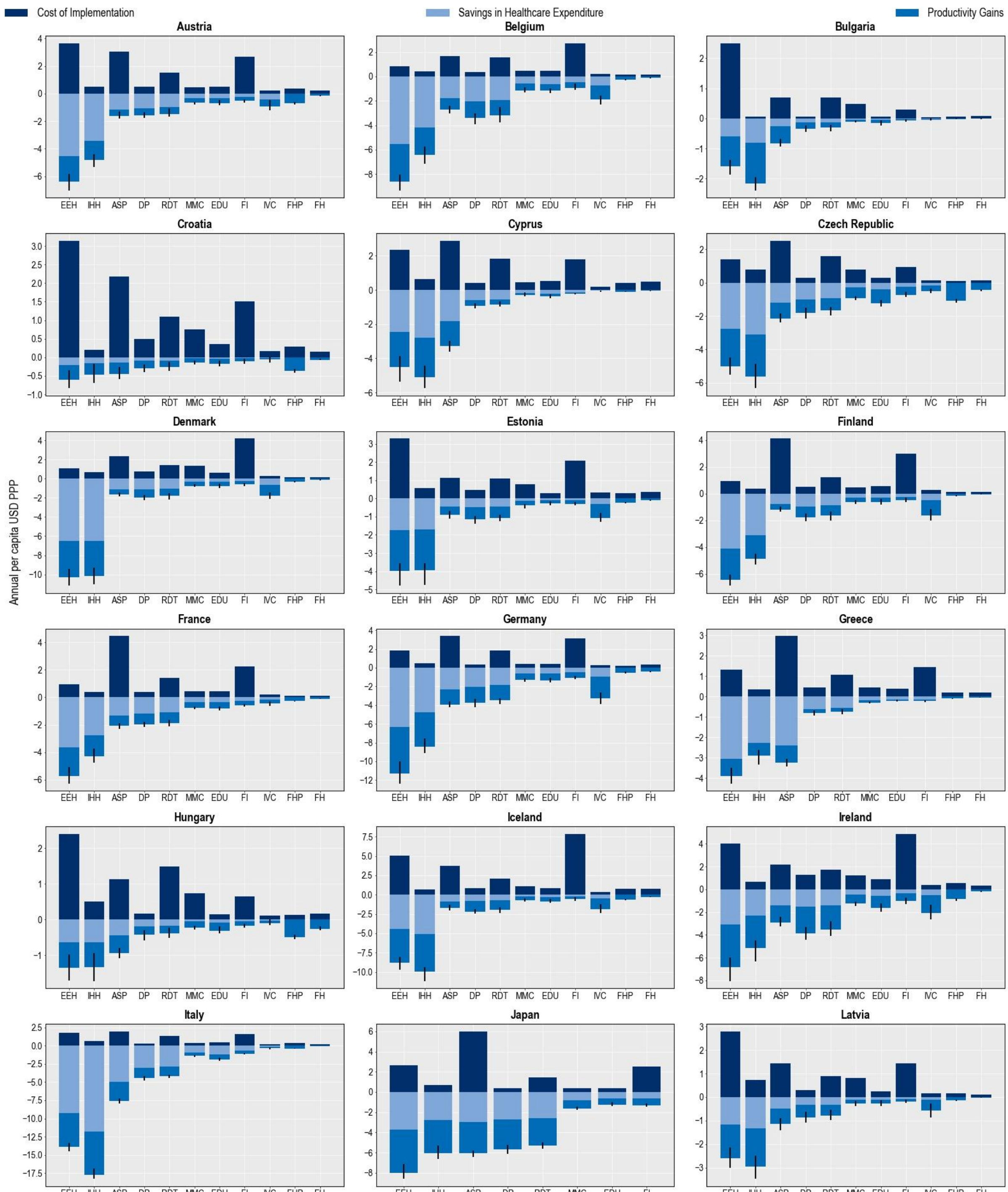
All modelled policy interventions are expected to yield reductions in health expenditure (Figure 6.6). IPC interventions such as improving environmental hygiene and hand hygiene practices promise the greatest impacts by reducing both resistant and susceptible infections. Across the 34 countries included in the analysis, enhancing environmental hygiene and improving hand hygiene in healthcare facilities are estimated to reduce health expenditure by nearly USD PPP 7.2 billion (corresponding to USD PPP 6.3 per capita) and more than USD PPP 6 billion (corresponding to USD PPP 5.3 per capita) respectively. Specifically, the reduction in health expenditure attributable to reducing resistant infections is expected to reach nearly USD PPP 1.4 billion (corresponding to USD PPP 1.2 per capita) and USD PPP 1.2 billion (corresponding to USD PPP 1.1 per capita) by enhancing environmental hygiene and improving hand hygiene respectively.

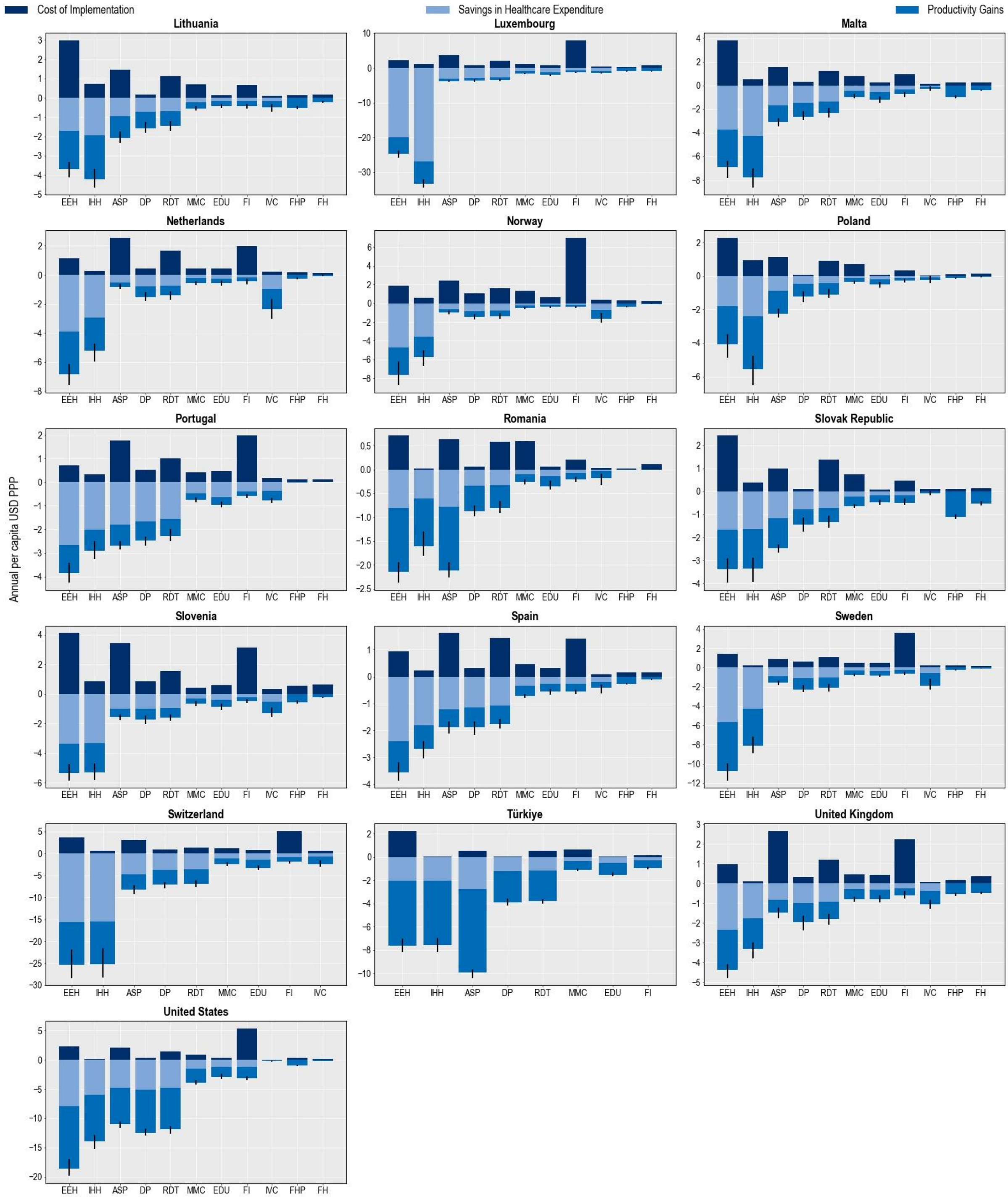
Scaling up ASPs and delayed prescription practices in primary healthcare settings also lead to notable reductions in health expenditure. Ramping up ASPs is expected to reduce health expenditure by more than USD PPP 2.7 billion annually, corresponding to USD PPP 1.2 per capita. This is roughly equivalent to 10% of the health expenditure in Greece in 2020. Whereas implementing delayed prescription practices can result in a decline in health expenditure by USD PPP 2.5 billion every year, corresponding to a USD PPP 1.05 reduction in per capita health expenditure.

Broadly, countries with higher incidences of resistant infections stand to achieve the greatest reductions in health expenditure by investing in the modelled interventions. For instance, as shown in Chapter 3, Italy and Luxembourg are two EU/EEA countries with the highest number of resistant infections every year. By investing in improved hand hygiene practices, Luxembourg can reduce health expenditure by USD PPP 22.6 per capita each year, the highest annual reduction across the EU/EEA countries. This is followed by Italy where the estimated annual reduction in health expenditure is estimated to average at around USD PPP 9.9 per capita.

Figure 6.6. Benefits accrued by scaling up policy interventions to tackle AMR outweigh costs

Cost of interventions and their impact on savings in health expenditure and productivity gains





Note: ASP: Antimicrobial stewardship programme; DP: Delayed prescribing; EDU: Education and training of healthcare professionals; EEH: Enhancing environmental hygiene; FH: Farm hygiene; FHP: Food handling practices; FI: Financial incentives; FMS: Improving farm hygiene practice; IHH: Improving hand hygiene; IVC: Increasing vaccine coverage; MMC: Mass media campaigns; RDT: Rapid diagnostic testing capacity.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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All of the modelled policy interventions yield productivity gains (Figure 6.7). These gains can be achieved primarily through increasing workforce participation, followed by reducing absence from work due to ill health and presenteeism at work. Scaling up ASPs is associated with the highest estimated gains in productivity. On average, this intervention is estimated to generate close to 67 000 full-time equivalents (FTEs) per year combined across the 34 countries included in the analysis. Of these potential gains, more than 56 000 FTEs are expected to be produced through increased participation in the workforce while more than 9 300 FTEs can be gained by reducing absenteeism. Combined, these productivity gains would amount to around USD PPP 3.9 billion (corresponding to USD PPP 3.5 per capita) each year across all of the countries included in the analysis. In many countries, the estimated productivity gains exceed savings in health expenditure.

Figure 6.7. Investing in AMR policies can improve workforce productivity equivalent to adding thousands of full-time workers every year

Number of FTEs gained per 100 000 persons annually up to 2050

Note: ASP: Antimicrobial stewardship programme; DP: Delayed prescribing; EDU: Education and training of healthcare professionals; EEH: Enhancing environmental hygiene; FH: Farm hygiene; FHP: Food handling practices; FI: Financial incentives; FMS: Improving farm hygiene practice; IHH: Improving hand hygiene; IVC: Increasing vaccine coverage; MMC: Mass media campaigns; RDT: Rapid diagnostic testing capacity.

Source: OECD analysis based on the OECD SPHeP-AMR model.

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The impact of AMR policies can be enhanced by implementing them as a package of interventions

In recognition of the complexities surrounding AMR, the OECD analysis looks at the effectiveness of bundling multiple policies into a policy package. Policy packages have several important advantages over implementing single policies. By implementing multiple policies as a package, countries can attempt to address various drivers of AMR at the same time. Further, different population groups can be targeted simultaneously if policies are scaled up simultaneously as part of the same package. In addition, various policies within the same package can facilitate and reinforce desirable changes in behaviour. In turn, these changes could generate protective effects that go beyond simply adding up the effectiveness of each intervention (i.e. super-additivity of policy packages). The results presented in the remainder of the chapter consider the first two advantages of policy packages, though the OECD analysis adopts a conservative approach by refraining from using the super-additivity assumption (i.e. no additional effect is considered).

Three packages were assessed:

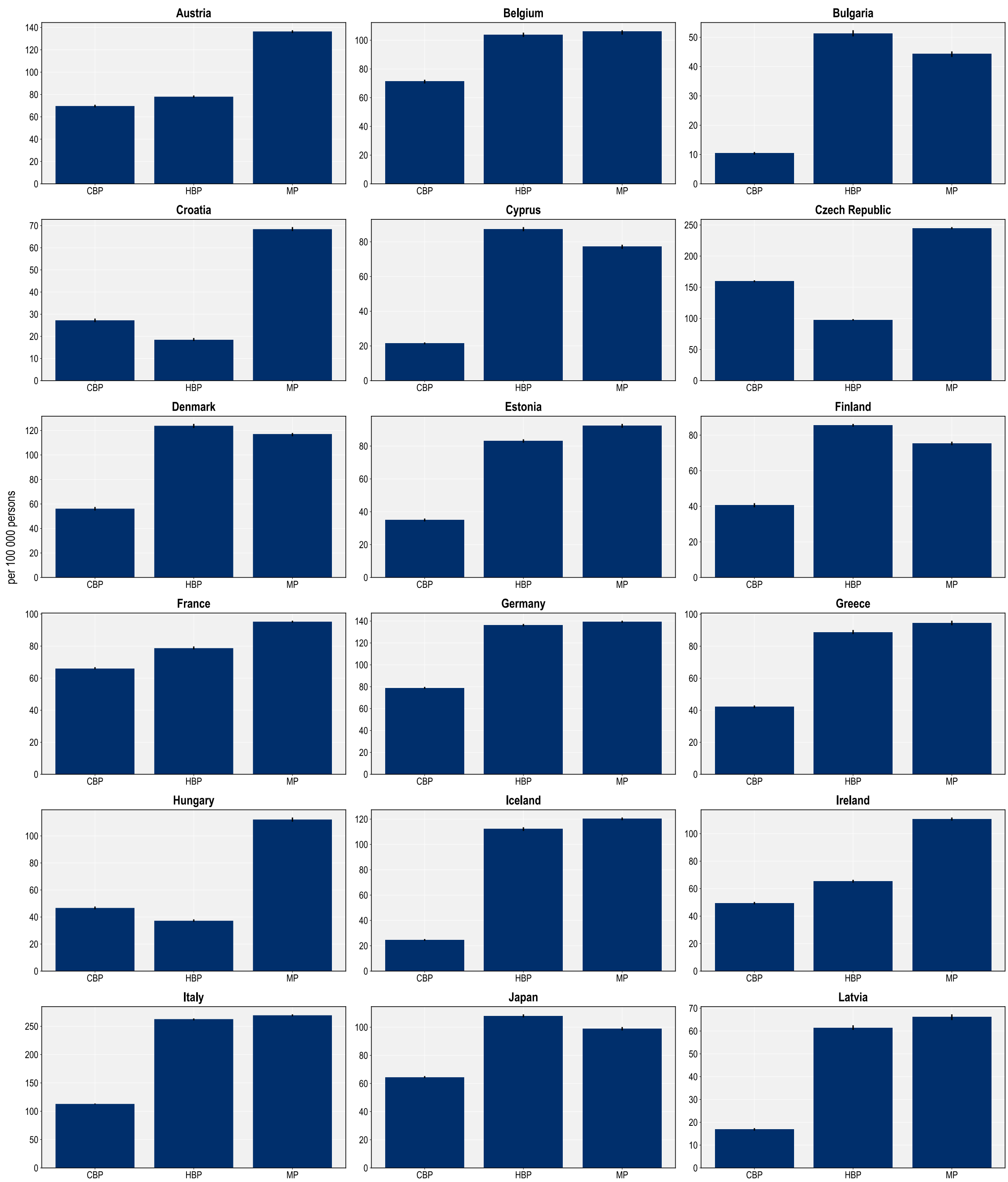
- **Hospital-based package**: This package focuses on hospital-based interventions that have the greatest estimated impact on health outcomes, including improving hand hygiene, enhancing environmental hygiene and scaling up ASPs. The design and implementation of these interventions vary substantially across countries. The estimated per capita cost of this package ranges between USD PPP 1.4 and USD PPP 9.4.
- **Community-based package**: This package examines the combined impact of community-based interventions with the greatest impact on population health and includes delayed antimicrobial prescriptions, introducing financial incentives to optimise antimicrobial use, scaling up the use of RDTs, mass media campaigns and prescriber training. This package is estimated to cost between USD PPP 0.8 and USD PPP 11.9 per capita.
- **Mixed package**: This package entails a One Health approach by incorporating action across human and non-human health sectors. It includes improving hand hygiene, scaling up ASPs, delaying antimicrobial prescription, increasing mass media campaigns and enhancing food handling practices. The per capita cost of this package is estimated to vary between USD PPP 0.7 and USD PPP 3.7.

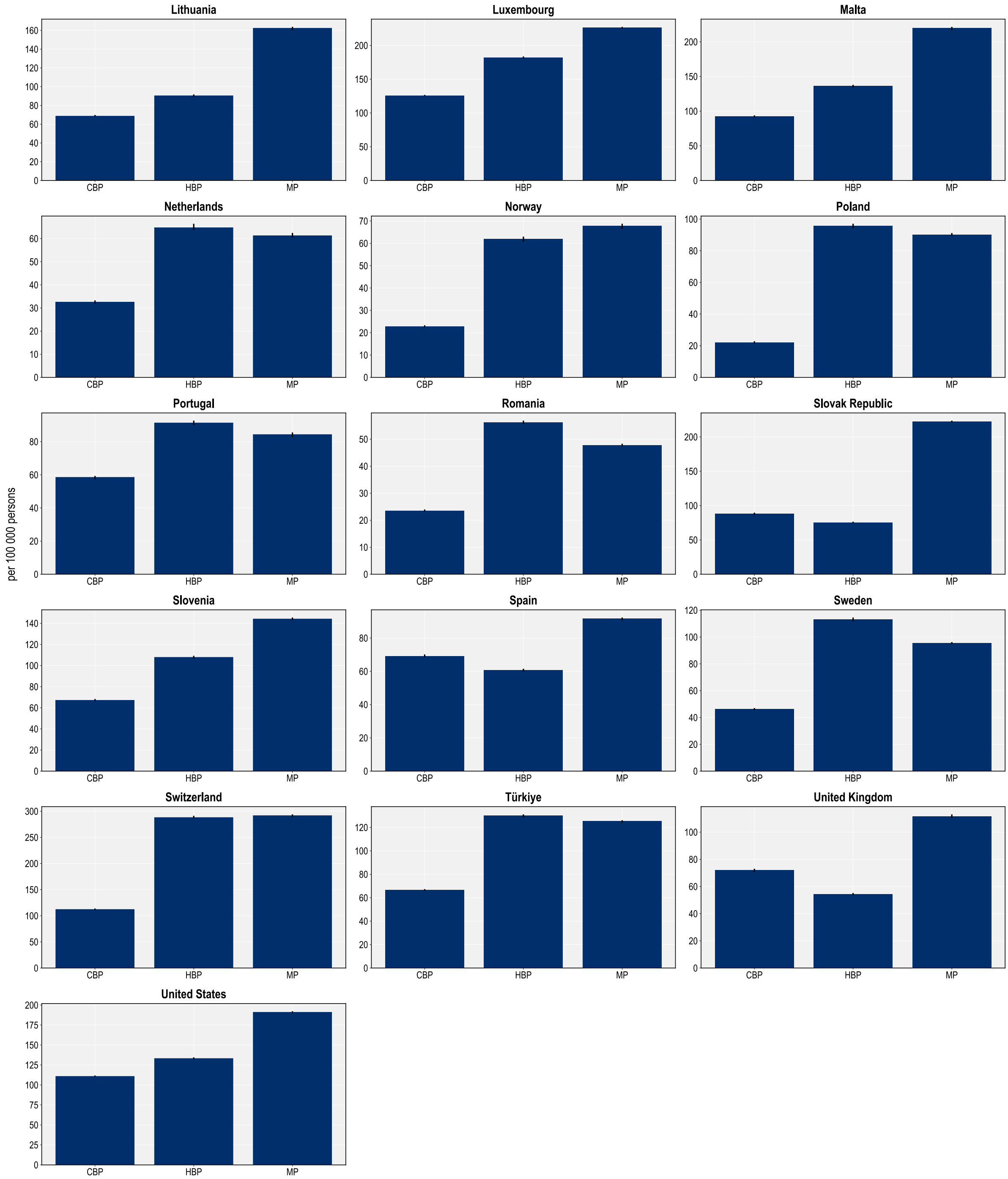
Across all three policy packages, the elimination scenario was used for interventions that influence antibiotic prescription.

The mixed package provides the largest reductions in the number of resistant infections (Figure 6.8), followed by the hospital- and community-based packages. On average, the mixed package is estimated to reduce more than 1.6 million resistant infections annually across all 34 countries included in the analysis. The hospital-based package is also highly effective, with the number of resistant infections eliminated through this intervention averaging around 1.3 million every year. Finally, the estimated number of resistant infections that can be eliminated through the community-based package is more than 900 000 infections. Much like single interventions, there is substantial cross-country variation in the effectiveness of each policy package.

Figure 6.8. The mixed package yields the largest reductions in the number of resistant infections

Number of resistant infections averted per 100 000 persons annually up to 2050





Note: CBP: Community-based package; HBP: Hospital-based package; MP: Mixed package.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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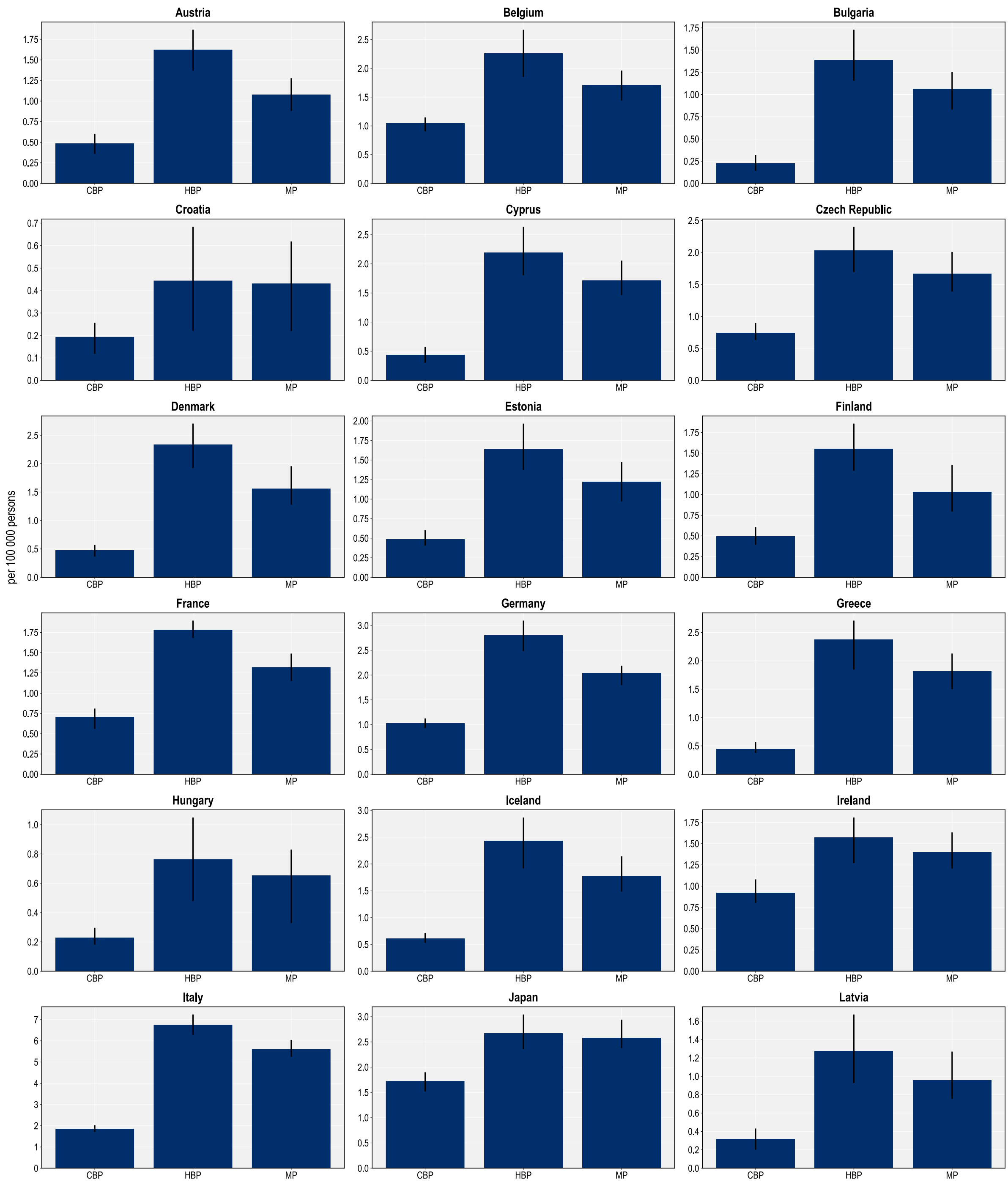
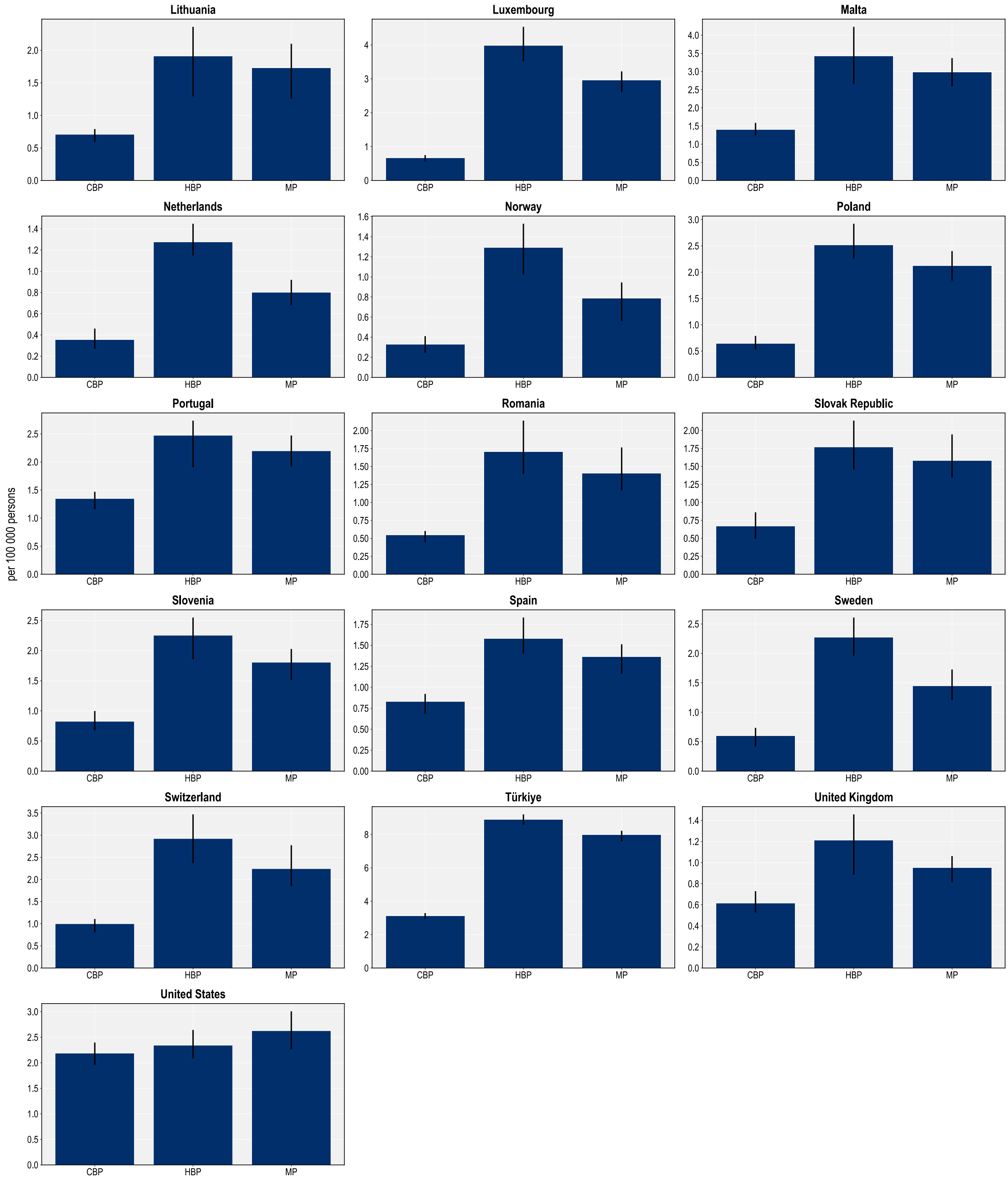
Upscaling the hospital-based package promises to prevent the largest number of deaths compared to the other two packages (Figure 6.9). On average, the hospital-based package is estimated to prevent more than 33 000 deaths each year compared to around 30 000 deaths by the community-based package and more than 17 000 deaths by the mixed package. In effect, scaling up the hospital package to the desirable levels is almost equivalent to preventing all deaths due to TB, influenza and HIV/AIDS in 2020 (or the nearest year for which data are available) across the 34 countries included in the analysis. Across the EU/EEA countries, Italy and Luxembourg are expected to avert the highest number of deaths by investing in a hospital-based package, preventing each year around 6.7 and 4 deaths per 100 000 persons respectively. Whereas Türkiye can avoid 8.9 deaths per 100 000 persons, the highest number of AMR-related deaths averted across the non-EU/EEA member OECD countries.

Figure 6.9. The hospital-based package prevents the highest number of deaths due to resistant infections

Number of deaths due to AMR averted per 100 000 persons annually up to 2050





Note: CBP: Community-based package; HBP: Hospital-based package; MP: Mixed package.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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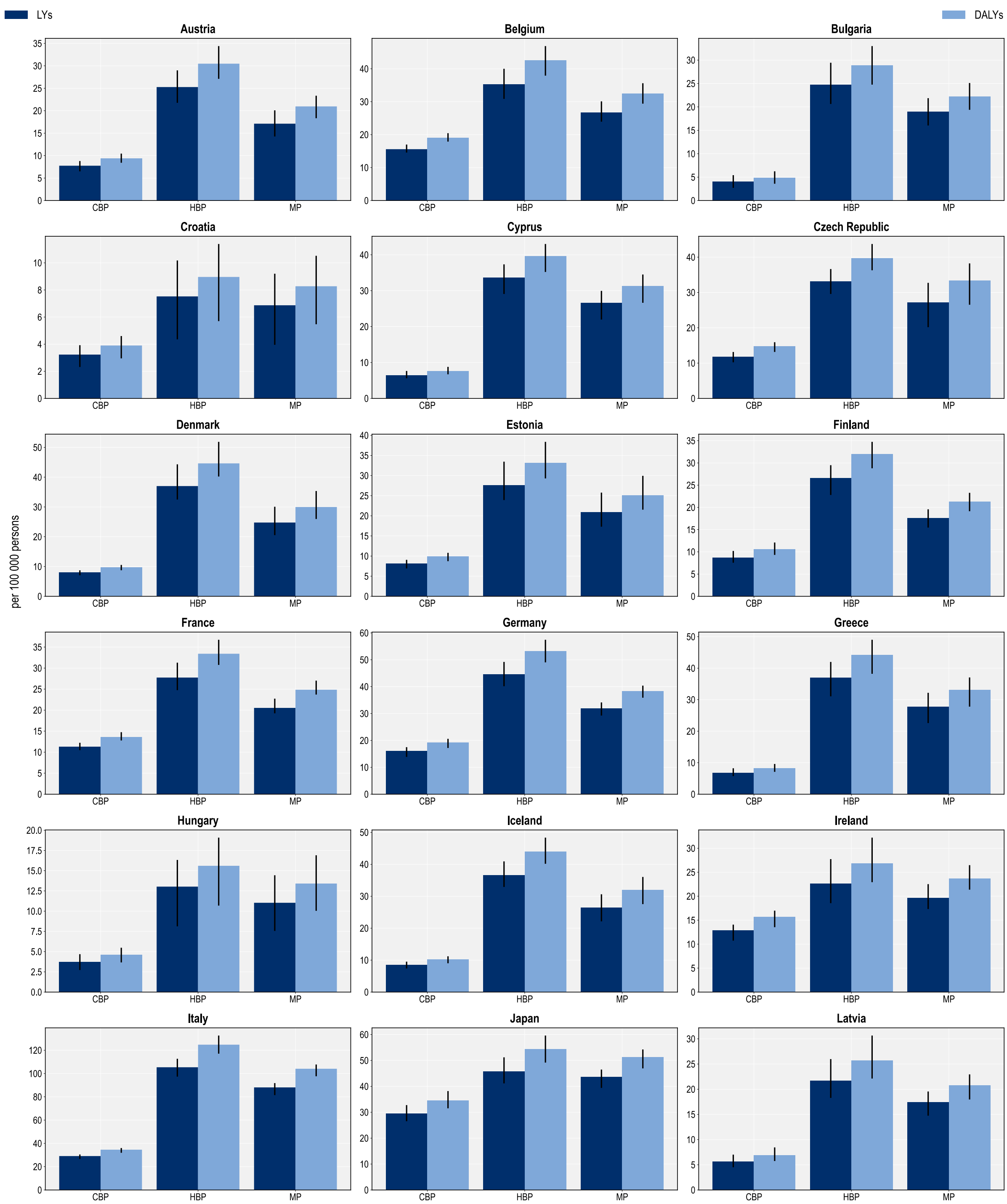
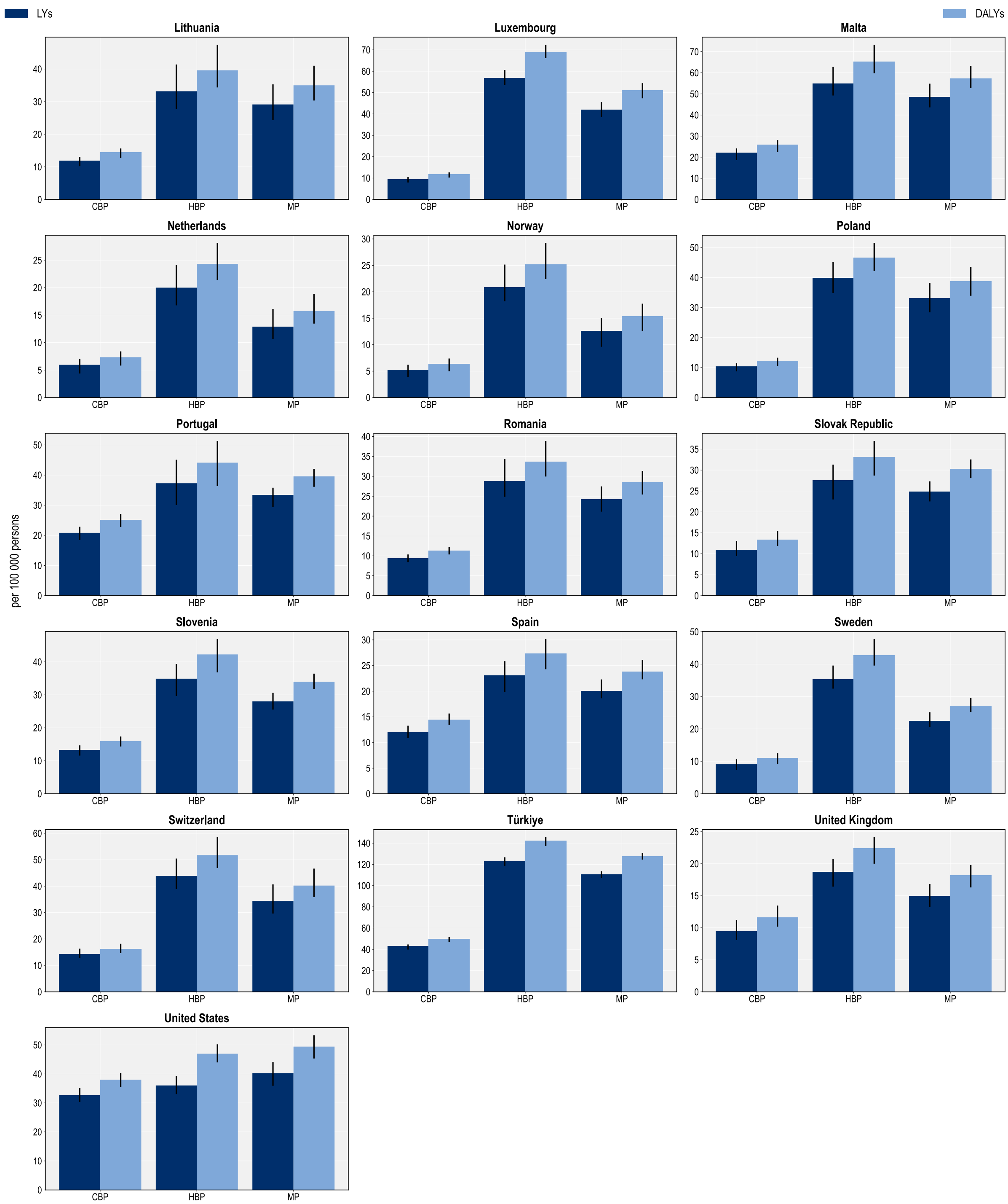
The hospital-based package also produces the highest gains in terms of LYs and DALYs gained (Figure 6.10). On average, a hospital-based package can produce a gain of more than 511 000 LYs and 618 000 DALYs per year across the 34 countries included in the scope of the analysis. A mixed package also offers important health gains. On average, a mixed package is expected to save more than 466 000 LYs and 556 000 DALYs every year across all countries included in the analysis. A community-based package is expected to generate relatively smaller gains. On average, this package is predicted to produce nearly 263 000 LYs and more than 308 000 DALYs per year.

Figure 6.10. The hospital-based package promises the highest savings in LYs and DALYs

Number of LY and DALYs gained per 100 000 persons annually up to 2050





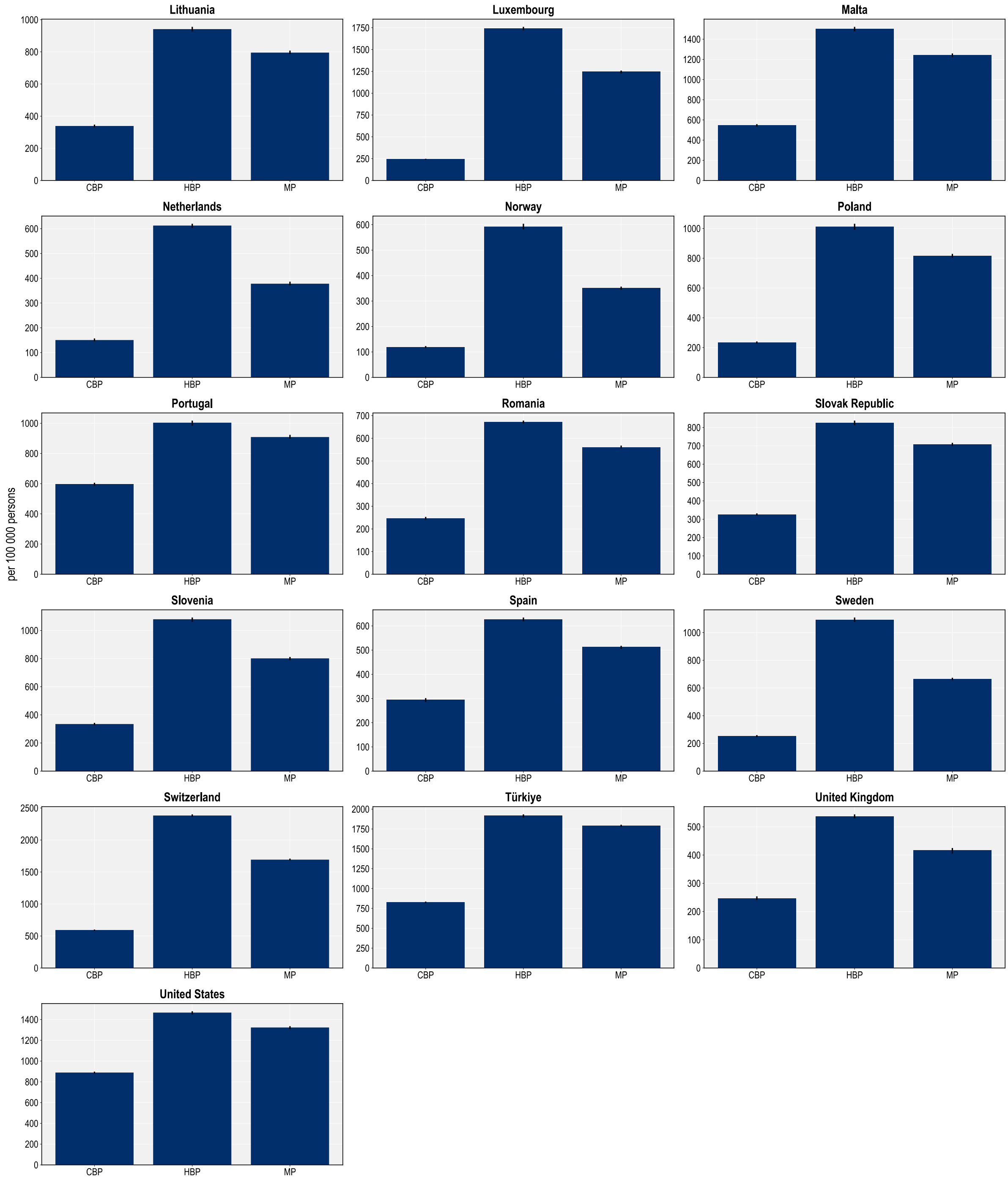
Note: CBP: Community-based package; DALYs: Disability-adjusted life-years; HBP: Hospital-based package; LYs: Life years; MP: Mixed package.
Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/7gu08s

The hospital-based package is expected to avoid more than 14 million extra days spent in hospital to treat complications due to resistant infections (Figure 6.11). This would be equivalent to freeing up the entire acute bed capacity in the Netherlands in 2020 for an entire year. In comparison, the mixed package can potentially prevent more than 12 million additional hospital days and the community-based package more than 6.7 million additional hospital days. The findings point to considerable cross-country variation. Across the EU/EEA countries included in the analysis, Italy is expected to make the most of gains from scaling up this intervention, with around 2 781 extra hospital days avoided per 100 000 persons, followed by Luxembourg and Germany (1 743 and 1 341 additional hospital days avoided per 100 000 persons respectively). Among the non-EU/EEA member OECD countries, Switzerland and Türkiye can prevent more than 2 383 and 1 918 additional days spent in hospital per 100 000 persons respectively.

Figure 6.11. More than 14 million days spent in hospital can be avoided through the hospital-based package

Number of additional days spent in hospital avoided per 100 000 persons annually up to 2050



Note: CBP: Community-based package; HBP: Hospital-based package; MP: Mixed package.
Source: OECD analysis based on the OECD SPHeP-AMR model.

StatLink https://stat.link/weg9cr

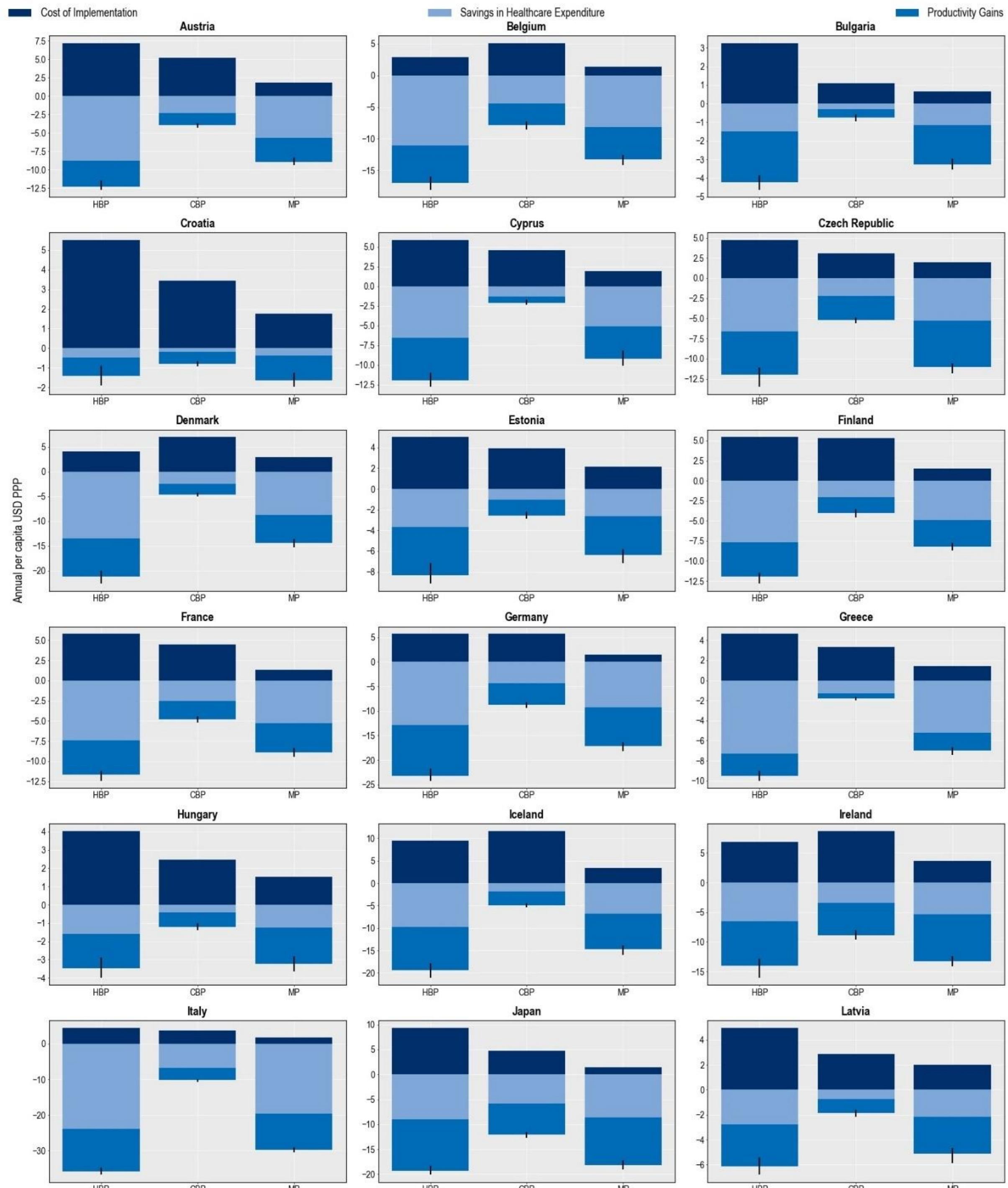
The hospital-based package is also estimated to have the greatest impact on health expenditures attributable to treating complications due to resistant infections (Figure 6.12). On average, this package is predicted to save more than USD PPP 11 billion each year (corresponding to USD PPP 9.8 per capita), compared to USD PPP 9.4 billion by the mixed package (corresponding to USD PPP 8.3 per capita) and USD PPP 5.3 billion (corresponding to USD PPP 4.7 per capita) by the community-based package. Savings that can be achieved by scaling up the hospital-based package can be roughly equivalent to half of all health spending in the Czech Republic in 2020. The estimated reductions in attributable health expenditures vary across countries. Luxembourg and Italy are poised to achieve the greatest savings in health expenditure across EU/EEA countries (USD PPP 38.7 per capita and USD PPP 20 per capita) and Switzerland across the non-EU/EEA member OECD countries (USD PPP 28.5 per capita).

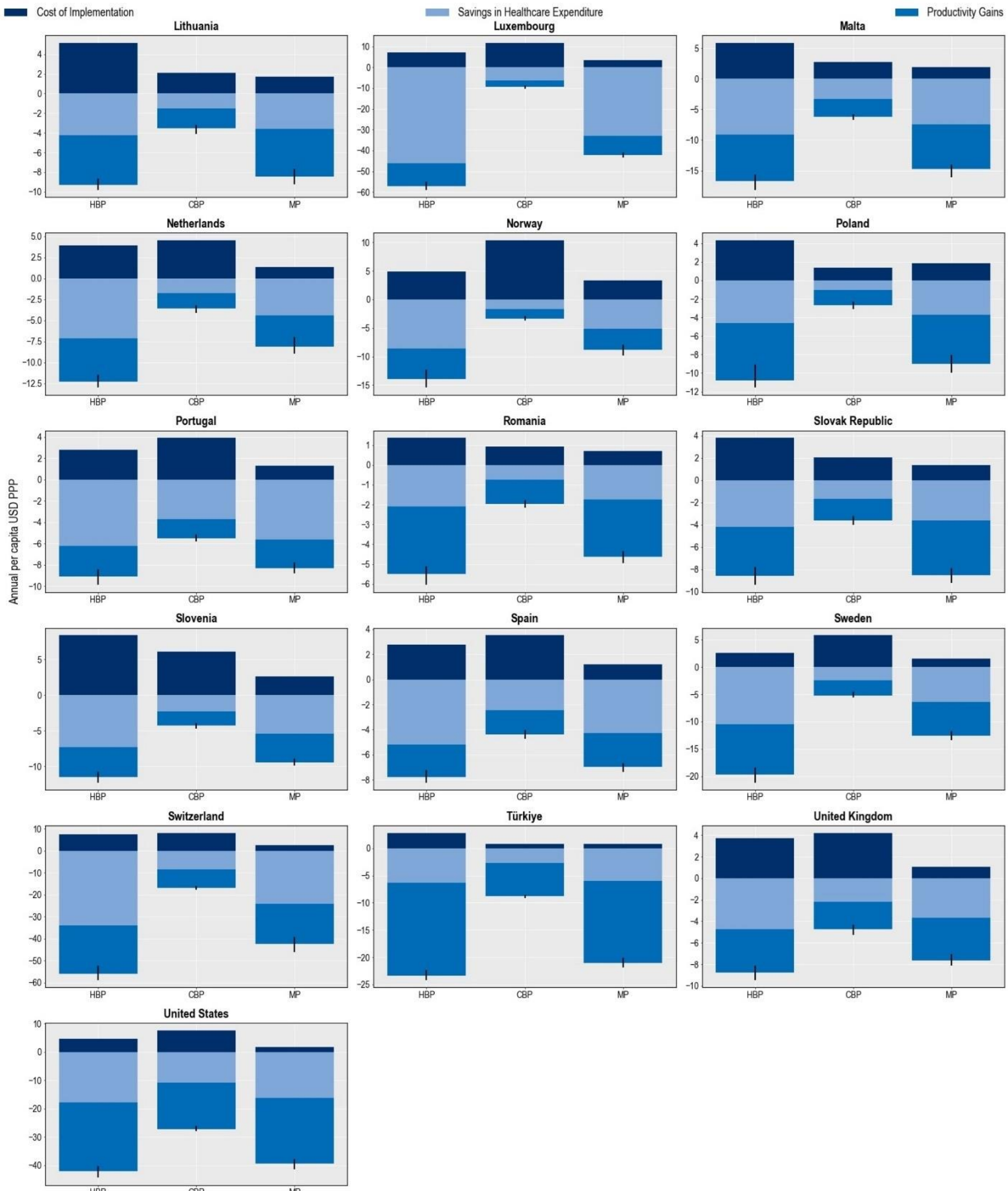
Across the three packages evaluated, the hospital-based package is predicted to yield the greatest productivity gains – a measure that combines improvements in participation in the workforce and workforce productivity. On average, this package can bring productivity gains exceeding USD PPP 14.9 billion (corresponding to USD PPP 13.2 per capita) annually across the 34 countries included in the analysis and nearly USD PPP 3.3 billion (corresponding to USD PPP 6.6 per capita) across the 29 EU/EEA countries. In comparison, the mixed package is expected to produce productivity gains to the tune of USD PPP 13.8 billion (corresponding to USD PPP 12 per capita) every year across all countries included in the analysis and around USD PPP 2.8 billion across EU/EEA countries (corresponding to USD PPP 5.6 per capita).

The estimated benefits that can be accrued by upscaling the policy packages exceed the cost of implementing these packages. For example, across the 34 countries included in the OECD analysis, the annual average cost of implementing the mixed package is around 5 times lower than the estimated benefits accrued through the reduction in health expenditure and productivity gains. Each year, the potential benefits that can be achieved through scaling up the hospital-based package are expected to be, on average, around 4.7 times the costs associated with the implementation of this package. In comparison, the potential benefits that can be reaped by implementing the community-based package are 2.5 times that of the cost of scaling up this package.

Figure 6.12. The hospital-based package can help reduce the pressure on healthcare budgets

Cost of interventions and their impact on savings in health expenditure and productivity gains





Note: CBP: Community-based package; HBP: Hospital-based package; MP: Mixed package.
Source: OECD analysis based on the OECD SPHeP-AMR model.

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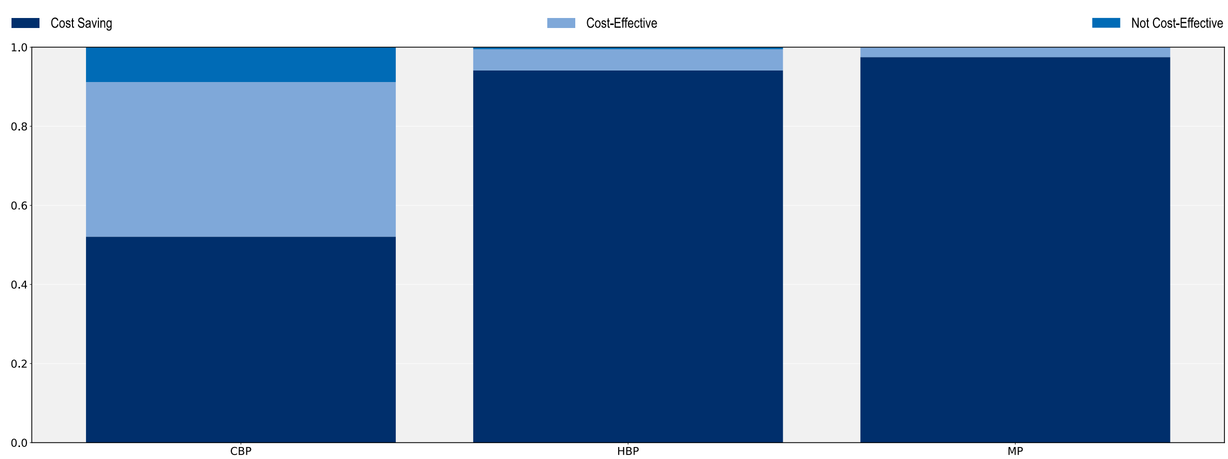
Cost-effectiveness of policy packages to tackle AMR

All three policy packages can be considered "best buys" given their favourable cost-effectiveness profiles (Figure 6.13). The mixed package is estimated to produce the most favourable cost-effectiveness profile. Across the 34 countries included in the analysis, the probability that the mixed package would be a cost-saving option was estimated to be around 98%, suggesting that this package would be the most efficient approach with a very high probability that its implementation will save lives. The hospital-based package also offers high value for money, with the probability that this intervention would be cost-saving reaching 94%. The community-based package also offers a valuable strategy to tackle AMR. The probability that this intervention could be a cost-saving strategy is estimated to be around 52% and that it would be cost-effective is around 39%. The finding that the community-package has a relatively less favourable cost-effective profile compared to the other two policy packages is not surprising. The community-based package is comprised of interventions that are meant to tackle resistant infections occurring in community settings, which have been shown to have a lower risk of mortality compared to resistant infections acquired in healthcare settings.

Figure 6.13. Probability of cost-effectiveness of the modelled policy packages vs. business-as-usual scenario



Note: CBP: Community-based package; HBP: Hospital-based package; MP: Mixed package.
Source: OECD analysis based on the OECD SPHeP-AMR model.

The cost-effectiveness estimates presented in this chapter align with previous evidence

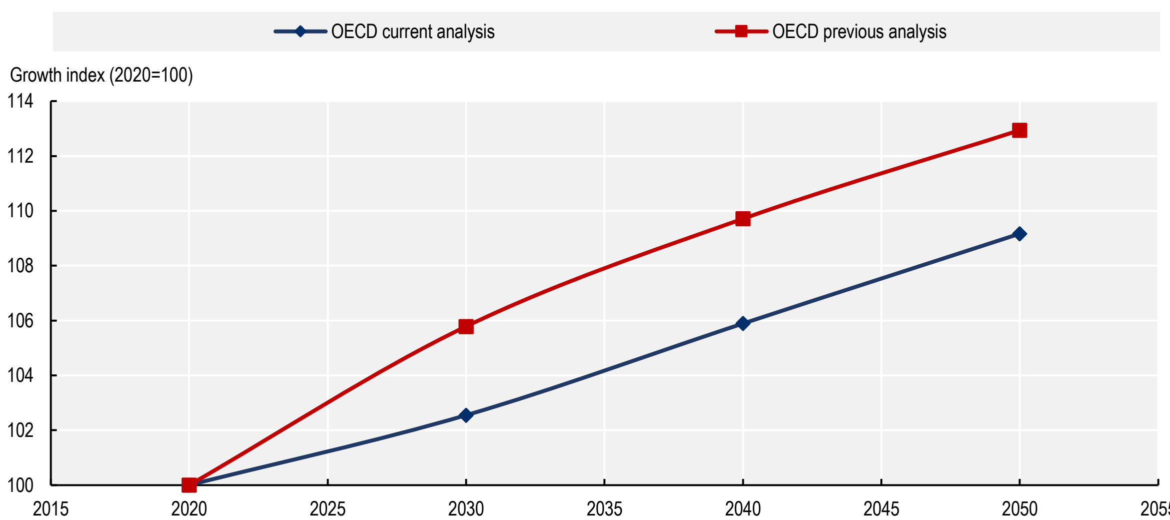
The findings presented in this chapter suggest that, compared to the 2018 OECD analysis, the OECD and EU/EEA countries included in the analysis stand to make relatively more conservative health and economic benefits by investing in policy intervention to tackle AMR. For example, the current chapter and the 2018 OECD publication concur that ASPs offer the greatest potential to reduce resistant infections, though the estimated number of deaths that can be avoided by scaling up ASPs is lower than the estimates provided in the 2018 OECD publication (OECD, 2018[14]).

These differences between the two iterations of the OECD analyses are driven primarily by two factors:

- **Increased level of business-as-usual coverage of the modelled interventions**: An analysis of the 2016-17 and 2019-20 Tripartite AMR Self-Assessments suggests that the implementation of many of the interventions modelled in this chapter improved over time. Beyond a significant improvement in the development of the national action plans for AMR, many OECD countries and EU/EEA countries assess that they experienced improvements in the implementation of all the interventions. For example, regulatory frameworks for the implementation of ASPs improved substantially with the share of countries indicating that they had no/weak policies for appropriate antibiotic use declining from 21% (7/34) in 2016-17 to 6% (2/34) in 2019-20.

- **Lower predicted rates of resistance proportion** (Figure 6.14): The new round of OECD projections suggest that AMR is likely to growth at a slower pace than predicted in the previous OECD analysis. The previous OECD analysis predicted that across the countries included in the analysis, resistance to antibiotics was expected to grow by 13% between 2020 and 2050, compared to a 9% growth rate in the most recent forecast. Beyond methodological differences between the two rounds of analysis, these findings are also suggestive of the recent advancements in the scale-up of AMR policies across considered countries.

Figure 6.14. The new OECD analysis suggests that AMR will grow at a slower pace than projected in the previous OECD work study



Note: Data on AMR growth rates were normalised to average AMR in 2020 (equal to 100). For example, a value of 113 for resistance in 2050 means that resistance is 13% higher than it was in 2020 in the countries included in the OECD analysis.
Source: OECD analysis based on the OECD SPHeP-AMR model.

The OECD analysis on the cost-effectiveness of the policy interventions to tackle AMR is in line with evidence generated at the country level. For example, the finding that ASPs are among the most cost-effective options to tackle AMR aligns with evidence generated in EU/EEA countries and OECD countries:

- In the Netherlands, one multi-modal ASP that was implemented in the Canisius Wilhelmina Hospital in Nijmegen involved building multi-professional stewardship teams, strengthening the monitoring of antibiotic use and developing feedback mechanisms. This intervention resulted in hospital-wide savings to the tune of EUR 40 000 over the first year of the implementation while reducing antimicrobial consumption by 10% (Oberjé, Tanke and Jeurissen, 2017[15]).
- In the United States, one ASP introduced procalcitonin-guided decision algorithms to improve antibiotic use for hospitalised patients with sepsis and lower respiratory tract infections. This intervention resulted in average per capita cost savings of USD 25 611 for sepsis and USD 3 630 for lower respiratory tract infections while reducing the length of hospital stays, reliance on antibiotics and reducing days spent in mechanical ventilation (Voermans et al., 2019[16]).

- In Canada, an ASP aimed to improve prudent antibiotic use in four intensive care units by providing in-person coaching by pharmacists and physicians combined with performance reports (Morris et al., 2019[17]). An evaluation of this ASP concluded that it was associated with reductions in antibacterial use to the tune of about 12.12 defined daily doses per 100 patient days while the monthly costs associated with antibiotic use declined by CAD 642.

The findings reported in this chapter are broadly aligned with results generated by previous multi-country studies. For example, the two IPC interventions modelled in this chapter – enhancing environmental hygiene and improving hand hygiene – are shown to be amongst the most effective means of reducing the burden of AMR on population health. This finding broadly aligns with the key messages of the first global IPC report published by the WHO (2022[9]). Building on global evidence as well as results from previous OECD analyses, this report highlighted that investments in hand hygiene and environmental hygiene are particularly valuable means to limit the impact of resistant infections. This report highlighted global evidence that showed that these interventions are cost-effective options for tackling infections acquired in healthcare settings in general and resistant infections in particular.

The OECD estimates on the potential benefits of vaccines in the fight against AMR are also in line with previous works. A growing body of evidence demonstrates that increasing vaccination coverage can help tackle AMR through multiple pathways (Vekemans et al., 2021[18]; Jit, Anderson and Cooper, 2020[19]) (e.g. lowering the rate with which populations are infected, lowering infection severity, etc.). Congruent with previous works, the OECD analysis showed that scaling up the coverage of PVV23 across the 34 countries included in the analysis could help reduce the incidence of resistant infections and deaths caused by these infections.

The OECD estimates presented in this chapter should be considered conservative estimates for many of the modelled interventions given that the positive implications of scaling up the assessed interventions may be greater than the impact accounted for in the model. For example:

- Previous studies demonstrated that IPC interventions in human health can indirectly contribute to efforts to optimise the use of antibiotics by preventing infections from occurring in the first place (Okubo et al., 2023[20]).
- Similar to the IPC interventions discussed above, the OECD model did not capture all potential pathways through which PVV23 can safeguard population health. For example, OECD estimates do not consider the potential reductions in the likelihood of disease transmission across people in the community attributable to vaccines, a concept referred to as heard immunity. However, vaccines have been shown to offer considerable health benefits through herd effects, even shortly after their rollout (Shiri et al., 2017[21]).
- Limited by the evidence gap on the complex pathways through which AMR is transmitted between and across humans, animals and the environment, the OECD analysis does not consider many of the potential pathways through which the One Health interventions can reduce the number of resistant infections. For example, the OECD analysis assumes that improving farm biosecurity can disrupt AMR transmission between people and animal populations. But the analysis does not consider that increased use of PPE can influence the spread of AMR through other channels (e.g. through reduced exposure to antibiotic residues during manure applications and in the soil (He et al., 2020[22]), reduced antibiotic use in human and animal populations by preventing infection from occurring in the first place, etc.).
- Similarly, the analyses of interventions outside of the human health sector do not consider all of the potential benefits of these interventions. For example, while modelling the effectiveness and cost-effectiveness of the intervention to improve farm biosecurity, the OECD analysis considers only the beneficial impacts mediated through declines in AMR in the human population. However, as discussed in more detail in Chapter 5, earlier works suggest that biosecurity measures could potentially help improve farm productivity and livestock production (Renault et al., 2019[23]; Postma et al., 2016[24]), generating greater economic benefits than quantified in the current analysis.

Conclusions

This chapter provides an assessment of the return on investment in 11 AMR policies spanning human health, animal health and food safety sectors. Findings from the chapter highlight that the modelled interventions could yield a substantial protective impact on population health and reduce the economic burden of AMR, with the magnitude of the impact varying across interventions. Of the 11 interventions modelled, upscaling stewardship programmes that promote prudent use of antibiotics were estimated to yield the greatest health and economic benefits. Beyond the human health sector, enhancing food safety measures and improving biosecurity in farm settings can be effective means to limit the impact of AMR though the findings also suggest that these two policies will not be sufficient on their own to eliminate AMR. Importantly, the chapter showed that the effectiveness of AMR policies is more pronounced when they are rolled out as part of a package of interventions, compared to a situation where they are rolled out individually.

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Annex 6.A. Modelling policy interventions to tackle AMR

This annex provides detailed descriptions of the design features of the 11 interventions modelled in the scope of the OECD analysis.

Policies to optimise the use of antibiotics in human health

Strengthen antimicrobial stewardship programmes (ASPs)

Modelled intervention

- The modelled intervention entails scaling up a hospital-based programme that involves the creation of multi-disciplinary teams that provide antibiotic stewardship and the scale-up of monitoring and surveillance systems.
- The beneficial effects are assumed to become observable immediately and sustained over the analysis period.

The modelled intervention is a hospital-based intervention with two main components. The first involves the creation of multi-disciplinary ASP teams comprised of infectious disease specialists, pharmacists and microbiologists who are tasked with providing antibiotic guidance in each health facility. The ASP teams would develop and disseminate antibiotic prescribing guidelines in line with national and international guidelines and deliver training sessions once a year on best practices in antibiotic prescribing behaviours. The second component entails the development of a monitoring and surveillance system which tracks antibiotic use and AMR burden in healthcare facilities. Results generated through this system would be used subsequently to assess whether course corrections are needed in the implementation of the intervention (e.g. revising treatment guidelines) and to provide feedback to prescribers in health facilities about their prescribing behaviours.

The individual-level effectiveness estimates were extracted from the Cochrane review conducted by Davey et al. (2017[25]). Based on evidence gathered through randomised controlled trials (RCTs), ASPs were associated with reductions in the risk of antibiotic consumption (risk difference = -0.25 [-0.37, -0.13]). Importantly, this review found that the majority of evidence suggested that the beneficial effects of ASPs were sustained 12 months after the initial rollout of the intervention.

The business-as-usual coverage was determined separately for each country using the 2020-21 Tripartite AMR Self-Assessment Survey, based on a survey question that examines the stage of implementation of ASPs to optimise antibiotic use in human health. This question characterises ASPs by identifying different stages of implementation ranging from having no guidelines on optimised antibiotic use to having in place antibiotic guidelines and data for all major syndromes (see Question 1 in Annex 6.B). The target coverage is set at 80%, such that the intervention is assumed to be rolled out in 80% of all hospitals in each country. The rollout of the intervention is assumed to affect only infections acquired in healthcare settings. The beneficial effects are assumed to become measurable immediately and remain at the same level over the simulation period.

The per capita cost of implementing such a programme was estimated to range from USD PPP 0.53 to USD PPP 6 per capita, reflecting the specific characteristics of the country. The most expensive cost component was those associated with building multi-disciplinary stewardship teams, which includes both salaries and training expenses. The remaining costs covered administrative costs at the national and local levels and monitoring and evaluation arrangements at the local level. Implementation costs varied quite substantially across countries, driven primarily by the cross-country differences in wages as well as the differences in the number of healthcare facilities across countries.

Delayed antibiotic prescribing

Modelled intervention

- The model intervention is the rollout of antimicrobial prescribing guidelines that promote delayed prescription in primary healthcare settings.
- The modelled intervention is assumed to result in a 60% reduction in antibiotic use.
- The effectiveness is assumed to be sustained over course of the simulation.

Delayed antibiotic prescribing is another means to reduce unnecessary use of antibiotics. A delayed prescription is similar to a typical prescription except that the patient is instructed to redeem the prescription only if symptoms remain unresolved in a time period determined by their prescriber. Since the last OECD publication, the evidence base on the effectiveness of delayed prescribing grew. In 2021, Stuart and colleagues showed that, compared to immediate antibiotic prescription, delayed prescriptions were associated with reductions in complications attributable to hospital admissions and deaths (Stuart et al., 2021[26]), while there were no detectable differences in follow-up symptom severity. This study further pointed out that delayed prescribing was correlated with significant reductions in re-consultation rates and increases in patient satisfaction in comparison to no antibiotic treatment.

The modelled intervention is conceptualised as a community-based intervention with multiple components. The first component aims to ensure that prescribers have access to clinical guidelines, which can help in their decisions related to whether they should recommend delayed use of antibiotics. The second component involves a training and education programme for prescribers in order to improve their awareness and understanding of best practices in delayed prescribing. A one-hour training programme is assumed to be conducted at regular intervals across the simulation period. The third component is the rollout of a feedback programme that will help assess prescriber performance over time and provide feedback. The final component involves the development and distribution of information materials targeting prescribers, like brochures and posters, to serve as best practice reminders.

The effectiveness of the intervention is calculated based on a Cochrane review by Spurling et al. (2017[27]). By pooling evidence from RCTs included in this review, it was calculated that a delayed antibiotic prescribing programme similar to the one included in the OECD analysis would lead to a 60% decline in antibiotic use in comparison to immediate antibiotic prescription (relative risk [RR] = 0.40, 95% confidence interval [CI]: 0.30-0.53). The intervention is assumed to target 40% of all prescribers. The effect of the intervention is assumed to become observable immediately after the programme rollout and sustained over the simulation period.

The estimated per capita cost of the intervention varied between USD PPP 0.06 and USD PPP 1.26. Costs are calculated as a composite of administrative expenses at the national and district levels, cost of trainings for prescribers and cost of producing informational materials and prescriber feedback programme. One-off costs of developing the guidelines are also included. The cost analysis does not consider any economic impact caused by a decrease in the sales of antimicrobials or the extra time needed for doctors to provide a prescription during the second visit, under the assumption that the prescription would be prepared during the first visit.

Scale up the use of rapid diagnostic tests (C-reactive protein [CRP] testing)

Modelled intervention

- A novel programme aims to increase the use of rapid diagnostic tests by increasing the availability of point-of-care (POC) CRP in ambulatory care settings in combination with antibiotic treatment guidelines depending on the CRP levels.
- The modelled increase in the availability of CRP is assumed to reduce immediate antibiotic prescribing by 32% in adults and 46% in children under 18 years of age.
- The intervention is assumed to yield immediate effects on antibiotic prescribing behaviours.

Increasingly, many healthcare providers are relying on POC CRP tests to reduce unnecessary antibiotic prescribing (Falk and Fahey, 2008[28]; Sanders et al., 2008[29]; Ebell et al., 2020[30]). The POC CRP tests can offer a relatively faster option to guide antibiotic prescribing decisions, as these tests can produce results in minutes (Martínez-González et al., 2020[31]), compared to traditional diagnostic testing methods that typically require 48-72 hours. Previous studies suggest that there is an inverse relationship between the use of POC CRP tests and antibiotic prescription rates. For instance, one recent systematic review and meta-analysis found that the use of POC CRP testing was linked with a 25% reduction in antibiotic prescription in general practice during first consultation for patients with respiratory tract infections (Huang et al., 2013[32]). Subsequently, a Cochrane review examined data from six RCTs and concluded that the use of CRP at the POC was associated with a 22% reduction in antibiotic prescribing in adults that suffered from acute respiratory tract infections (Aabenhus et al., 2014[33]).

Since the last OECD analysis, the literature on the use of rapid diagnostic tests grew. A recent systematic review and meta-analysis conducted by Verbakel et al. examined evidence from randomised trials and found that, in ambulatory care settings, the use of POC CRP testing is associated with a reduction in immediate antibiotic prescribing in the first consultation (RR = 0.81, 95% CI: 0.71-0.92) in comparison to usual care (Verbakel et al., 2019[34]). Importantly, this study showed that when guidelines focusing on when to start antibiotic treatment depending on CRP levels were available, the beneficial effects were more pronounced, with an overall 32% (RR = 0.68, 95% CI: 0.63-0.74) reduction in antibiotic prescribing for adults and 46% for children under 18 years of age (RR = 0.54, 95% CI: 0.33-0.95) (Verbakel et al., 2019[34]). Similarly, another meta-analysis conducted by Martínez-González et al. found that, in primary healthcare settings, the use of POC CRP testing was associated with reductions in immediate antibiotic prescribing (RR = 0.79, 95% CI: 0.70-0.90) compared to usual care (Martínez-González et al., 2020[31]), though this study did not examine whether the effect size varied depending on the availability of antibiotic treatment guidance in accordance with CPR levels.

The modelled intervention is conceptualised as a novel programme that aims to scale up the use of POC CRP in primary care facilities. It is assumed that the increased use of POC CRP testing is paired with increasing the availability of antibiotic prescribing guidelines on when to initiate antibiotic treatment in relation to the level of CRP. It is assumed that health workers would be provided with a one-hour training session at regular intervals throughout the simulation period to increase awareness of the benefits of using POC CRP testing and to highlight that antibiotic prescribing guidelines are available. In addition, informational materials (e.g. flyers and leaflets) would be disseminated. Finally, monitoring and evaluation arrangements are assumed to be put in place to ensure compliance with antibiotic prescribing guidelines that include the use of POC CRP testing.

The individual-level estimates for the intervention effectiveness reflect those generated by Verbakel et al. (2019[34]). The business-as-usual coverage is set at 0 because this is considered to be a novel intervention and the scale-up of the intervention is assumed to cover 70% of primary healthcare facilities. The intervention is assumed to have an immediate impact on antibiotic prescribing behaviours. The beneficial effects are assumed to persist throughout the simulation based on findings generated by Martínez-González et al., which showed that the beneficial impact of POC CRP tests was sustained one year after their rollout (Martínez-González et al., 2020[31]). The incidence of HAIs and susceptible infections acquired in the community are assumed to remain unchanged.

The per capita cost of the intervention is estimated to vary between USD PPP 0.53-2.15 across countries. The estimated costs take into account the cost of buying the POC CRP tests, costs related to training the prescribers on the clinical guidelines related to the use of POC CRP tests and informational materials. The total intervention cost also includes some administrative expenses and expenses covering monitoring and evaluation activities at the national and local levels. No additional costs were included in these estimates to account for any additional time that prescribers may spend to perform the POC CRP tests because the tests are assumed to be carried out during the standard period that the prescriber spends with the patient to make a diagnosis.

Financial incentives to optimise antimicrobial use

Modelled intervention

- A nationwide pay-for-performance (P4P) programme that aims to optimise antimicrobial use in community settings by rewarding bonuses to prescribers for achieving pre-set antibiotic prescribing targets.
- The modelled P4P programme is assumed to result in an 8% decrease in antibiotic prescribing.
- The effectiveness is assumed to be sustained over the course of the simulation.

A growing strand of literature demonstrates that financial incentives targeting prescribers can be an effective means to promote the prudent use of antimicrobials. For example, one recent systematic review conducted by the OECD found that financial incentives are associated with measurable changes in prescribing behaviours, with the magnitude of the desired effects varying across different provider payment methods (Yoshikawa et al., 2021[35]). Capitation payments and pay-for-performance schemes that reward prescribers for achieving pre-specified antibiotic prescribing targets are found to be among the most successful financial instruments in terms of promoting prudent antibiotic prescribing behaviours.

Building on findings from this review, the modelled intervention involves a nationwide P4P programme that aims to encourage the prudent use of antimicrobials in primary healthcare settings. The modelled intervention rests on a two-pronged approach. The first prong entails the rollout of a nationwide pay-for-performance programme that aims to incentivise more prudent antibiotic prescribing practices. To this end, the programme is assumed to ensure that prescribers have access to clinical guidelines which delineate the classes of antimicrobials that should be used across different cases. In countries where clinical guidelines are already available, the existing guidelines will be linked to set performance targets for antibiotic prescription. New clinical guidelines will be developed only if a country does not already have clinical guidelines for antibiotic prescriptions. This is assumed to be supplemented with a monitoring mechanism to assess whether prescribers are meeting their prescribing targets. To this end, primary healthcare centres will provide self-reported prescriber-level data on relevant antibiotic prescription indicators.

Each month, approximately 10% of the self-reported data will be selected at random by the authorities responsible for monitoring and evaluation of the programme. Data from the selected primary healthcare centres will, then, be audited by the existing authorities that are responsible for monitoring and evaluation arrangements to verify the self-reported data through reviews of patient records and patient interviews. The volume of the bonus payment will be based on the performance of the primary healthcare centre as a whole, and account for 1-5% of the total reimbursement of each healthcare centre. This choice is similar to the design of P4P programmes from OECD countries that have been shown successful in promoting the appropriate use of antibiotics (Ellegård, Dietrichson and Anell, 2017[36]). Prescribers who meet their performance targets will be rewarded lump-sum bonus payments corresponding to about 1% of their base salary, in addition to their base salaries. No financial penalties will be administered for primary healthcare centres that do not meet their performance targets.

It is assumed that the modelled P4P programme is associated with an 8% decline in antibiotic prescribing calculated as an average of the effect size reported in three studies that were determined to have with relatively lower/moderate risk of bias by (Yoshikawa et al., 2021[35]). One study examined the impact of the 2015/16 NHS England Quality Premium programme, which provided financial rewards to Clinical Commissioning Groups for meeting antibiotic prescribing targets like a 1% reduction in total antibiotic prescribing in primary care and a 10% decline in the share of broad-spectrum antibiotics like co-amoxiclav, cephalosporins and quinolones. This study found a 3% decline in the antibiotic prescribing rate (Bou-Antoun et al., 2018[37]). Another study from the State of California in the United States showed that two P4P programmes that provided performance bonuses to providers that meet a set of quality measures that included targets on antibiotic prescriptions. This study found that the introduction of the P4P programmes was associated with a 6% decline in preferred antibiotic use (Mullen, Frank and Rosenthal, 2010[38]). Finally, another study conducted a matched-pair cluster-randomised experiment in China between 2009 and 2012. In this study, a new P4P programme awarded bonus payments to primary care providers for meeting their performance targets that included antibiotic prescription rates, in combination with capitation payments. This intervention was associated with an approximately 15% reduction in antibiotic prescription (Yip et al., 2014[39]).

The intervention is assumed to cover 70% of prescribers who work in outpatient care settings. Based on identified evidence, it is assumed that there is a perfectly elastic relationship between antibiotic consumption and AMR rate (Kaier, Frank and Meyer, 2011[7]). This means an 8% decline in antibiotic prescribing is assumed to yield an 8% decline in AMR rate for community-based resistant infections. The beneficial effects are modelled to be sustained over the course of the simulation, which is consistent with the findings generated by Bou-Antoun and colleagues, which showed that the observed effects of the interventions remained at the same Level 2 years after the rollout of the intervention (Bou-Antoun et al., 2018[37]).

The per capita cost associated with this intervention ranges from USD PPP 0.15-8.01. The cost estimated takes into account the ingredient costs of the two streams of work. The running costs – i.e. the spending related to the bonus payment – account for most of the total intervention costs. Costs related to the strengthening of the monitoring mechanism are also included in the analysis, as well as one-off costs of developing or updating guidelines. Planning at the central and local levels as well as checks at the local level are also included in the costs.

Policies in human health to reduce the incidence of infections

Enhance hand hygiene practices

Modelled intervention

- A facility-based intervention that aims to enhance hand hygiene practices among health workers.
- The effectiveness of the modelled intervention is assumed to be associated with a 33% reduction in the incidence of healthcare-acquired infections.
- The beneficial effects of the modelled intervention are assumed to become observable immediately and persist over the course of the simulation.

A growing strand of literature points to the importance of enhancing hand hygiene for reducing the AMR burden. The protective effects of hand hygiene practices have been demonstrated again in the context of COVID-19 (Jefferson et al., 2020[40]) and previous outbreaks including SARS-CoV-1 during the 2003 epidemic and MERS-CoV (Jefferson et al., 2011[41]; Chou et al., 2022[42]). Further, one systematic review and meta-analysis of evidence generated through RCTs, cluster RCTs and quasi-experimental study designs demonstrates that hand hygiene interventions that incorporate multiple components in line with the WHO-5 moments approach achieve a greater level of compliance among health workers in comparison to interventions that rely on a single component (Luangasanatip et al., 2015[43]). Though, evidence is not yet sufficient to determine the precise combination of components within the WHO-5 moment approach that generates the highest compliance rates (Gould et al., 2017[44]).

Consistent with the emerging literature, the modelled intervention aims to enhance hand hygiene practices in healthcare settings through multiple components. The first component aims to ensure that alcohol dispensers are available throughout health facilities. In addition, in each health facility, one trained health worker per 250 beds is assumed to take up the responsibility of the IPC focal point, as recommended by the WHO. The IPC focal point will be responsible for organising and co-ordinating all educational activities around improving hand hygiene practices like developing the training curriculum and logistical materials like identifying the physical space in which the training session will take place. The selection of the IPC focal point will depend on the availability and skillset of the health workers deployed in each health facility to avoid any potential disruption in healthcare service provision.

Hand hygiene training sessions will be carried out on a regular basis throughout the simulation period, with each session lasting two-hours. Teaching materials will be consistent with the open-access IPC training course developed by the WHO, as well as the IPC Core Components. Training sessions will prioritise participation and include simulation exercises, as these teaching methods have been shown to produce greater teaching outcomes. The learning outcomes will combine both improvements in theoretical knowledge around best practices in communication with patients and practical applications. Each training session will be evaluated and updated based on feedback collected from participating health workers. The training and education programme will be supported by the distribution of informative materials (e.g. posters and brochures) in visible spaces across health facilities as a reminder of best practices. Finally, compliance with hand hygiene guidelines will be monitored and feedback will be provided.

The effectiveness of the modelled intervention is based on a systematic review of the literature conducted by the OECD. In congruence with WHO guidance, evidence generated through these studies suggests that enhancing hand hygiene practices is linked with declines in the incidence of resistant and susceptible infections. Specifically, it is assumed that the modelled intervention is associated with a 33% decline in the incidence of healthcare-acquired infections, with the estimated relative risk equivalent to 0.67 (95%CI: 0.64-0.71). It is also assumed that the scale-up of the modelled intervention does not affect the incidence of community-acquired resistant infections.

The level of coverage in the *business-as-usual* scenario was determined based on data extracted from the 2019 Hand Hygiene Self-Assessment Framework Survey conducted by the WHO (de Kraker et al., 2022[3]). The intervention is assumed to be scaled up at 70% of health facilities in each country. It is assumed that the beneficial effects become observable as soon as the intervention is scaled up and remain unchanged throughout the simulation period.

The implementation costs associated with this intervention range from USD PPP 0.02-1.06 per capita. Costs associated with this intervention include the purchase of supplies to ensure the handwashing practices comply with the WHO guidelines (e.g. sufficient supplies of alcohol-based hand rub or liquid soap), training on best practices in hand hygiene, expenses associated with developing informational materials, as well as administrative costs at the national and local levels to support the implementation of the intervention across healthcare services. The estimated costs also include monitoring and evaluation arrangements to ensure smooth implementation of the programme at the healthcare facility level.

Enhance environmental hygiene practices

Modelled intervention

- A bundled intervention that aims to enhance environmental hygiene practices in hospitals.
- The modelled intervention is assumed to reduce the risk of infection by 26% in hospital settings.
- The beneficial effects are assumed to become observable immediately and persist over the course of the simulation.

Broadly, environmental hygiene practices can be grouped into three broad categories (Donskey, 2013[45]):

- *Disinfectant product substitution: S*hifting to disinfectants that have shown greater effectiveness against pathogens (e.g. substituting sporicidal products with non-sporicidal products).
- *No-touch disinfection methods:* Using of hydrogen peroxide vapour, aerosol devices and ultraviolet (UV) radiation devices.
- *Strategies that aim to improve the effectiveness of existing cleaning and disinfection practices:* training of cleaning staff members to improve daily and terminal cleaning, and checklists to guide environmental cleaning practices.

The modelled intervention is a hospital-based programme that aims to enhance routine cleaning practices through the introduction of a bundled intervention that combines all three broad categories of environmental hygiene practices. Specifically, the first component of the intervention will entail the substitution of disinfectant products already being used in health facilities with those that have shown greater effectiveness in line with the WHO guidance. The second component will involve the introduction of no-touch disinfection methods as part of the terminal cleaning of rooms/areas in between occupying patients. These two components will be complemented with a one-hour training programme for staff members who are responsible for environmental cleaning. This training will provide information and recommendations on cleaning techniques, frequency of cleaning and best practices in environmental cleaning. The environmental cleaning activities will be audited by a designated hospital staff member on a regular basis.

For this intervention, the individual-level effectiveness was quantified by the OECD based on a systematic review of the studies that focused on the implementation of the three groups of environmental hygiene categories discussed earlier compared to traditional environmental cleaning practices. Based on this review, it is assumed that enhancing environmental hygiene practices in hospital settings is associated with a 26% reduction in the risk of acquiring hospital-acquired infections, with relative risk equivalent to 0.74 (95%CI: 0.72, 0.76).

The level of coverage in the *business-as-usual* scenario was calculated using data gathered from studies that use information from the 2019 Infection Prevention and Control Assessment Framework Survey conducted by the WHO (Tomczyk et al., 2022[4]). The intervention is assumed to be adopted by 70% of hospitals in each country. It is assumed that the intervention results in reductions in the incidence of infections acquired in healthcare settings. The impact of the intervention is assumed to become observable immediately and the protective effects are assumed to remain constant over time.

The per capita cost of the modelled intervention varies from USD PPP 0.71-5.06. The estimated costs are calculated as a combination of national and local level administrative costs, the procurement of disinfectant products in line with WHO guidelines, expenses associated with environmental cleaning training and regular audits.

Improve vaccination coverage

Modelled intervention

- Scale up of nationwide campaign of 23-valent pneumococcal polysaccharide (PVV23) targeting older adults
- The modelled intervention is associated with a 64% decline in the incidence of all serotypes of invasive pneumococcal disease and pneumococcal pneumonia
- The effectiveness is assumed to be sustained over the course of the simulation

The modelled intervention consists of a nationwide vaccination campaign targeting older adults to provide protection against *Streptococcus pneumoniae (S. pneumoniae)*, an opportunistic pathogen which can result in severe illness and failures in medical treatment. It is estimated that about 30% of infections caused by this pathogen are resistant to at least one antibiotic. Though data on the burden of *S. pneumoniae* remains limited, data collated from countries in the WHO European Region in 2020 suggested that, compared to previous years, the number of *S. pneumonia* isolates was lower (ECDC/WHO, 2022[46]). However, the available evidence points to large cross-country variations. For instance, in 2020, in European countries like Austria, the Netherlands and the Czech Republic, the proportion of *S. pneumonia* isolates that have increased exposure or resistance to penicillin remained at or below 5%, whereas this figure stood at least 25% in countries like Cyprus, France, Iceland, Malta, Romania and Türkiye (ECDC/WHO, 2022[46]).

Pneumococcal vaccines offer one effective strategy to curb the burden of *S. pneumonia.* To date, the scale-up of pneumococcal vaccines has been associated with reductions in the incidence of infections and slow the pace with which pneumococcal resistance occurs (Pavia et al., 2009[47]; CDC, 2019[48]). In many OECD countries, various pneumococcal vaccines are recommended for children under 5 years of age, as well as adults with certain health risks and older adults.

Over the last two decades, many OECD countries made important strides in improving pneumococcal conjugate vaccine (PCV) coverage among young children, with the coverage of PCV3 vaccine averaging at 87% in 2020 among OECD countries and key partners, EU/EEA and G-20 countries. In comparison, the coverage of the vaccine PVV23 vaccine among older adults remains relatively low and varied, with the estimated coverage standing at about 74% in Japan in 2018 (Naito et al., 2020[49])to 24% in Greece in 2019 (Papagiannis et al., 2020[50]).

The vaccination programme is conceptualised to have three components. The first component involves scaling up the availability of PVV23 vaccines in health facilities. The second component involves a vaccination campaign which will entail developing and disseminating informational materials that target the general public's understanding and knowledge of the benefits associated with PVV23 vaccines. This awareness campaign is assumed to rely heavily on promotional materials disseminated in mass media outlets (e.g. television, radio) and social media platforms. Additionally, the update of the vaccines among the target population will be regularly monitored.

The individual-level effectiveness estimates were extracted from a recent literature review and meta-analysis conducted by Falkenhorst and colleagues (Falkenhorst et al., 2017[51]). In their review, the authors identified studies conducted primarily in OECD countries to quantify the effectiveness of PVV23 vaccine among adults at the age of 60 and above. Building on this review, it is assumed that the efficacy of the PPV23 vaccine is 64% (95%CI: 35-80%) against all serotypes of invasive pneumococcal disease and pneumococcal pneumonia.

The level of vaccination coverage in the *business-as-usual* scenario was determined based on a review of the publicly available data sources whenever possible. For countries for which this information was not available, it was assumed that approximately 50% of adults at the age of 65 and older assumed have already received their PVV23 vaccines, reflecting the average of PVV23 vaccine coverage among countries where data were available. It is assumed that the modelled vaccination campaign will aim to cover 90% of adults at the age of 60 and above, reflecting recommended vaccination schedules in many OECD countries (ECDC, 2022[52]). The intervention is assumed to have immediate beneficial impacts, which are sustained over the simulation period.

The per capita cost of this intervention is calculated to vary between USD 0.03-0.57. The estimated costs reflect expenses associated with administrating the vaccination campaign at the national and central levels including costs to cover the time of health workers who administer vaccines, costs associated with the purchase of vaccines and the development and dissemination of informational materials. In addition, the estimated costs also include monitoring the uptake of the vaccines among the target population at the local and national levels.

Policies to promote AMR awareness and understanding

Enhance health professional training on enhanced communication skills

Modelled intervention

- A training programme for health professionals to improve communication skills during consultations with their patients in outpatient care settings.
- The modelled intervention is associated with a 39% reduction in antibiotic prescribing.
- The effectiveness of the intervention is assumed to remain unchanged over time.

Several strands of literature focusing on professional education and training programmes suggest that these programmes are linked to improvements in AMR-relevant behaviours, including antibiotic prescribing patterns (Davey et al., 2017[25]), greater compliance with hand hygiene (Gould et al., 2017[44])and IPC guidelines (Chou et al., 2022[42]). In recent years, a growing body of evidence further point to the potential benefits of professional education and training programmes that focus on improving communication between prescribers and patients on antibiotic use. Broadly, these training programmes attempt to improve health professionals' communication skills relevant to eliciting patient beliefs and expectations; clarifying any misconceptions around antibiotic use; and conveying the potential benefits and harms associated with the use of antibiotics, as well as self-medication (Coxeter et al., 2015[53]). A recent Cochrane review showed that educational interventions aiming to improve communication between prescribers and patients in outpatient care settings can help reduce antibiotic prescribing for acute respiratory infections in the tune of 39% within six weeks of the first consultation, with a risk ratio equivalent to 0.61 (95%CI: 0.55-0.68) (Coxeter et al., 2015[53]).

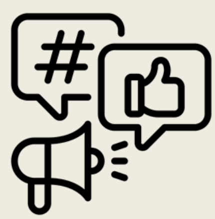
The modelled intervention is conceptualised as a training programme, with the aim of improving communication skills among prescribers in outpatient care settings. Two-hour communication training sessions will be carried out in the winter and/or autumn months on a regular basis. Teaching materials will focus on improving proficiency in communication during consultations and skills in building rapport with patients. Teaching sessions will aim to improve providers' awareness of methods to assess and modify patients' beliefs and expectations about the use of antibiotics; and teach techniques to communicate with patients on prognosis and treatment options, as well as communicating benefits and harms associated with antibiotic use and self-medication. During each training session, active participation and simulation exercises will be prioritised. Learning outcomes will measure improvements in both theoretical knowledge and practical communication skills. Informative materials such as posters and brochures will be made available in visible areas within health facilities to serve as best practice reminders. A feedback programme will be put in place to ensure the training sessions result in the improvement of communication skills among providers.

The individual-level effectiveness estimates were extracted from the Cochrane review conducted by Coxeter and colleagues (Coxeter et al., 2015[53]). In line with this review, it is assumed that the modelled intervention results in a 39% reduction in antibiotic prescribing. The same Cochrane review found that the beneficial effects of the intervention may wane after 12 months, though these results were not statistically significant (Coxeter et al., 2015[53]). In recognition of these findings, the modelled intervention is assumed to have an immediate beneficial impact on health worker communication skills and the beneficial impacts are modelled to remain the same over the simulation period.

For each country, the level of coverage in the *business-as-usual* scenario was identified based on data retrieved from the 2020-21 Tripartite AMR Self-Assessment Survey based on the question that investigates the extent to which AMR training and education opportunities are available in each country (See Question 2 in Annex B). It is assumed that 70% of health facilities will roll out the modelled communication training and all prescribers that work in these facilities will be enrolled in the training sessions.

The per capita cost of this intervention is estimated to range from USD PPP 0.05-0.86. Intervention costs comprise expenses associated with developing the training at the national level and delivering it at the local level. In addition, the preparation and the printing of the material to be provided to participants are included in the total intervention cost as well as some administrative costs at the national and local levels. Expenses associated with building and administrating the feedback programme are also included. Conversely, the intervention costs do not include the time spent by participants on the training as this is assumed to be part of regular training activities for these workers (e.g. as part of continuing medical education initiatives that are normal practice across many OECD countries.)

Scale up mass media campaigns



Modelled intervention

- The modelled intervention is a nationwide mass media campaign involving mass media and social media platforms to raise AMR understanding and awareness across key stakeholders.
- The modelled mass media campaign is assumed to result in a 7% decline in antibiotic prescription.
- The effectiveness is assumed to be sustained over the course of the simulation.

Among OECD countries, mass media campaigns are a frequently used tool to raise awareness and understanding of AMR among health professionals and the general public (Rogers Van Katwyk et al., 2019[54]). Typically, these campaigns aim to demonstrate the beneficial and harmful effects of antibiotic use and attempt to improve knowledge and understanding of good prescribing practices.

Despite the ubiquity of campaigns to raise AMR awareness and understanding in the general public, the effectiveness of these programmes on behaviours around antibiotic use has not yet been well understood (Rogers Van Katwyk et al., 2019[54]). A handful of studies suggest modest improvements attributable to AMR awareness campaigns, though many of the studies should be interpreted with care due to methodological concerns. To date, one non-randomised controlled trial from Italy showed that a community-level awareness campaign led to a 4.3% decline in antibiotic prescribing in areas that received the intervention in comparison to the areas that did not receive a community-wide awareness campaign (Formoso et al., 2013[55]). Another study from the United Kingdom found a 5.8% decline in antibiotic reduction in areas where two mass media campaigns disseminated information on the appropriate use of antibiotics, in comparison to areas that did not receive any antibiotic-relevant information (Lambert, Masters and Brent, 2007[56]; Formoso et al., 2013[55]). In the United States, a community-wide, year-long

AMR awareness campaign in the State of Tennessee led to an 11% decline in antibiotics prescribed to children compared to the communities that did not roll out similar community-wide interventions (Perz, 2002[57]).

The modelled intervention is designed as a nationwide mass media campaign that aims to improve AMR awareness and understanding in the general population. It is conceptualised as an AMR awareness campaign carried out annually, though the majority of the activities are assumed to take place in winter/autumn months when there is a peak in antibiotic consumption often for influenza-like illnesses that do not require antibiotic use. The awareness campaign entails developing several toolkits that contain communication tools and key messages tailored for various target audiences like health professionals in human health, pharmacists and to the general public. Materials targeting the general public will focus primarily on considerations around self-medication and the safe disposal of antibiotics. The modelled intervention will rely not only on mass media outlets (e.g. television, radio, print media etc.) but also on social media platforms). The use of social media platforms reflects the growing evidence from OECD countries that the Internet and social media platforms are widely used by people who are seeking antibiotic-related information (Zucco et al., 2018[58]). In addition, public health agencies will make guidelines and recommendations around the appropriate use of antibiotics available online through their websites.

The national-wide mass media campaigns are assumed to lead to a modest reduction in antibiotic prescription in the tune of 7% based on the average effect size emerging from existing studies (Perz, 2002[57]; Lambert, Masters and Brent, 2007[56]). The intervention is assumed to be scaled up nationally, reaching about 70% of all relevant stakeholders in the human health sector including health professionals and the general public. Under the assumption that the relationship between AMR rate and antibiotic consumption is perfectly elastic (Kaier, Frank and Meyer, 2011[7]), the estimated decline in antibiotic prescription is modelled to result in a 7% decline in AMR rate for community-based infections. The modelled intervention is assumed not to influence the incidence of healthcare-acquired infections (HAIs) and susceptible infections acquired in the community.

For each country, the 2020-21 Tripartite AMR Self-Assessment Survey was used to set the level of coverage in the business-as-usual scenario based on the question that investigates the stage of implementation of activities to raise awareness and understanding of AMR risks and response (see Question 3 in Annex 6.B). It is assumed that the beneficial effects are realised as soon as the campaign is launched and remain unchanged over time.

The per capita cost of this intervention is estimated to vary from USD PPP 0.40 to USD PPP 1.36. The estimated costs are driven primarily by buying advertising space on mass media outlets, followed by the costs of devising and planning the campaign at the local and national levels.

Policies outside of human health sector to reduce the incidence of infections

Enhance farm hygiene

Modelled intervention

- The modelled intervention is a procurement programme that facilitates the purchase of PPE in farm settings by farmers and professional visitors like veterinarians.
- The modelled intervention is associated with a 12% reduction in the risk of infection.
- The protective effects are assumed to become observable immediately and remain unchanged over time.

In recent years, a strand of literature increasingly examined the role of farm-level biosecurity measures in preventing the emergence and spread of infections in farm settings. For instance, one systematic review demonstrated that a range of biosecurity measures, including handwashing, sanitisation and hygienic measures, scaling up the use of PPE, animal vaccines and other specific interventions like using automatic milking, can yield protective effects against infections (Youssef et al., 2021[59]).

The modelled intervention is conceptualised as the introduction of a regulatory framework that aims to improve the availability of PPE in farm settings in line with the International Labour Organization (ILO) Code of Practice on Safety and Health in Agriculture (ILO, 2011[60]). This intervention involves a novel programme which will help facilitate the purchase of PPE that can be used by farmers and technical visitors like veterinarians. Reflecting the evidence from the literature, the PPE includes farm boots, work clothes worn upon arrival to the farm and outfits for professional visitors. The use of the PPE will be complemented by the development and dissemination of brochures and posters that will be distributed to each farm to serve as a reminder of the importance of wearing PPE in the farm setting. Compliance with the intervention will be monitored through yearly audits, where 10% of farms will be selected for in-person visits by auditors.

It is assumed that the modelled intervention is associated with a 12% reduction in the risk of infection (RR = 0.88, 95% CI: 0.81-0.96) among farmers and professional visitors like veterinarians. This estimate was calculated by the OECD as a combination of two studies included in a systematic review conducted by Youssef et al. (2021[59]). In one study from dairy goat farms in the Netherlands, Schimmer et al. found that consistently wearing boots and protective clothing by farm staff was associated with a 16% reduction in the risk of *Coxiella burnettii* infection (RR = 0.84, 95% CI: 0.72-0.98) (Schimmer et al., 2012[61]). In a subsequent study, Schimmer et al. (2014[62]) also showed that, in dairy cattle farms in the Netherlands, the use of farm boots and work clothes by professional visitors was associated with a 9% reduction in the risk of *Coxiella burnettii* infection (RR = 0.91, 95% CI: 0.80-1.03) and wearing work clothes among farm workers was associated with a 12% reduction in the risk of the same infection (RR = 0.88, 95% CI: 0.72-0.98). In addition, several scenarios that rest on different assumptions of spill-over effects of this intervention beyond farmers and professional visitors will be conducted.

The business-as-usual coverage was identified based on data retrieved from the 2020-21 Tripartite AMR Self-Assessment Survey and on the question that assesses the stage of implementation of good health, management, and hygiene practices in animal production (see Question 4 in Annex 6.B). The target coverage is set at 70%. It is assumed that the protective effects of enhancing hygiene practices in farm settings become observable immediately and remain unchanged over time.

The per capita costs associated with this intervention are estimated to vary between USD PPP 0.02 and USD PPP 0.73. The estimated costs reflect expenses associated with the administration of the programme at the national and local levels and the cost of developing, printing and disseminating information materials. In addition, costs also cover expenses due to developing monitoring and evaluation arrangements at the national and local levels to ensure a high degree of compliance with the intervention. Conversely, costs associated with the purchase of PPE are excluded because these are considered to be purchased directly by farms.

Enhance food handling practices

Modelled intervention

- A food safety control training programme targes food service workers in food establishments, coupled with visual reminders and regular audits based on checklists.
- The rollout of the modelled intervention results in a 28.6% reduction in microbial count.
- The protective effects are assumed to become observable immediately and sustained over time.

Food safety policies are an effective option to help prevent foodborne illnesses in food establishments. A growing body of literature suggests that a range of food safety and hygiene policies, referred to as hazard analysis and critical control points (HACCP)-based interventions, can help reduce the emergence of foodborne illnesses throughout the food supply chain (FDA, 1997[63]). In particular, interventions focusing on meal preparation have become the focus of many studies in recent years (Young et al., 2019[64]; 2020[65]). These studies demonstrated that educational interventions targeting food handlers were associated with improvements in self-reported knowledge, attitudes and practices, though substantial variation exists in the effect size of these interventions (Young et al., 2020[65]). Importantly, emerging studies broadly concur that multi-faceted interventions yield greater beneficial impacts than interventions that rely on a single component (Gillison et al., 2018[66]).

The modelled intervention is conceptualised as a HACCP-based food safety control training programme targeting food service workers in food establishments. The intervention entails providing one hour of training on a regular basis by a trainer who has expertise in HACC systems. The training will focus on personal hygiene, food preparation and storage. In addition to the training programme, posters and reminders would be made available to the food service workers in order to reinforce the lessons learned during the training sessions. The third component involves regular audits, where a trained person visits food establishments for visual inspection of the tasks performed by food service workers. These inspections will also include a checklist of questions related to facilities (e.g. availability of soap dispensers, paper towels, waste management), staff hygiene and preparation and storage of food (e.g. measures taken to avoid cross contamination), prerequisites and control activities (e.g. pest control) and administrative matters (e.g. recording of activities).

In a systematic review and meta-analysis recently published in a peer-reviewed journal, the OECD found that, in a sample of OECD countries, the rollout of food safety interventions in catering establishments was associated with a 28.6% reduction in microbial count, with relative risk equivalent to 0.71 (95% CI: 0.69-0.73) (Levy, Cravo Oliveira Hashiguchi and Cecchini, 2022[67]). Importantly, findings from this analysis further concluded that microbial reductions were consistently observed across different types of microorganisms screened, sample origin and type of food establishment.

The business-as-usual coverage was determined through the 2020-21 Tripartite Country Self-Assessment Survey based on each country's response to the question that inquires whether there are good management and hygiene practices in place to reduce the development and transmission of AMR in food processing (see Question 5 in Annex 6.B). It is assumed that the intervention will be taken up by 70% of food establishments. The protective effect of the modelled intervention is assumed to become observable immediately and sustained over the simulation period. This assumption was made based on the finding from Levy, Cravo Oliveira Hashiguchi and Cecchini that showed that microbial reductions continued to be observed regardless of the time elapsed between the introduction of the intervention and sample collection (Levy, Cravo Oliveira Hashiguchi and Cecchini, 2022[67]).

The per capita cost of this training ranges from USD PPP 0.08 to USD PPP 0.78. Intervention costs include all three components of the intervention, namely costs related to providing training to food service workers, the preparation and printing of the educational material as well as administrative and enforcement costs at the national and local levels.

Annex 6.B. Calculating the level of coverage in the business-as-usual scenarios

The questions and response categories from the 2020-21 Tripartite AMR Country Self-Assessment Survey used to determine the level of coverage in the business-as-usual scenarios of modelled interventions are as follows (Annex Table 6.B.1):

Annex Table 6.B.1. Questions from the 2020-21 Tripartite AMR Country Self-Assessment Survey used to inform the OECD analysis

Modelled intervention	Survey questions	Response categories
Question 1: Strengthen ASPs	Optimising antimicrobial use in human health	A. No/weak national policies for appropriate use. B. National policies for antimicrobial governance developed for the community and healthcare settings. C. Practices to ensure appropriate antimicrobial use are being implemented in some healthcare facilities and guidelines for the appropriate use of antimicrobials are available. D. Guidelines and other practices to enable appropriate use are implemented in most health facilities nationwide. Monitoring and surveillance results are used to inform action and to update treatment guidelines and essential medicines lists. E. Guidelines on optimising antibiotic use are implemented for all major syndromes and data on use are systematically fed back to prescribers.
Question 2: Enhance health professional training on enhanced communication skills	Training and professional education on AMR in the human health sector	A. No training for human health workers on AMR. B. Ad hoc AMR training courses in some human health-related disciplines. C. AMR is covered in: i) some pre-service training; and ii) some in-service training or other continuing professional development (CPD) for human health workers. D. AMR is covered in pre-service training for all relevant cadres. In-service training or other continuing professional development covering AMR is available for all types of human health workers nationwide. E. AMR is systematically and formally incorporated in pre-service training curricula for all relevant human health cadres. In-service training or other CPD on AMR is taken up by relevant groups for human health nationwide, in public and private sectors.
Question 3: Scale up mass media campaigns	Raising awareness and understanding of AMR risks and response	A. No significant awareness-raising activities on relevant aspects of risks of antimicrobial resistance. B. Some activities in parts of the country to raise awareness about the risks of antimicrobial resistance and actions that can be taken to address it. C. Limited or small-scale antimicrobial resistance awareness campaigns targeting some but not all relevant stakeholders. D. Nationwide, government-supported antimicrobial resistance awareness campaign targeting all or the majority of priority stakeholder groups, based on stakeholder analysis, utilising targeted messaging accordingly within sectors. E. Targeted, nationwide government-supported activities regularly implemented to change the behaviour of key stakeholders within sectors, with monitoring undertaken over the last 2-5 years.
Question 4: Enhance farm hygiene	Good health, management and hygiene practices in animal production	A. No systematic efforts to improve good production practices. B. Some activities in place to develop and promote good production practices. C. National plan agreed to ensure good production practices in line with international standards (e.g. World Organisation for Animal Health Terrestrial and Aquatic Animal Health Codes, Codex Alimentarius). Nationally agreed guidance for good production practices developed, adapted for implementation at the local farm and food production levels. D. Nationwide implementation of a plan to ensure good production practices and national

Modelled intervention	Survey questions	Response categories
		guidance published and disseminated. E. Implementation of the nationwide plan is monitored periodically.
Question 5: Enhance food handling practices	Good management and hygiene practices to reduce the development and transmission of AMR in food processing	A. No systematic efforts to improve good management and hygiene practices. B. Some activities in place to develop and promote good management and hygiene practices. C. The national plan agreed to ensure good management and hygiene practices in line with international standards (e.g. Codex Alimentarius). Nationally agreed guidance for good practices developed, and adapted for implementation according to local food processing approaches. D. Nationwide implementation of a plan to ensure good management and hygiene practices and national guidance published and disseminated. E. Implementation of the nationwide plan is monitored periodically.

7 Antimicrobial resistance in long-term care facilities

This chapter analyses the complex threat posed by antimicrobial resistance (AMR) in long-term care facilities (LTCFs). After reporting on the latest data and trends on AMR in LTCFs, it presents findings from an OECD survey on policies in place across up to 34 European Union (EU) and European Economic Area (EEA) members and OECD countries. Results from the survey identify a number of gaps, particularly related to current surveillance systems and policies to promote prudent use of antibiotics and prevent infections. Finally, the chapter concludes by making the case for more piloting of policy actions specifically designed and adapted to LTCFs.

Key findings

- Antimicrobial resistance (AMR) in long-term care facilities (LTCFs) is a complex threat not only to residents and staff of LTCFs but also to broader communities. When staff, visitors and residents move in and out of LTCFs, so do organisms, including resistant pathogens.
- Residents of LTCFs are at a higher risk of healthcare-associated infections (HAIs) compared to community-dwelling older adults.
  - On average across OECD countries for which point prevalence survey (PPS) data are available, in 2016-18, about 3.8% of residents in participating LTCFs had an HAI.
  - On average across OECD countries for which data are available, in 2016-17, almost one in three isolates from HAIs among LTCF residents were resistant to first-line antimicrobial treatments.
  - LTCF residents in Australia and England (United Kingdom) were two to four times more likely than community-dwelling older adults to have resistant infections or isolates.
- Many residents of LTCFs receive multiple courses of antibiotics each year.
  - On average across OECD countries for which PPS data are available, in 2016-17, around 5% of LTCF residents had at least one systemic antibiotic prescription on survey dates.
  - Based on an analysis of period prevalence estimates from nine countries, between 1985 and 2017, 62% of residents of LTCFs used at least one antibiotic over a period of 12 months.
  - Despite it being crucial to ensure that antibiotics are used wisely, up to one in four antibiotic prescriptions in LTCFs are unnecessary or inappropriate. Moreover, in Europe, between 54% and 96% of antibiotic prescriptions in LTCFs are given without laboratory or diagnostic testing, not always in alignment with evidence-based guidelines.
- Many countries have legislation and policies to tackle AMR in LTCFs but there are important gaps in the effective use of antimicrobial stewardship programmes (ASPs) and infection prevention and control (IPC) practices.
  - Just over half of EU/EEA and OECD countries (17 out of 33) report having a national action plan on AMR that specifically references LTCFs.
  - In most countries, there are no guidelines, protocols or requirements for the adoption of ASP in LTCFs, with only 3 out of 20 countries having guidelines, protocols or requirements for the adoption of budgets dedicated to ASP in LTCFs.
  - Four in 5 countries (21 out of 26) report having guidelines, protocols or requirements for the adoption of IPC programmes or protocols in LTCFs, but only 12 out of 25 countries report having a process of surveillance/audit of IPC policies in LTCFs.
- Data on antibiotic use and AMR in LTCFs can i) help guide the development of lists of antibiotics that should be preserved, ii) enable benchmarking, auditing and goal setting, and iii) be used to assess the impact of policy actions to tackle inappropriate antibiotic use as well as AMR in LTCFs. Yet, data on antibiotic consumption and AMR in LTCFs are not yet widely available and routine surveillance is still limited in most countries.
  - Just over a third of countries (9 out of 25) conduct surveillance of antibiotic consumption in LTCFs, and only 32% (8 out of 25 countries) conduct surveillance of AMR in LTCFs.
  - About 40% (9 out of 23 countries) conduct surveillance of HAIs and 50% (12 out of 24 countries) have surveillance of multidrug-resistant organisms.

- Fewer than 1 in 5 (4 out of 23 countries) report having surveillance of indicators of ASP and 22% (6 out of 23 countries) have surveillance of indicators of IPC in LTCFs.
- Moreover, existing data suffer from important limitations, such as the lack of a standard unit of measurement for antibiotic use, and a heavy reliance on PPSs, which suffer from limitations, including seasonal variations and cross-country differences in sampling.
- Tackling AMR in LTCFs is a key part of addressing the threat of AMR more broadly, but responses to this challenge must acknowledge that LTCFs have different needs and face different risks compared to acute care hospitals. It is positive that 28 countries (out of 28) report that they plan to include references to long-term care (LTC) in their next national action plan on AMR, making it clear that AMR and inappropriate antibiotic use in LTCFs require targeted policy actions. Policy options for countries to consider include:
    - Setting up routine surveillance systems that can collect and report data on antibiotic use and AMR in LTCFs. Routine surveillance is essential to establish a baseline situation, design policies that are fit for LTCFs, and monitor and evaluate the impact of those policies.
    - Promoting the design, implementation and effective use of ASPs that are fit for LTCFs, including more integration with prescribers (e.g. general practitioners), better feedback on antibiotic use and AMR profiles, regular training and a budget dedicated to ASP.
    - Incentivising adoption and compliance with IPC practices that are tailored to LTCFs, emphasising the need for budgets specifically earmarked for IPC, creation of IPC committees and adoption of procedures for surveillance and auditing of IPC processes in LTCFs.
- Many countries (e.g. Belgium, France, Greece, Ireland and Portugal) do not mandate, incentivise or monitor the adoption of ASP and IPC in LTCFs. While guidelines and centralised policy advice are helpful, these may be insufficient to ensure change at scale. Many LTCFs face enormous challenges, from staff shortages to limited financial resources, to significant and complex demands from their residents. Financial strategies targeting healthcare providers to promote the prudent use of antibiotics have been shown to improve the appropriateness of antibiotic prescribing in various healthcare settings and a combination of well-funded mandates and financial incentives may be a way forward.
- More work is needed to understand what policies are most effective in what contexts (e.g. which financial strategies are most effective in LTCFs) and countries seeking to improve antibiotic consumption and minimise the threat of AMR in LTCFs should make greater use of pilot projects and experimentation, coupled with monitoring and evaluation.

Why a special focus on AMR in LTCFs?

Many factors come together to make AMR in LTCFs an especially challenging threat, not only to residents and staff of LTCFs but also to broader communities in which these facilities are located.

First, the majority of LTCF residents are older (i.e. aged 65 years and over) and frail, and many have multiple comorbidities, often suffering from incontinence, disorientation, malnourishment, limited mobility and pressure ulcers. Caring for residents with multiple comorbidities can require the use of invasive devices such as gastronomy feeding tubes and indwelling urinary catheters. Frailty, comorbidities and use of invasive devices are all factors that make residents of LTCFs more susceptible to HAIs, including from resistant organisms, compared to older people living in the community (Bonomo, 2000[1]; Moyo et al., 2020[2]; Tandan et al., 2018[3]; Nicolle, 2001[4]). Box 7.1 provides an overview of the definition of LTC used in this report, the types of LTCFs included, and how the definition and scope of the paper affect the interpretation of the key findings.

Second, while many infections are preventable, IPC practices are more difficult to implement effectively in LTCFs than in acute care hospitals. Most IPC policies are designed for closed systems, such as hospital wards in acute care hospitals, but LTCFs are different from acute care hospitals in important ways that require IPC programmes to be modified and tailored (Marra et al., 2018[5]; Oberjé, Tanke and Jeurissen, 2016[6]). Residents of LTCFs are encouraged to socialise and share communal spaces as a way to promote good mental health and well-being (Mody et al., 2015[7]). Some residents of LTCFs have cognitive impairments; they may suffer from disorientation, wander and be less willing to use personal protective equipment (Auditor General of Ontario, 2009[8]). Stays at LTCFs are also typically much longer than stays in acute care hospitals. To add to these challenges, LTCFs tend to have more limited budgets, often have lower staff-to-resident ratios and fewer staff qualified in IPC compared to acute care hospitals (Stone et al., 2018[9]). Certain IPC measures, such as isolation, can be difficult to implement in LTCFs and may lead to depressive symptoms and reduced quality of life among residents (Loeb et al., 2001[10]; Schora et al., 2014[11]) and may be ineffective if not well designed (e.g. targeted at high-risk situations).

Third, because LTCF residents are at a higher risk of HAIs, antibiotics are frequently prescribed to residents, not only to treat but also often to prevent, infections. Many residents of LTCFs receive multiple courses of antibiotics each year (Stuart, Lim and Kong, 2014[12]; Nicolle et al., 2000[13]). AMR evolves naturally because of antibiotic use and the more antibiotics are used, the less effective they become (OECD, 2018[14]). It is thus crucial to ensure that antibiotics are used wisely. Yet, up to one in four antibiotic prescriptions in LTCFs are unnecessary or inappropriate in terms of not only the duration and choice of therapy but also the need for therapy in the first place (Furuno and Mody, 2020[15]; Patterson et al., 2019[16]). In Europe, between 54% and 96% of antibiotic prescriptions in LTCFs are given without laboratory or diagnostic testing (Latour et al., 2012[17]; Szabó and Böröcz, 2014[18]). Antibiotics are commonly used in LTCFs for asymptomatic urinary tract infections, even though randomised controlled trials suggest that this offers no benefit and may promote AMR (Zabarsky, Sethi and Donskey, 2008[19]). Inappropriate use of antibiotics is associated with high rates of multidrug-resistant organisms recovered in LTCFs, rates which are comparable to those in acute care hospitals (Bonomo, 2000[1]; Nicolle, 2014[20]; Cassone and Mody, 2015[21]; Suetens et al., 2018[22]).

Fourth, due to the greater propensity for HAIs among LTCF residents, challenges in implementing good IPC practices and high rates of inappropriate antibiotic use, residents of LTCFs are more likely to be infected with resistant pathogens, including multidrug-resistant organisms, compared to community-dwelling older adults (Cassone and Mody, 2015[21]). For example, in a large retrospective cohort study of individuals aged 70 years and older in England (United Kingdom), residents of LTCFs were over four times more likely than community-dwelling older adults to have laboratory-confirmed resistant *Escherichia coli* or *Klebsiella* urinary tract infections (Rosello et al., 2017[23]). In another study of community-dwelling older adults and LTCF residents, aged 65 years and older, who visited emergency departments and outpatient clinics in Australia, methicillin resistance among *Staphylococcus aureus* isolates from LTCF residents was more than double than those from community-dwelling adults (Xie et al., 2012[24]).

Box 7.1. LTCFs: Definitions, scope and implications

What is long-term care or LTC?

While the exact definition of LTC does differ from country to country, its main goal can be defined as supporting individuals who have a degree of long-term functional or cognitive disability to live as independently and safely as possible (OECD/Eurostat/WHO, 2017[25]). This type of care can be provided at home (e.g. home care), in the community (e.g. day care) and in LTCFs. While people of any age may require LTC, most care recipients are aged 65 years and older.

What types of LTCFs are included in this chapter?

Residential homes, general nursing homes and mixed LTCFs that mainly provide care for older adults are included in this chapter, under the umbrella of LTCFs.

- *Residential homes* are also known as personal care homes, assisted living facilities, aged care facilities or care homes. Residents of these facilities are unable to live independently and typically require help with (instrumental) activities of daily living such as personal care, housekeeping and meal preparation.
- *General nursing homes* are facilities that care for older people with severe illness or injuries, requiring skilled nursing care 24 hours a day. They many also include nursing homes specialised in a specific type of care such as physical impairment, dementia, psychiatric illness, rehabilitation, intensive or palliative care.
- *Mixed LTCFs* are a combination of residential homes and general nursing homes. Facilities for the mentally and physically disabled, rehabilitation centres, day care centres and palliative care centres are excluded, as are acute care hospitals, primary, community or outpatient healthcare settings.

Implications of definitions and scope on the interpretation of findings in this chapter

There are cross-country differences in the types of services provided by LTCFs and the individual needs that they seek to meet. While these differences may help explain differences in the prevalence of AMR in LTCFs, it is challenging to capture these differences empirically. Moreover, these differences may also lead to variations in measuring antibiotic use in different countries (van Buul et al., 2020[26]). Further research is needed to characterise the provision of care in LTCFs and how this provision relates to antibiotic use and AMR in LTCFs.

Source: OECD/Eurostat/WHO (2017[25]), *A System of Health Accounts 2011: Revised edition*, https://doi.org/10.1787/9789264270985-en.

Fifth, and finally, surveillance and monitoring of antibiotic use and AMR in LTCFs are limited. Without accurate, timely and detailed data, many policy options are not available or not effective. Data on antibiotic use and AMR in LTCFs can help guide the development of lists of antibiotics that should be preserved, they can enable benchmarking, auditing and goal setting, and they can be used to assess the impact of policy actions to tackle inappropriate antibiotic use as well as AMR in LTCFs. Despite this, data on antibiotic consumption and AMR in LTCFs are not yet widely available and routine surveillance is still limited in most countries (Haenen et al., 2019[27]).

Inappropriate antibiotic use and AMR in LTCFs are not just a problem for LTCFs, as they can have negative spill-overs into the broader community, putting wider populations at risk of AMR. When staff, visitors and residents move in and out of LTCFs, so do organisms, including resistant pathogens. As a result, AMR in

LTCFs is a threat to not only LTCF residents but also to local communities in which facilities are located. Movement of residents between LTCFs and acute care hospitals is especially important, with one study conducted in the United States finding that in a 15-month period, 4.4 million admissions to LTCFs came from acute care hospitals and 2.1 million discharges from LTCFs were to acute care hospitals (Kahvecioglu et al., 2014[28]). Moreover, there are also opportunities for LTCF staff to spread organisms as they often work at multiple sites (van den Dool et al., 2016[29]). LTCFs are thus important reservoirs of AMR and multidrug-resistant organisms (Augustine and Bonomo, 2011[30]; Nucleo et al., 2018[31]).

Tackling AMR and inappropriate antibiotic use in LTCFs is a key part of addressing the threat of AMR more broadly. Crucially, public responses to this challenge must take into account the specificities of LTCFs, acknowledging that these facilities have different needs and face different risks compared to acute care hospitals. This chapter provides an overview of trends in AMR and the use of antibiotics in LTCFs in OECD countries, presents the results of a new survey on country actions to address AMR and inappropriate antibiotic use in LTCFs, and proposes strategies that countries may adopt to tackle the threat of AMR in LTCFs.

Trends in antibiotic consumption and resistance in LTCFs

In the last decades, it has become increasingly clear that AMR in LTCFs is an area of concern. Studies going back to the late 1980s explored the appropriateness of antibiotic therapy in LTCFs and the potential for the emergence of resistant strains and the spread of infections from LTCFs to other healthcare settings (Jones et al., 1987[32]; Warren et al., 1991[33]; Zervos, 1987[34]). Since then, there have been multiple studies and surveys focusing on LTCFs seeking to quantify antibiotic use, appropriateness of antibiotic use and AMR. Chief amongst these surveys are the multiple point prevalence surveys conducted at the national and cross-country levels (e.g. by the European Centre for Disease Prevention and Control, ECDC).

Notwithstanding this long history of previous work, benchmarking and assessing trends in antibiotic use and AMR in LTCFs continues to present challenges due to a lack of a standard unit of measurement for antibiotic use (Fulchini et al., 2019[35]) and an aggregate measure of AMR. For example, metrics used in different studies include defined daily doses per 1 000 resident days (Marra et al., 2017[36]), the percentage of LTCF residents nationally that received at least one antibiotic in a 12-month period (Thornley et al., 2019[37]) and days of therapy per 100 regimens (Peron et al., 2013[38]). The variables monitored in these studies as well as the units of measurement differ so much that comparisons across studies are very difficult.

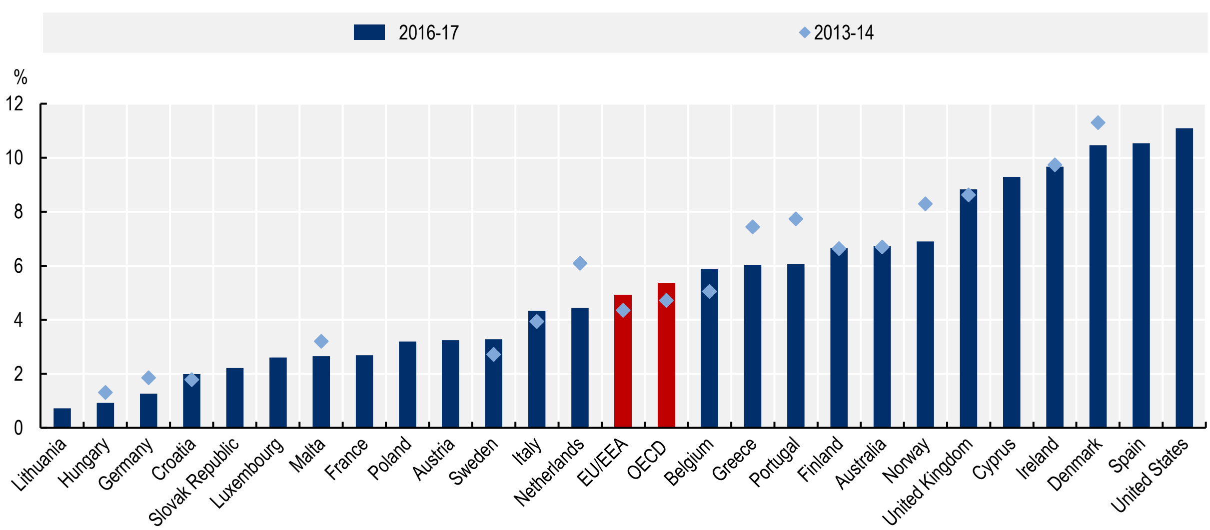
Moreover, most country-level data on antibiotic use and AMR in LTCFs are collected through PPSs but these may not provide a true representation of infection prevalence or antibiotic use for a number of reasons. For example, PPSs can be affected by seasonal variations, with more infections being reported in colder months compared to warmer months (Lee et al., 2019[39]). Like any other survey, participation may be lower in some subgroups (e.g. countries), which may affect the representativeness of results. The ECDC, the United States Centers for Disease Control and Prevention (CDC), the Australian Commission on Safety and Quality in Health Care and many other governmental agencies in OECD countries, have conducted PPSs in LTCFs. Across these different studies, and even within each study, the average age of LTCF residents surveyed varied widely. In participating LTCFs in the EU/EEA, residents aged 85 years and older ranged from 12% in Lithuania to over 60% in France (ECDC, 2014[40]; Suetens et al., 2018[22]). In Australia, 59.5% of residents were aged 85 years and older (ACSQHC, 2019[41]). There is also variation in other factors relevant to antibiotic use and AMR, such as the use of urinary catheters and recent surgery (Suetens et al., 2018[22]). Differences in these and other factors can naturally lead to differences in the prevalence of infections, consumption of antibiotics and AMR proportions. The trends presented in this section should thus be interpreted with caution.

Trends in antibiotic consumption in LTCFs

On average across OECD countries for which PPS data are available (specifically Australia, England [United Kingdom], the United States and OECD countries in the EU/EEA), in 2016-17, around 5% of LTCF residents had at least 1 systemic antibiotic prescription on survey dates, ranging from 0.7% in Lithuania to 10.5% in Denmark and Spain (Figure 7.1). In 2013 (in Australia and OECD countries in the EU/EEA), a cross-country average of 4.7% of LTCF residents had at least one systemic antibiotic prescription on survey dates, ranging from 1.3% in Hungary to 11.3% in Denmark.

Figure 7.1. Antibiotic prescriptions in LTCFs in EU/EEA and OECD countries, in 2013-14 and 2016-17 (or closest years)

Percentage of residents with at least one systemic antibiotic prescription on survey dates (see note)



Note: Australian surveys were held in 2017 and 2018, and the US survey was from 2013-14. In the United Kingdom, England did not participate in the 2016-17 survey and Scotland did not participate in the 2013 survey. A PPS for England (United Kingdom) conducted at the end of 2017 has reported that 6.3% of LTCF residents on the survey date were on at least one antibiotic (Thornley et al., 2019[37]); these data are not included in the figure as it was not possible to determine comparability with the 2016-17 ECDC survey. In 2013, within-country data representativeness was poor or very poor in Croatia, England (United Kingdom), Finland, Greece, Malta, the Netherlands, Norway and the United States.
Source: Ricchizzi, E. et al. (2018[42]), "Antimicrobial use in European long-term care facilities: Results from the third point prevalence survey of healthcare-associated infections and antimicrobial use, 2016 to 2017", https://doi.org/10.2807/1560-7917.ES.2018.23.46.1800394; ECDC (2014[40]), *Point Prevalence Survey of Healthcare-associated Infections and Antimicrobial Use in European Long-term Care Facilities April to May 2013*, https://doi.org/10.2900/24172; Thompson, N. et al. (2016[43]), "Prevalence of antimicrobial use and opportunities to improve prescribing practices in U.S. nursing homes", https://doi.org/10.1016/j.jamda.2016.08.013; ACSQHC (2019[41]), 2*018 Aged Care National Antimicrobial Prescribing Survey Report*, Australian Commission on Safety and Quality in Health Care.

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The average EU/EEA prevalence of antibiotics was 4.9%, similar to that reported in previous similar surveys that report data on HAIs in LTCFs from 2010 (4.3%) and 2013 (4.4%) (Ricchizzi et al., 2018[42]). As in previous ECDC surveys, approximately one-third of all antibiotic prescriptions were for prophylactic use (Ricchizzi et al., 2018[42]). In the 2018 Australian PPS, 6.7% of residents in participating LTCFs were prescribed an oral antibiotic on the day of the survey, the same rate as the previous 2017 survey and 27% of all antibiotics were for prophylactic use (ACSQHC, 2019[41]). The latest Aged Care National Antimicrobial Prescribing Survey, from 2019, found prolonged prophylaxis for conditions where this is not recommended by guidelines, an issue of concern, which was thought to require urgent attention (ACSQHC, 2021[44]). In the United States, 11.1% of residents in participating LTCFs received at least one antibiotic on the survey date (Thompson et al., 2016[43]). In England (United Kingdom), in 2017, about 6.3% of LTCF residents on the survey date were on at least one antibiotic (Thornley et al., 2019[37]).

According to an analysis by Raban et al. (2021[45]) of 19 period prevalence estimates from 9 countries (including Australia, the United Kingdom, the United States and EU/EEA countries) between 1985 and 2017, the percentage of residents of LTCFs that used at least one antibiotic over a period of 12 months ranged from 45% to 79%, with a pooled estimate of 62%. Box 7.2 briefly discusses how the COVID-19 pandemic has affected antibiotic use in LTCFs and how consumption may change in the longer term.

Box 7.2. The impact of the COVID-19 pandemic on antibiotic use in LTCFs

Overall, antibiotic use in LTCFs seems to have decreased during the COVID-19 pandemic but consumption may rebound as countries move towards "living with the virus"

During the first wave of COVID-19, there was significant uncertainty and there was a surge in the use of antibiotics to treat COVID-19 patients (Beović et al., 2018[46]; Pelfrene, Botgros and Cavaleri, 2021[47]). Around three in every four COVID-19 patients were given antibiotics (Langford et al., 2021[48]; Rawson et al., 2020[49]), yet only around 4% of COVID-19 patients actually had a bacterial coinfection (Strathdee, Davies and Marcelin, 2020[50]). On the other hand, a higher proportion of around 14% of COVID-19 patients did acquire nosocomial infections, especially those patients requiring intensive care (Strathdee, Davies and Marcelin, 2020[50]), and these types of infections tended to be multidrug resistant (Khurana et al., 2021[51]).

A study of antibiotic use data from 1944 LTCFs in the United States noted a 16% reduction in overall antibiotic use between January and June 2020 – compared to the 9% seasonal decrease observed in 2019 – and a 4% reduction in October 2020 compared to October 2019 (Gouin et al., 2021[52]). However, there was an overall increase in antibiotics commonly used for respiratory tract infections (Gouin et al., 2021[52]). The authors posited that the reduction in antibiotic use in LTCF might have been attributable to changes in the resident population during the pandemic and lower rates of elective procedures, which may have affected rates of short-stay residents who require skilled nursing care after discharge and typically use more antibiotics. Increased use of IPC measures (e.g. physical distancing, mask use) in the second and subsequent waves of the pandemic may have also led to the lower transmission of bacterial infections and consequently lower antibiotic use in LTCFs.

Apparent reductions in antibiotic use during the pandemic could be reversed as countries move towards "living with the virus" and as non-pharmaceutical interventions are relaxed or even abandoned altogether. Moreover, the impact of post-COVID-19 condition (colloquially known as long COVID), with its associated risks of loss of longitudinal function and cognitive decline on the already weakened immune systems of LTCF residents, remains unclear.

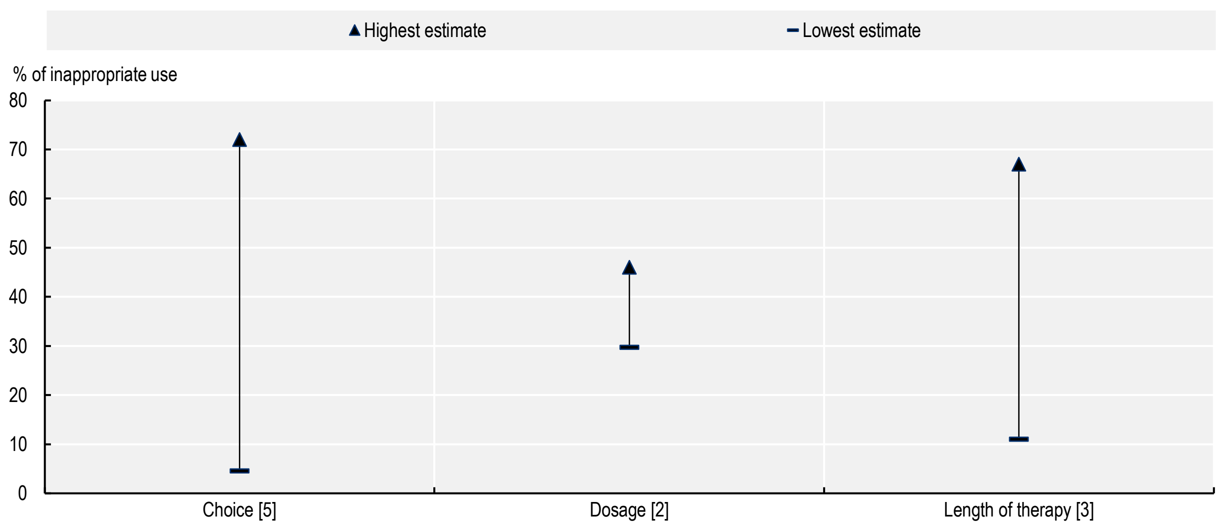
Source: Beović, B. et al. (2018[46]), *Antibiotic Prescribing in Long-term Care Facilities for the Elderly*, https://www.euro.who.int/__data/assets/pdf_file/0004/386419/evipnet-euro-slovenia-no3-eng.pdf (accessed on 29 October 2020); Pelfrene, E., R. Botgros and M. Cavaleri (2021[47]), "Antimicrobial multidrug resistance in the era of COVID-19: A forgotten plight?", https://doi.org/10.1186/S13756-021-00893-Z; Rawson, T. et al. (2020[49]), "Bacterial and fungal coinfection in individuals with coronavirus: A rapid review to support COVID-19 antimicrobial prescribing", https://doi.org/10.1093/CID/CIAA530; Langford, B. et al. (2021[48]), "Antibiotic prescribing in patients with COVID-19: Rapid review and meta-analysis", https://doi.org/10.1016/J.CMI.2020.12.018; Strathdee, S., S. Davies and J. Marcelin (2020[50]), "Confronting antimicrobial resistance beyond the COVID-19 pandemic and the 2020 US election", https://doi.org/10.1016/S0140-6736(20)32063-8; Khurana, S. et al. (2021[51]), "Profile of co-infections & secondary infections in COVID-19 patients at a dedicated COVID-19 facility of a tertiary care Indian hospital: Implication on antimicrobial resistance", https://doi.org/10.1016/J.IJMMB.2020.10.014; Gouin, K. et al. (2021[52]), "Trends in prescribing of antibiotics and drugs investigated for coronavirus disease 2019 (COVID-19) treatment in US nursing home residents during the COVID-19 pandemic", https://doi.org/10.1093/cid/ciab225.

The appropriateness of antibiotic prescribing in LTCFs

Estimates vary, but a significant share (up to 75%) of antibiotic prescriptions in LTCFs are considered unnecessary or inappropriate, as seen in Figure 7.2 (Loeb, 2003[53]; Morrill et al., 2016[54]; Beović et al., 2018[46]; Furuno and Mody, 2020[15]; Patterson et al., 2019[16]). Antibiotics can be inappropriate based on their indication, choice, dosage and length of therapy.

Figure 7.2. A significant share of antibiotic prescriptions in LTCFs are considered inappropriate

Estimated proportion of inappropriate antibiotic prescriptions by choice, duration and length of therapy



Note: Where indicated, criteria for inappropriate use: Loeb, McGeer, CDC FDA Guidelines, Consensus criteria, literature and patient chart reviews. Numbers in square brackets indicate the number of studies used to determine the range of inappropriate use. Assessing the appropriateness of antibiotic prescribing in LTCFs is not without challenges. Guideline-based criteria such as the McGeer criteria are widely used but they were developed for infection surveillance purposes and are highly specific rather than sensitive (McGeer et al., 1991[55]; van Buul et al., 2015[56]). In addition, resident chart reviews may be unreliable because residents often receive antibiotics without any documented signs or symptoms of infection (ACSQHC, 2019[41]). This lack of documentation hinders efforts to assess the appropriateness of antibiotic use in LTCFs.

Source: OECD analysis based on Loeb (2003[53]), “Risk factors for resistance to antimicrobial agents among nursing home residents”, https://doi.org/10.1093/aje/kwf173; Morrill et al. (2016[54]),”Antimicrobial stewardship in long-term care facilities: A call to action”, http://doi.org/10.1016/j.jamda.2015.11.013; Noević et al. (2018[46])“Antibiotic Prescribing in Long-term Care Facilities for the Elderly”, https://www.euro.who.int/__data/assets/pdf_file/0004/386419/evipnet-euro-slovenia-no3-eng.pdf; Furuno and Mody (2020[15]), “Several roads lead to Rome: Operationalizing antibiotic stewardship programs in nursing homes”, http://doi.org/10.1111/jgs.16279; Patterson et al. (2019[16]) “Evidence of a care home effect on antibiotic prescribing for those that transition into a care home: A national data linkage study”, http://doi.org/10.1017/s0950268818003382.

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Inappropriate initiation of antibiotics occurs when antibiotic therapy was not indicated for the clinical condition being treated, as when prescribing antibiotics for a viral infection or for an asymptomatic urinary tract infection (Morrill et al., 2016[54]). Inappropriate choice of antibiotics occurs when an antibiotic is inappropriate for the infection indicated. For example, quinolones are the highest priority antibiotics recommended only in the case of resistance, or for serious infections, yet they are commonly used to treat uncomplicated urinary tract infections (Bergman, Schjøtt and Blix, 2011[57]). Incorrect dosage of antibiotics, and prolonged or inadequate length of therapy, also constitute inappropriate use. In LTCFs, prolonged use of antibiotics is far more prevalent than inadequate length of therapy and is often contrary to guideline recommendations (ACSQHC, 2019[41]). An example is a high rate and prolonged use of prophylactic antibiotics for urinary tract infections in LTCFs, which inevitably selects for resistant organisms (Daneman et al., 2011[58]; Stuart, Lim and Kong, 2014[12]; Lee et al., 2012[59]). Factors associated with inappropriate prescribing in LTCFs are discussed in Box 7.3.

One unintended consequence of high rates of antibiotic use in LTCFs is infection with *Clostridioides difficile* (Jump and Donskey, 2014[60]). Residents of LTCFs who receive inappropriate antibiotics may be eight times more likely to develop a *C. difficile* infection compared to those who receive appropriate therapy (Rotjanapan, Dosa and Thomas, 2011[61]). These infections are associated with extended hospital stays, increased costs and further use of antibiotics (Guerrero et al., 2011[62]; Chopra and Goldstein, 2015[63]), potentially leading to a vicious cycle.

Box 7.3. Factors associated with inappropriate use of antibiotics in LTCFs

Unnecessary and inappropriate use of antibiotics in LTCFs have been associated with a combination of factors, from factors related to residents and their relatives to factors related to prescribers, facilities, healthcare systems and countries.

Resident factors

In the elderly, typical signs and symptoms of infection are often absent or diminished, and cognitive impairment among residents may reduce their ability to communicate symptoms (Furuno and Mody, 2020[15]; Hedin et al., 2002[64]). This may lead to diagnostic uncertainty for prescribing physicians and impedes effective empirical diagnosis (Cassone and Mody, 2015[21]). Residents and their family members may also request antibiotics, against the advice of their healthcare practitioners (Kistler et al., 2013[65]).

Prescriber factors

Some physicians may be more likely to prescribe certain antibiotics, and for longer periods (seven days or longer) even though most common infections can be treated with antibiotic courses of seven or fewer days (Daneman et al., 2013[66]). Perceived risks such as fear of treatment failure and the emergence of secondary infection, particularly in older chronic patients, may also contribute to inappropriate prescribing (Vazquez-Lago et al., 2011[67]).

Long-term care facility factors

Fragmented access to visiting medical staff, lack of continuity of care for LTCF residents, high staff turnover, limited access to microbiological labs and rapid diagnostic testing, lack of onsite pharmacists and reliance on nursing staff to communicate resident symptoms, are all LTCF factors that contribute to inappropriate prescribing (ECDC, 2014[40]; Lim et al., 2014[68]; Nicolle et al., 2000[13]).

Healthcare system factors

Healthcare system and wider organisational characteristics, from poor continuity of care to limited access to resident files, may also contribute to the inappropriate use of antibiotics (Lim et al., 2014[68]). Residents of LTCFs often visit other healthcare facilities, such as the emergency room in acute care hospitals and outpatient clinics in the community. Physicians at these healthcare facilities may be unfamiliar with the specific needs and history of residents and are more likely to prescribe antibiotics inappropriately compared to prescriptions written by the residents' usual physicians (Pulia et al., 2018[69]).

Country-level factors

The inappropriate use of antibiotics in LTCFs varies across countries. Some countries may lack data on local resistance patterns, or LTCF-specific guidelines, which may help to reduce inappropriate antibiotic use (Dyar, Pagani and Pulcini, 2015[70]; Tandan et al., 2018[3]). In the United States, fear of litigation may lead to the practice of defensive medicine and contribute to the inappropriate use of antibiotics (Fleming et al., 2015[71]).

Source: Furuno, J. and L. Mody (2020[15]), "Several roads lead to Rome: Operationalizing antibiotic stewardship programs in nursing homes", https://doi.org/10.1111/jgs.16279; Hedin, K. et al. (2002[64]), "Asymptomatic bacteriuria in a population of elderly in municipal institutional care", https://doi.org/10.1080/028134302760234627; Cassone, M. and L. Mody (2015[21]), "Colonization with multidrug-resistant organisms in nursing homes: Scope, importance, and management", https://doi.org/10.1007/s13670-015-0120-2; Kistler, C. et al. (2013[65]), "Challenges of antibiotic prescribing for assisted living residents: Perspectives of providers, staff, residents, and family members", https://doi.org/10.1111/jgs.12159; Daneman, N. et al. (2013[66]), "Prolonged antibiotic treatment in long-term care", https://doi.org/10.1001/jamainternmed.2013.3029; Vazquez-Lago, J. et al. (2011[67]), "Attitudes of primary care physicians to the prescribing of antibiotics and antimicrobial resistance: A qualitative study from Spain", https://doi.org/10.1093/fampra/cmr084; (ECDC, 2014[40]). Lim, C. et al. (2014[68]), "Antimicrobial stewardship in residential aged care facilities: Need and readiness assessment", https://doi.org/10.1186/1471-2334-14-410; Nicolle, L. et al. (2000[13]), "Antimicrobial use in long-term-care facilities", https://doi.org/10.1086/501798; Pulia, M. et al. (2018[69]), "Comparing appropriateness of antibiotics for nursing home residents by setting of prescription initiation: A cross-sectional analysis", https://doi.org/10.1186/s13756-018-0364-7; Dyar, O., L. Pagani and C. Pulcini (2015[70]), "Strategies and challenges of antimicrobial stewardship in long-term care facilities", https://doi.org/10.1016/j.cmi.2014.09.005; Tandan, M. et al. (2018[3]), "Antimicrobial prescribing and infections in long-term care facilities (LTCF): A multilevel analysis of the HALT 2016 study, Ireland, 2017", https://doi.org/10.2807/1560-7917.ES.2018.23.46.1800278; Fleming, A. et al. (2015[71]), "Antibiotic prescribing in long-term care facilities: A meta-synthesis of qualitative research", https://doi.org/10.1007/s40266-015-0252-2.

Empirical antibiotic prescribing and prophylactic use in LTCFs

Between 54% and 96% of antibiotic prescriptions in LTCFs are estimated to be empirical, meaning they are prescribed based on prescriber experience and patient signs and symptoms, often while waiting for confirmation of results from laboratory testing (Latour et al., 2012[17]; Szabó andBöröcz, 2014[18]). This type of prescribing may be appropriate in certain clinical situations but there are a number of risks with empirical therapies and it is important to ensure therapies are in line with evidence-based guidelines on diagnosis and treatment. Drawbacks of empirical therapies include therapy lasting longer than necessary (Boivin et al., 2013[72]; Dyar, Pagani and Pulcini, 2015[70]), treatment failure due to prescribers using experience rather than antibiograms (Hughes et al., 2016[73]) and frequent use of broad-spectrum antibiotics (Cassone and Mody, 2015[21]).

The use of antibiotics for prophylaxis in LTCFs is common, especially for urinary tract infections. As previously mentioned, approximately one in three antibiotic prescriptions are for prophylactic use in EU/EEA countries and Australia (ACSQHC, 2019[41]; HALT Study Group, 2018[74]). Prophylactic use can have benefits, for example reducing recurrent urinary tract infections in female residents of LTCFs, yet it is also associated with higher proportions of resistant bacteria isolated in urine and faeces from residents (HALT Study Group, 2018[74]).

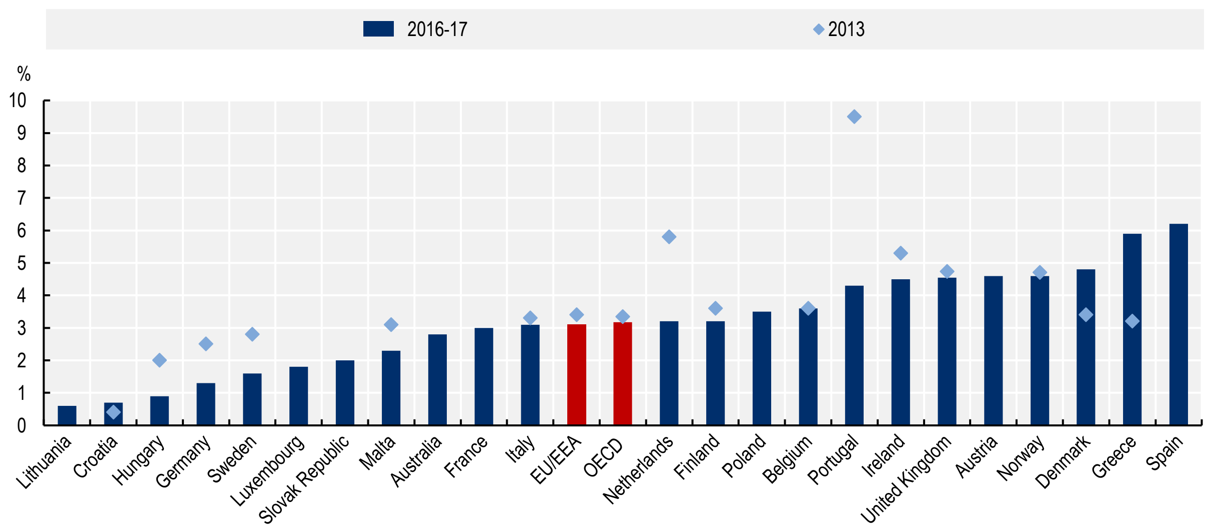
Trends in antibiotic resistance in LTCFs

On average across OECD countries for which PPS data on AMR are available (specifically Australia, England [United Kingdom] and OECD countries in the EU/EEA), in 2016-17 (2018 in Australia) about 3.8% of residents in participating LTCFs had an HAI on the days the surveys were conducted (Figure 7.3). In 2013, the average was 3.3% (excluding Australia). The percentages of residents of LTCFs with an HAI on the days of the surveys ranged from 0.9% in Lithuania to 8.5% in Spain in 2016-17 (it is worth noting that Lithuania had one of the lowest shares of participants over the age of 85).

The average EU/EEA rate of HAIs among LTCF residents was 1.02 infections per infected resident and 1.2 infections per infected resident in Australia (ECDC, 2014[40]; Suetens et al., 2018[22]; ACSQHC, 2019[41]). Most infections were associated with the LTCF where the survey was conducted (84.7% in the EU/EEA and 80.1% in Australia). Annual estimates from the EU/EEA indicate that acute care hospitals and LTCFs have a similar prevalence of HAIs (Suetens et al., 2018[22]).

Figure 7.3. HAIs among LTCF residents in participating EU/EEA and OECD countries, in 2013 and 2016-17 (or closest year)

Percentage of residents surveyed in point prevalence surveys with at least one infection on survey dates (see note)



Note: Australian PPS was held in 2017, while ECDC PPS were held in 2013 and 2016-17. In the United Kingdom, England did not participate in the 2016-17 survey and Scotland did not participate in the 2013 survey. In 2016-17, within-country data representativeness was poor in Austria, Croatia, Cyprus, Greece, Luxembourg, Malta and Poland. In 2013, within-country data representativeness was poor or very poor in Croatia, England (United Kingdom), Finland, Greece, Malta, the Netherlands and Norway. Differences in infections across countries should be interpreted with caution due to differences in sampling (e.g. age of participants). Only HAIs associated with residents' own facilities are shown.
Source: ECDC (2014[40]), *Point Prevalence Survey of Healthcare-associated Infections and Antimicrobial Use in European Long-term Care Facilities April to May 2013*, https://doi.org/10.2900/24172; Suetens, C. et al. (2018[22]), "Prevalence of healthcare-associated infections, estimated incidence and composite antimicrobial resistance index in acute care hospitals and long-term care facilities: Results from two European point prevalence surveys, 2016 to 2017", https://doi.org/10.2807/1560-7917.ES.2018.23.46.1800516; ACSQHC (2019[41]), *2018 Aged Care National Antimicrobial Prescribing Survey Report*, Australian Commission on Safety and Quality in Health Care.

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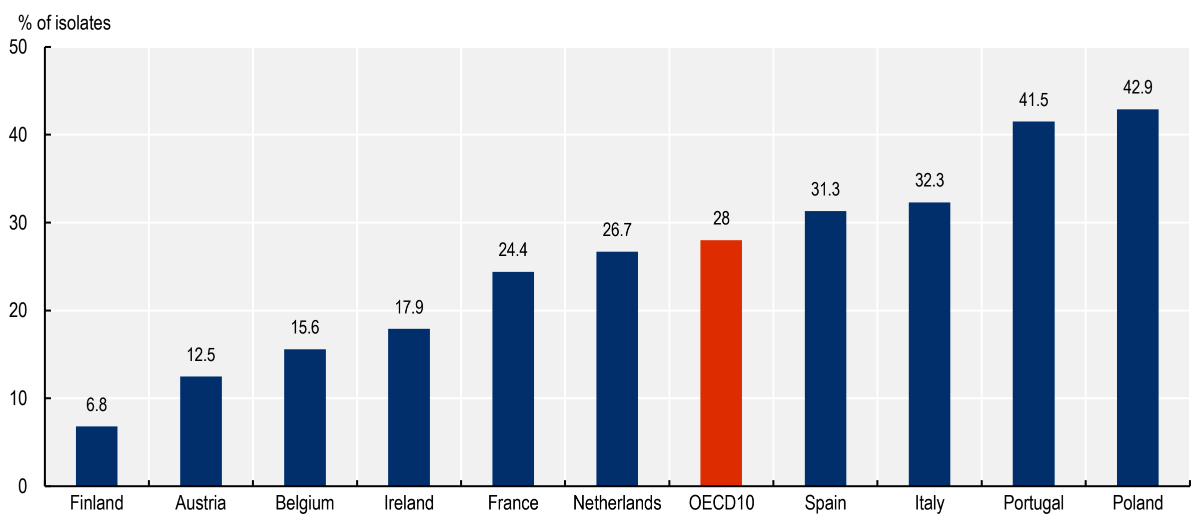
Resistance to first-line antibiotic treatments in LTCFs is high

On average across OECD countries for which the ECDC Composite Index of AMR is available, in 2016-17, almost one in three isolates from HAIs among LTCF residents were resistant to first-line antibiotic treatments (Figure 7.4). The percentages of isolates resistant to first-level AMR markers in HAIs from LTCF residents ranged from 6.8% in Finland to 42.9% in Poland (Suetens et al., 2018[22]). As with the prevalence of HAIs, an analysis of the ECDC Composite Index of AMR shows that LTCFs and acute care hospitals have similar levels of AMR. The ECDC Composite Index of AMR – a drug resistance index – is the percentage of isolates from HAIs that are resistant to first-level AMR markers.[1] A drug resistance index is a composite measure that combines the ability of antibiotics to treat infections with the extent of their use in clinical practice. A drug resistance index can be interpreted as the probability of inadequate treatment given observed drug use (Laxminarayan and Klugman, 2011[75]; Hughes et al., 2016[73]). While limitations with PPSs (e.g. country representativeness and low testing frequency in LTCFs) should be considered, these high proportions of AMR in LTCFs are a cause for concern.

Resistance to first-line antibiotics means that second- and third-line antibiotics are increasingly needed and used. The more antibiotics are used, the more selective pressure on common pathogens there is, potentially leading to the emergence of resistant organisms (Capitano and Nicolau, 2003[76]; Cassone and Mody, 2015[21]) and growing resistance to second- and third-line treatments. For example, in the United States, rising numbers of carbapenem-resistant *K. pneumoniae* isolates are being found in LTCFs (Braykov et al., 2013[77]). In a period of 11 years, the percentage of *K. pneumoniae* isolates resistant to carbapenems and third-generation cephalosporins increased from 5.3% to 11.5% (Braykov et al., 2013[77]). An Italian study of urine cultures from LTCF residents found a prevalence of carbapenem-resistant *Enterobacteriaceae* among LTCF residents of 20% (Marinosci et al., 2013[78]). Moreover, the prevalence of carbapenem-resistant *Enterobacteriaceae* may be underestimated because of the heterogeneous expression of resistance (El-Halfawy and Valvano, 2015[79]), which makes it difficult to detect this pathogen during routine cultures (Hajogrundmannrivmnl et al., 2010[80]; Van Dulm et al., 2019[81]).

Figure 7.4. ECDC Composite Index of AMR in isolates from HAIs among LTCF residents in participating OECD countries, 2016-17

The ECDC Composite Index is the percentage of isolates resistant to first-level AMR markers in HAIs



Note: The percentage of resistance was not calculated if less than ten isolates were reported.
Source: Suetens, C. et al. (2018[22]), "Prevalence of healthcare-associated infections, estimated incidence and composite antimicrobial resistance index in acute care hospitals and long-term care facilities: Results from two European point prevalence surveys, 2016 to 2017", https://doi.org/10.2807/1560-7917.ES.2018.23.46.1800516.

StatLink https://stat.link/vhl8wd

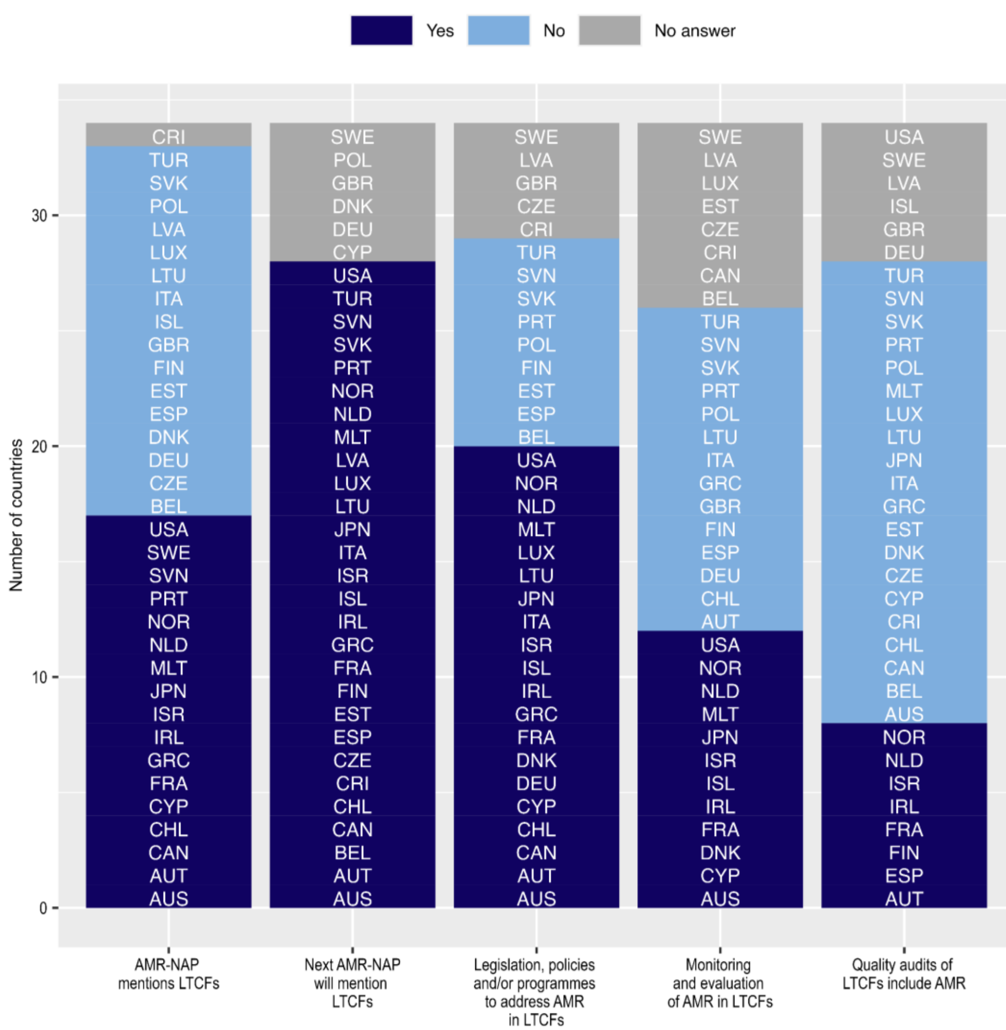
Country responses to AMR in LTCFs

Many countries have legislation and policies to tackle AMR in LTCFs but fewer countries have a process to audit the quality of care in LTCFs that includes ASP and IPC indicators. According to a new OECD survey (see Box 7.4 for more details), just over half of reporting[2] EU/EEA and OECD countries (52%; 17 out of 33 countries) report having a national action plan on AMR that specifically references LTCFs, while 28 countries (out of 28 reporting countries) report planning to include references to LTC in their next national action plan on AMR (Figure 7.5). A higher number of countries (69%; 20 out of 29 reporting countries) report having legislation, policies and/or programmes aimed at addressing AMR in LTCFs, beyond national action plans. Around half (46%; 12 out of 26 reporting countries) have monitoring and evaluation plans focusing specifically on LTCFs.

Box 7.4. OECD Survey on Antibacterial Resistance in LTCFs, 2021-22

Based on a rapid review of surveys of AMR in LTCFs (including, for example, the ECDC's PPS), the OECD designed a new Survey on Antibacterial Resistance in Long-Term Care Facilities for circulation to EU/EEA and OECD countries. The survey focused on actions by central governments related to antibacterial resistance in LTCFs, with sections specifically on ASP in LTCFs, IPC in LTCFs, surveillance in LTCFs, the impact of COVID-19 on addressing AMR in LTCFs, challenges that countries face in tackling AMR in LTCFs, and finally data and indicators. The survey instrument was reviewed by experts at the ECDC and the World Health Organization and piloted by representatives from two countries. The questionnaire was sent to countries in October 2021 and responses were accepted until September 2022. A total of 34 countries, including both EU/EEA and OECD countries, participated in the survey. More details on participation in the survey are provided in Annex 7.A.

Figure 7.5. Overview of policies and legislation from central governments to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22



Note: AMR-NAP – National Action Plan on Antimicrobial Resistance; LTCFs – long-term care facilities; AMR – antimicrobial resistance.
Source: Analysis of OECD Survey on Antibacterial Resistance in LTCFs (2021-22).

A third of countries (32%; 9 out of 28 reporting countries) report having a process to audit the quality of care provided in LTCFs that includes indicators related to ASP or IPC. In France, the national missions co-ordinated by Public Health France develop national audit tools, with associated IPC indicators. These audit tools are made available to ASP and IPC regional centres and teams that may provide expert support to LTCFs using data and digital tools to drive quality improvements. Among the indicators of IPC and ASP included in the audit process are indicators of hand hygiene, as well as faecal and respiratory transmission. Proxy indicators on the appropriateness of antibiotic prescribing have been developed and will be collected at the national level in the near future. No incentives (e.g. pay for performance, certification) are currently attached to auditing or monitoring activities but this is a topic under discussion.

In Ireland, as part of its statutory responsibility for setting standards for health and social services, the Health Information and Quality Authority monitors the quality of care provided in LTCFs and is currently developing an inpatient survey for LTCFs. National standards for IPC in community services published by the Health Information and Quality Authority in 2018 are applicable to LTCFs. The Medicines Management Programme and the Antimicrobial Resistance and Infection Control team in the Health Service Executive have developed a preferred antibiotics initiative referred to as the Green/Red antibiotic list. Antimicrobial guidelines for community prescribers recommend the preferred use of “green” agents, which are effective, have fewer side effects and are less likely to lead to resistant infections than “red” agents. Red-green reports are sent to all general practitioners on a quarterly basis including to LTCFs that are serviced by these general practitioners. No incentives are currently in use.

In Lithuania, the National Public Health Centre performs periodic external audits (inspections), assessing compliance with different national hygiene regulations. In Finland, local municipalities make audit visits to private LTCFs from which they purchase services, and regional authorities perform random audits. In Israel, the audit process includes hand hygiene, environmental cleaning and isolation measures for patients infected or colonised with multidrug-resistant organisms. Portugal reports not having a process to audit the quality of care provided in LTCFs that includes indicators related to ASP or IPC, but the Directorate General of Health monitors standard basic precautions such as hand hygiene and glove use. Both Belgium and Greece are developing systems to audit the quality of care in LTCFs. In Greece, the National Agency for Quality Assurance in Health has established indicators for patient safety that include staffing levels, skills and training for LTCF workers but this has not yet been operationalised.

Addressing AMR in LTCFs is not without challenge, with many countries reporting a number or hurdles to the design, adoption and effectiveness of policy actions related to AMR in LTCFs (Box 7.5).

Box 7.5. Countries face challenges in tackling AMR in LTCFs

Countries report significant challenges in addressing AMR in LTCFs, from staff shortages to limited financial resources, to significant and complex demands from LTCF residents.

Scarcity of LTCF-specific surveillance data

Countries report a lack of LTCF-specific surveillance data on infections, antibiotic use and AMR in LTCFs. In Canada, Italy and Portugal, central-level surveillance data are needed to assist in developing recommendations and guidelines for LTCFs. In Ireland, feedback mechanisms for antibiotic use and an AMR surveillance system in LTCFs are needed.

Communication between providers in LTCFs and other healthcare settings

Multiple prescribers and inadequate communication among healthcare workers in LTCFs create a fragmented model for healthcare delivery that contributes to inappropriate antibiotic prescribing and hinders the implementation of ASP and IPC. In France, there are multiple prescribers in LTCFs and, in

Germany, a lack of communication between LTCF staff and general practitioners and specialists hinders the effectiveness of ASPs. In Slovenia, better dissemination of data from LTCFs and collaboration are required and, in Canada, improved communication protocols are needed within provincial health networks. In Italy, information from LTCFs is not shared with the central level and, in Israel, computer systems in LTCFs do not interface with systems in acute care hospitals.

Staffing shortages and insufficient training of long-term care staff

Widely reported staff shortages and insufficiently trained LTCF staff are important barriers to the implementation of ASP and IPC in LTCFs. In Austria, Belgium, Israel, Italy, Japan, Malta, Portugal and Slovenia, LTCFs are understaffed and lack staff trained in ASP and IPC. In Lithuania, there is a shortage of medical staff in LTCFs.

Challenges related to infrastructure

In some countries, LTCFs are ageing structures with outdated infrastructure, layouts with long corridors far from nursing stations, multi-occupancy rooms and a majority do not have access to microbiological laboratories. In Malta, there is no screening before antibiotics are prescribed in LTCFs. In Slovenia, general practitioners working in LTCFs often prescribe antibiotics empirically which leads to unnecessary use. In Ireland, there is a need to integrate ASP as part of routine medication management. In Ireland and Israel, many LTCFs have multi-occupancy rooms in public LTCFs, making IPC practices challenging.

Lack of guidelines and resource constraints

Italy reports a lack of LTCF-specific guidelines to diagnose and treat common infections and in Austria, Belgium and Malta, budget constraints are a barrier to implementing ASPs and IPC. Many countries do not mandate, incentivise or monitor the adoption of ASPs and IPC in LTCFs. For example, in Belgium, France, Greece, Ireland and Portugal, there are no incentives or mandates to ensure compliance or adoption of ASPs or IPC measures in LTCFs.

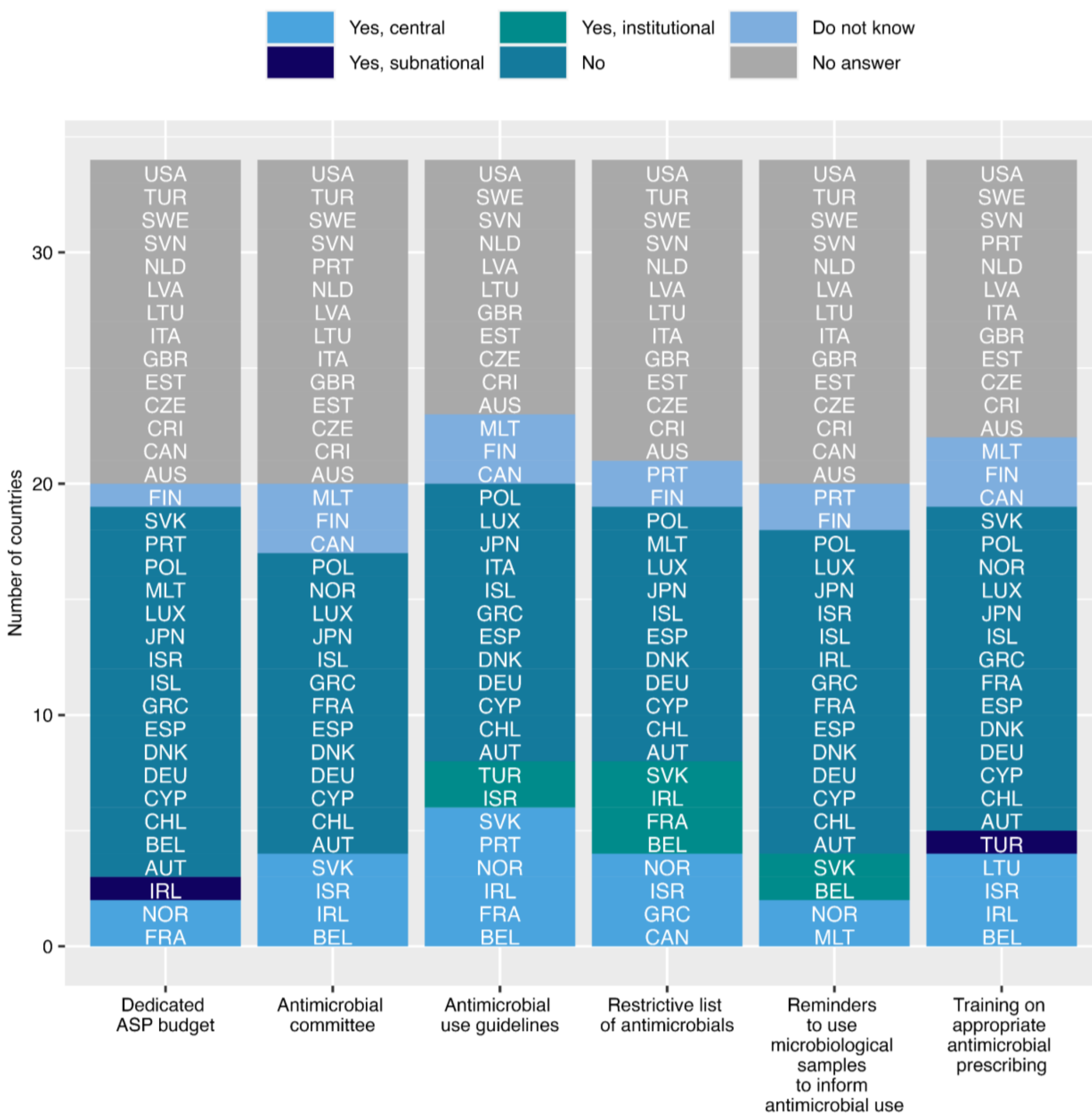
Antimicrobial stewardship programmes (ASPs) in LTCFs

In most EU/EEA and OECD countries, there are no guidelines, protocols or requirements for the adoption of ASPs in LTCFs (Figure 7.6). Only 15% (3 out of 20 reporting countries) report having guidelines, protocols or requirements for the adoption of budgets dedicated to ASPs in LTCFs. Twenty percent (4 out of 20 reporting countries) report having guidelines, protocols or requirements for the adoption of antimicrobial committees in LTCFs. Thirty-five percent of countries (8 out of 23 reporting countries) report having written guidelines on the appropriate use of antibiotics in LTCFs, but only 9% (2 out of 22 countries) have guidelines on the appropriate use of antibiotics for residents with cognitive impairments or advanced dementia. Most guidelines are adopted at the level of central governments.

About 38% (8 out of 21 reporting countries) report having guidelines, protocols or requirements for the adoption of restrictive lists of antimicrobials to be prescribed in LTCFs and 20% (4 out of 20 reporting countries) have guidelines, protocols or requirements for the adoption of a system to remind healthcare workers to request microbiological samples before prescribing antibiotics in LTCFs. Finally, almost 1 in 5 countries (5 out of 22 reporting countries) report having guidelines, protocols or requirements for the provision of regular training on appropriate antibiotic prescribing in LTCFs.

Among the majority of EU/EEA and OECD countries, the adoption of ASP protocols and programmes in LTCFs varies at the subnational level and is typically not mandatory nor incentivised. In Canada, where healthcare policy is decentralised, ASP guidelines, protocols or requirements for LTCFs may exist at the provincial or territorial level (these subnational actions are not necessarily known to the central government). In Ontario, for example, Public Health Ontario produces resources to promote and support ASPs as an effective strategy for limiting inappropriate antibiotic use, while improving antibiotic therapy and clinical outcomes for residents in LTCFs. Similarly, in Italy, regional or local initiatives may exist but information is not always shared with the central government. In Belgium, a minority of LTCFs have ASP elements in place. In Ireland, there are no incentives to adopt ASP components in LTCFs. Norway generally has policies related to ASP at the federal level but, as LTCFs are run by municipalities, federal agencies can only send reminders and information.

Figure 7.6. Overview of key country actions related to ASP in LTCFs in the EU/EEA and OECD, 2021-22



Note: ASP – antimicrobial stewardship programme.
Source: Analysis of OECD Survey on Antibacterial Resistance in LTCFs (2021-22).

Written therapeutic antibiotic guidelines for the treatment of specific infections adopted in about half of reporting countries

Almost half (11 out of 23 reporting countries) report having written guidelines for the treatment of respiratory and urinary tract infections in LTCFs and 50% (11 out of 22 reporting countries) have guidelines for the treatment of wound and soft tissue infections in LTCFs. In France, there are no national LTCF-specific guidelines on antibiotic use or prescribing, but regional health authorities are free to develop regional guidance and/or tools. In Finland, national therapeutic antimicrobial guidelines for most common infections include sections for the elderly and LTC. Other guidelines are local and regional. In Greece, r elements exist at the central level but they are not mandatory. In Poland, therapeutic guidelines prepared within the National Programme for Antibiotic Protection in 2012-20 include guidelines for respiratory tract infections, wound and skin infections, preoperative prophylaxis, urinary tract infections, *C. difficile* and orthopaedic infections. The guidelines cover therapies in the community, hospitals and LTCFs.

In Spain, the National Treatment Guideline for Antimicrobial Use in Infectious Diseases includes recommendations to manage infections in LTCFs. In Malta, in most cases, general practitioners do not screen residents before starting antimicrobials. In Denmark, ASP policies and guidelines are not targeted to LTCFs because LTCF residents are under the care of a general practitioner, who is responsible for all antibiotic prescriptions in LTCFs and the community.

Very limited use of monitoring of and feedback on antibiotic consumption

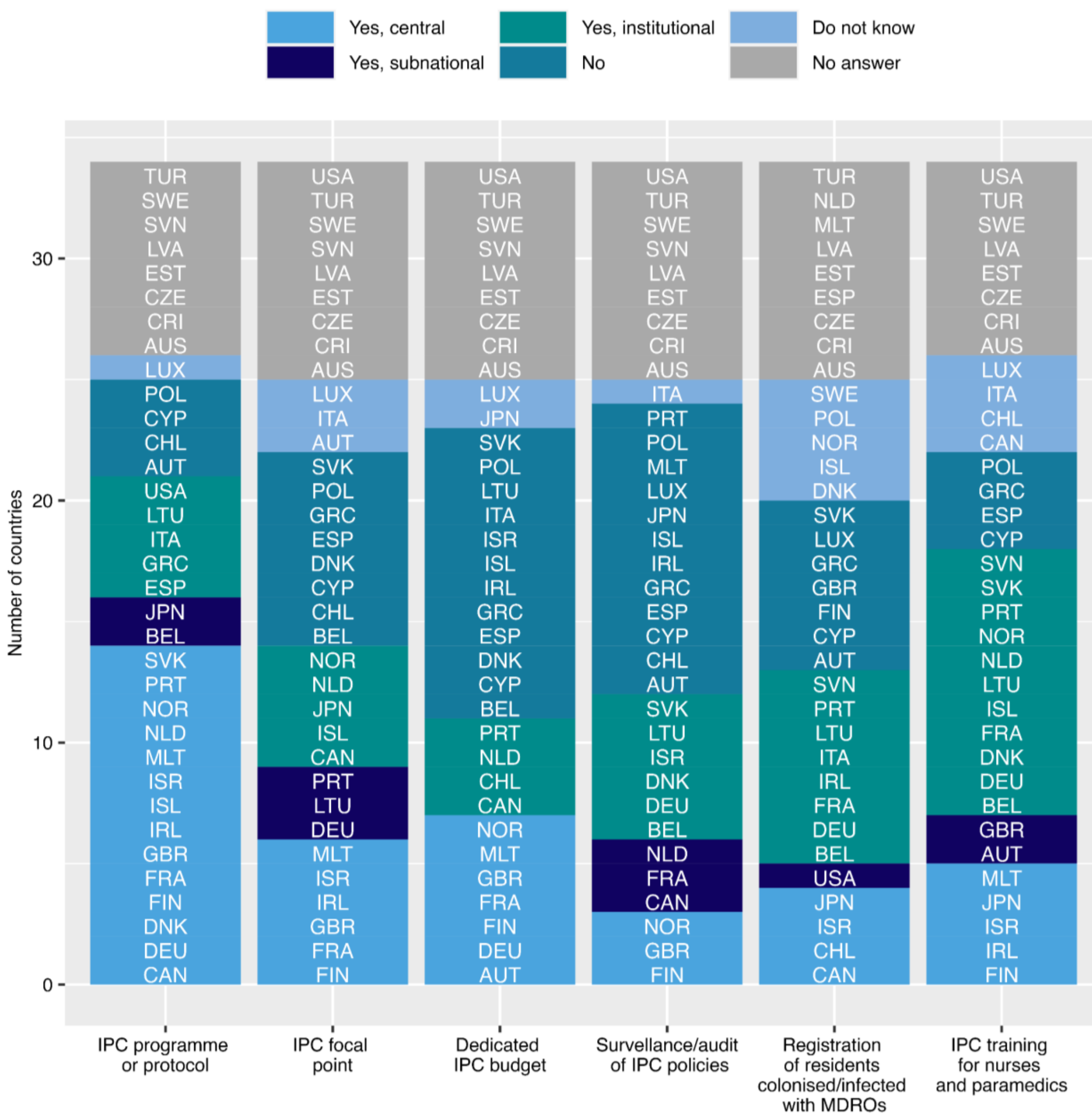
Only 14% (3 out of 21 countries) report having data available on an annual consumption of antimicrobials by antimicrobial class in LTCFs, or subnational AMR summaries available in LTCFs and local primary care practices. About 1 in 4 countries (5 out of 21 countries) provide feedback to local general practitioners on antibiotic consumption in LTCFs.

In Australia, for example, surveillance of antibiotic consumption and appropriateness of use is conducted nationally through the National Antimicrobial Utilisation Surveillance Program and National Antimicrobial Prescribing Survey (NAPS, which includes an aged care module). Aged Care NAPS is a standardised surveillance tool that Australian LTCFs have used annually since 2015 to monitor the prevalence of infections and antibiotic use, provide feedback to clinicians and administrators, and measure the effectiveness of IPC measures and ASPs. Participation in Aged Care NAPS is mandatory for LTCFs in Victoria and voluntary for other jurisdictions. Incentives for participation in these surveillance activities include access to antibiograms and benchmarking reports. Both ASPs and IPC practices in LTCFs are supported at the national level by the Aged Care Quality Standards but they are implemented at the LTCF level. In Denmark, while the country has a detailed surveillance system for antibiotic consumption, antibiotic use in LTCFs is not routinely monitored. The Danish Health Data Authority has published disaggregated antibiotic use data at the LTCF level and is developing a system for regular monitoring in co-operation with the *Statens Serum Institut*.

Infection prevention and control in LTCFs

In most EU/EEA and OECD countries, in contrast to the adoption of ASPs, there are guidelines, protocols or requirements for the adoption of IPC practices in LTCFs (Figure 7.7). Four in 5 countries (21 out of 26 reporting countries) report having guidelines, protocols or requirements for the adoption of IPC programmes or protocols in LTCFs. Over half (14 out of 25 reporting countries) report having guidelines, protocols or requirements for the adoption of IPC focal points in LTCFs and 44% (11 out of 25 reporting countries) have guidelines, protocols or requirements for the adoption of a budget dedicated to IPC in LTCFs. Fifty-two percent (13 out of 25 reporting countries) of countries require LTCFs to register residents infected or colonised with multidrug-resistant organisms. Close to half (12 out of 25 reporting countries) report having a process of surveillance/audit of IPC policies in LTCFs. With respect to requirements or guidelines for the adoption of educational IPC elements in LTCFs, 69% (18 out of 26 reporting countries) provide regular training for nursing and paramedical staff and 48% (12 out of 25 reporting countries) provide training for general practitioners working in LTCFs.

Figure 7.7. Overview of key country actions related to infection prevention and control in LTCFs in the EU/EEA and OECD, 2021-22



Note: IPC – infection prevention and control; MDROs: multidrug-resistant organisms.
Source: Analysis of OECD Survey on Antibacterial Resistance in LTCFs (2021-22).

In Japan, IPC committees, guidelines and regular training on IPC are mandatory in LTCFs and have been implemented nationwide at the subnational and LTCF levels. In addition, budgets dedicated to IPC in LTCFs exist at the subnational level. In Canada, an IPC programme, a budget dedicated to IPC in LTCFs, and guidelines on influenza vaccination, which include references to LTCF staff, exist at the central level. At the subnational level, provinces and territories regulate IPC in LTCFs through legislation and policies, but variations and gaps exist in oversight of IPC and quality of care. In Chile, regulations are developed at the central level. In Israel, there is a national system to report LTCF residents colonised by *carbapenemase-producing Enterobacteriaceae* (CPE) or *C. difficile*, and IPC committees exist in LTCFs. In the United States, LTCFs serving Medicare and Medicaid patients are required to have IPC and AMS programmes.

In France, almost all regions have IPC elements in LTCFs. Funding is available at the central level for regional IPC centres and will soon be available for IPC teams in LTCFs. In Luxembourg, IPC elements are not mandatory in LTCFs, however new legislation may introduce incentives. In Finland, the Resident Assessment Instrument (RAI), which includes indicators related to AMR and IPC to audit the quality of care in Finnish LTCFs, will be mandatory from April 2023. The registration of residents colonised by multidrug-resistant organisms takes place at the subnational level. In Poland, the isolation of persons colonised with multidrug-resistant organisms (e.g. CPE) is regulated by legislation approved by the Ministry of Health. In Iceland, IPC requirements exist on a national level and are mandatory. In Malta, every LTCF has an IPC focal point. IPC policies are available in all LTCFs, however not all of them are LTCF-specific.

Most countries offer vaccination to LTCF residents and staff

A large majority of countries (96%; 26 out of 27 reporting countries) offer annual influenza vaccination to LTCF staff and 88% (22 out of 25 reporting countries) offer vaccines to all residents in LTCFs. Two-thirds (16 out of 24 reporting countries) develop care protocols in LTCFs. In the United States, Medicare and Medicaid-certified LTCFs are required to provide immunisation against influenza and pneumococcal disease to all residents. However, other types of LTCFs may not have such requirements and are regulated by the respective state in which they are located. In Italy, the national seasonal influenza campaign strongly recommends vaccination for staff and residents in LTCFs. In Ireland, IPC elements are mandatory in LTCFs except for patient and staff vaccination, which are voluntary but strongly encouraged.

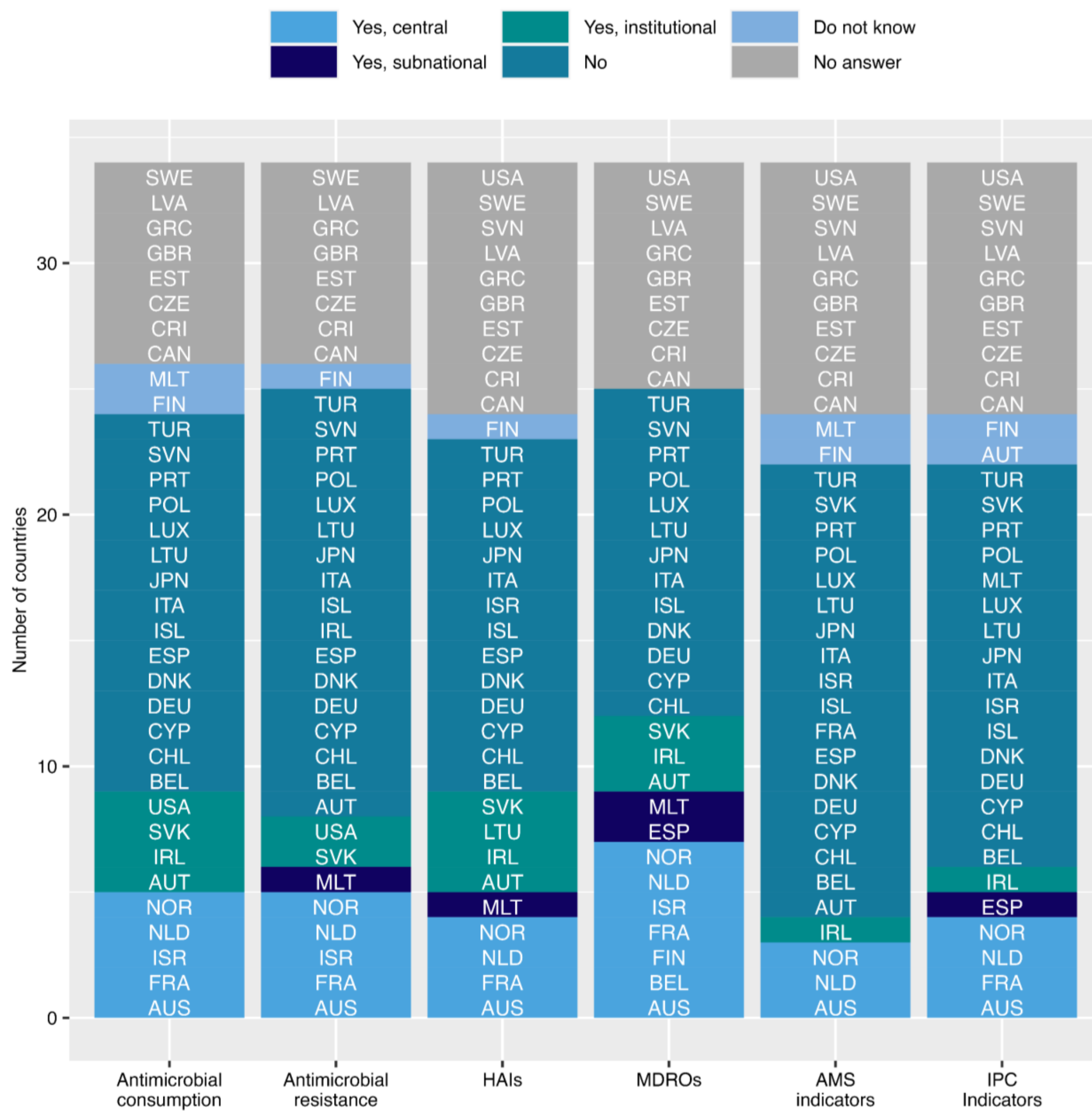
Several German LTCFs have IPC protocols and offer vaccination to staff and residents. At the federal level, the recommendations of the Commission for Hospital Hygiene and Infection Protection at the Robert Koch Institute provide advice for LTCFs related to resistant organisms. In Poland, influenzae vaccinations are offered free of charge to medical staff and LTCF residents. IPC is at the LTCF level and is not mandatory. In Iceland, influenza vaccines are offered to all LTCF staff and residents but there are no incentives to increase uptake. In Malta, vaccinations are available for both staff and residents and some of the vaccinations are administered free of charge.

Monitoring of AMR in LTCFs

Many countries do not have any guidelines, protocols or requirements for the adoption of surveillance of antibiotic use and AMR in LTCFs (Figure 7.8). Just over a third of countries (9 out of 25 reporting countries) conduct surveillance of antibiotic consumption in LTCFs and 32% (8 out of 25 reporting countries) conduct surveillance of AMR in LTCFs. About 40% (9 out of 23 reporting countries) conduct surveillance of HAIs and 50% (12 out of 24 countries) have surveillance of multidrug-resistant organisms. Fewer than 1 in 5 (4 out of 23 reporting countries) have surveillance of indicators of ASP and 26% (6 out of 23 reporting countries) have surveillance of indicators of IPC in LTCFs.

In Israel, all LTCFs are required to report cases of CPE. In the United States, Medicare and Medicaid requirements for certified LTCFs include stipulations for a system to monitor antibiotic use. In France, surveillance in LTCFs is not mandatory but the country reports there is good national coverage. No incentives are currently used and surveillance is annual except for HAIs where the national PPS is conducted every five to seven years. Indicators of ASP in LTCFs are currently under development. In Belgium, there is a mandatory notification of outbreaks of multidrug-resistant infections at the national level. Work is in progress at the subnational level. In Spain, some regions have protocols and requirements for the mandatory surveillance of AMR at the regional level. Malta maintains an LTCF-specific database of residents that have HAIs and multidrug-resistant organisms and is used to monitor AMR in LTCFs.

Figure 7.8. Overview of key country actions related to surveillance of antibiotic consumption and AMR in LTCFs in the EU/EEA and OECD, 2021-22



Note: HAIs – healthcare-associated infections; multidrug-resistant organisms; ASP – antimicrobial stewardships; IPC – infection prevention and control.
Source: Analysis of OECD Survey on Antibacterial Resistance in LTCFs (2021-22).

Data sharing between long-term care and healthcare settings

In most countries, when an LTCF resident is admitted, transferred or discharged to another healthcare facility, data on infections and multidrug-resistant organisms are shared with the receiving facility. In some countries, data sharing is mandatory and/or supported by legislation or guidelines. In Israel, when an LTCF resident is discharged from the hospital, the hospital notifies the facility of multidrug-resistant organisms. The National Institute for Antimicrobial Resistance and Infection Control is notified if a resident from an

LTCF screened positive for CPE upon hospital admission and then notifies the LTCF and gives instructions for contact screening. In the United States, when a resident is discharged, the discharging facility (i.e. the hospital or LTCF) should provide details of the patient's health condition.

In France, national guidelines recommend sharing information when patients are infected, using antibiotics or colonised with multidrug-resistant organisms but there is no national process in place to incentivise or facilitate this. All hospitals and a majority of LTCFs have electronic medical records but these records are usually not shared. In Ireland, patient-specific information is shared with the receiving facility in relation to the patient's status regarding HAIs, however no central patient information database of this currently exists. In many German regions, MRE Networks bring together hospitals, general practitioners, public health services and LTCFs. Information on infections and resistant organisms is shared via these networks. In Austria, it is mandatory to share data on infections and multidrug-resistant organisms with the National Standard for Admission and Discharge Management (*Qualitätsstandard Aufnahme- und Entlassungs-management*). In both Cyprus and the Slovak Republic, when a patient or resident is discharged, information on infection and colonisation is provided in the discharge letter.

In Luxembourg, patient-specific data are shared between hospitals and LTCFs on admission and upon discharge. In Finland, sharing information is a routine process recommended in the national guidelines. In Greece, current legislation mandates that the patient discharge letter include previous infection or colonisation by an MDRO. In Poland, acute care hospitals should notify the facility when the LTCF resident is colonised or infected with MDRO and vice versa. In Iceland, patient-specific data on resistant organisms are registered in patient electronic medical records that may be shared among facilities. In Denmark, hospitals routinely notify LTCFs of infections requiring special precautions on discharge, even though the law does not specifically require this. In Norway, data are shared with the national public health institute and are summarised and disseminated to other LTCFs. In Spain, when a resident who has or has had a multidrug-resistant infection is discharged from an ACH to an LTCF, the ACH shares this information with the LTCF and vice versa. In some Spanish regions, it is mandatory for LTCFs to share information on multidrug-resistant infections with the regional public health authority.

Impact of COVID-19 on AMR in LTCFs

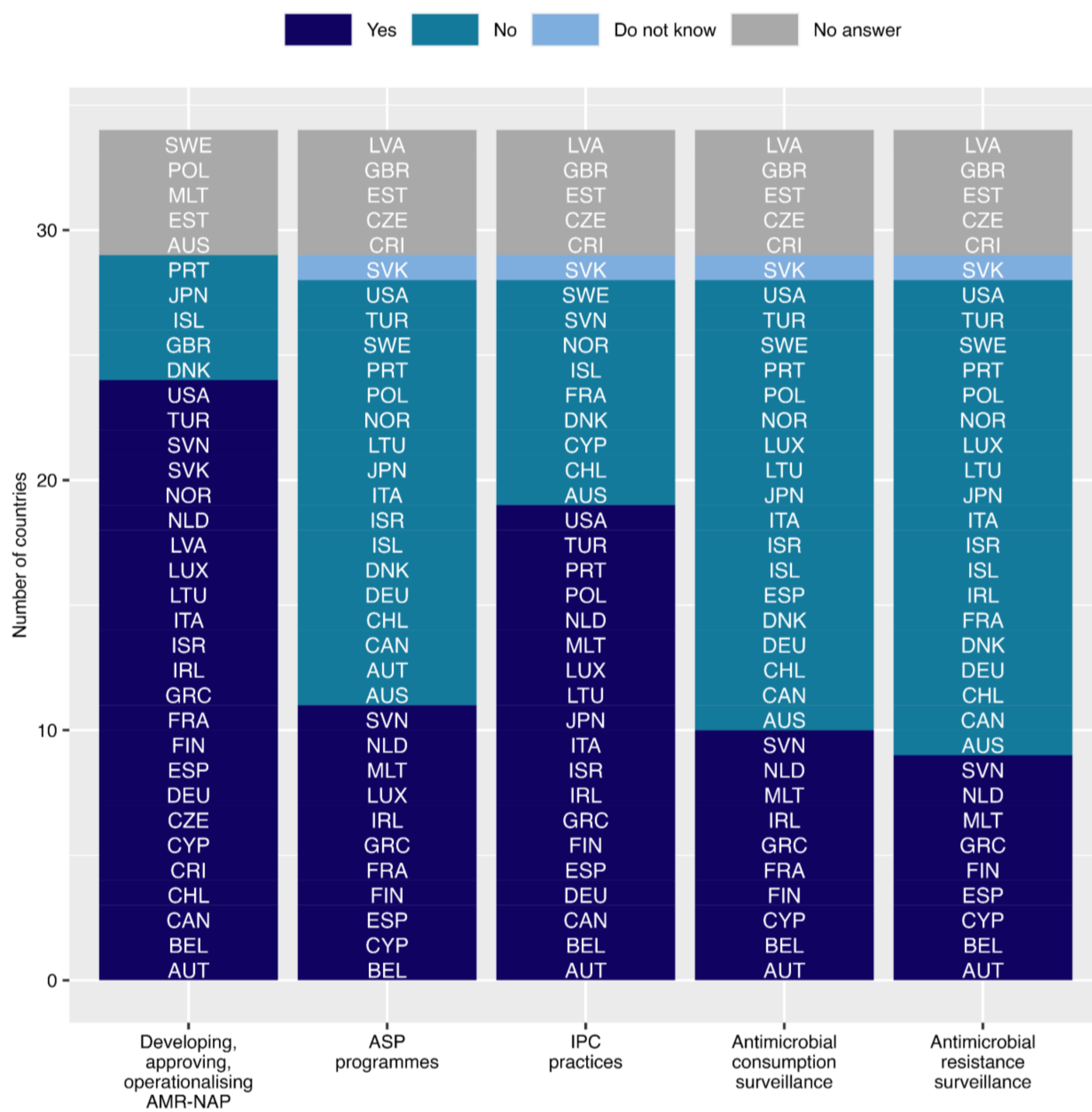
Across the EU/EEA and OECD countries, the COVID-19 pandemic has had a significant impact on policy actions related to antibiotic use and AMR in LTCFs, as illustrated in Figure 7.9. In 83% of countries (24 out of 29 reporting countries), the pandemic led to delays in developing, approving or operationalising the national action plan on AMR. In 37% of countries (10 out of 27 reporting countries), the pandemic affected surveillance of antibiotic consumption, in 33% (9 out of 27 reporting countries), it impacted surveillance of AMR and, in 41% (11 out of 27 reporting countries), it impacted surveillance of HAIs. A third of countries (9 out of 27 reporting countries) report that the COVID-19 pandemic affected the rapid testing of residents and 30% of countries (8 out of 27 countries) report it had an impact on audits of antibiotic prescribing behaviours.

Austria, Cyprus, Greece, Lithuania, Luxembourg, the Slovak Republic, Slovenia and Spain all reported delays in developing, approving or operationalising their national action plan on AMR due to staff reallocation as a result of the pandemic. Canada and Chile reported delays in finalising their national action plans because of the pandemic. The United States reported a six-month delay in the publication of the national action plan and, in Italy, work on the national action plan was halted in the first six months of 2020 due to the pandemic. France reported a one-year delay in finalising the national action plan and delayed the final approval and budget allocation for the full implementation of the plan. Ireland's national action plan was delayed. Belgium postponed the validation of the human health pillar of the national action plan. In Germany and Norway, although the national action plan was delayed, there was no perceived negative impact on the fight against AMR or IPC.

In the United States, there was a decline in compliance surveys during some periods of the pandemic to reduce the number of people entering and leaving LTCFs, unless there was an eminent threat to patient health. In Belgium, France, Ireland and Spain, surveillance of antibiotic use was either stopped or delayed because of increased workload, and available resources were redirected to fighting the pandemic. Similarly, Belgium, Greece and Spain all reported delays in the development and implementation of surveillance of AMR in LTCFs. In Ireland, surveillance of HAIs was delayed for the period 2019-20.

Figure 7.9. Overview of the impact of the COVID-19 pandemic on country actions related to AMR in LTCFs in the EU/EEA and OECD, 2021-22

Did the COVID-19 pandemic affect the following country actions?



Note: AMR-NAP – National Action Plan on Antimicrobial Resistance; ASP – antimicrobial stewardships; IPC – infection prevention and control.
Source: Analysis of OECD Survey on Antibacterial Resistance in LTCFs (2021-22).

Box 7.6. COVID-19 has been a grim reminder of vulnerabilities in LTCFs

COVID-19 infections disproportionately affected residents of LTCFs

Residents of LTCFs died from COVID-19 at a much higher rate compared to older people living in the community and outbreaks in LTCFs were larger and more severe than in acute care hospitals. COVID-19 infection is more severe in older adults who experience much higher morbidity and mortality rates, compared to the younger population. In LTCFs, the pandemic had a devasting effect on residents and staff. LTCF residents who were admitted to hospital with a COVID-19 infection were much more likely to die in hospital from COVID-19 compared to those admitted from their homes (D'ascanio et al., 2021[82]). A study comparing COVID-19 mortality rates between older LTCF residents and community-dwelling older adults (aged 65 years and older) in 12 OECD countries in the first 4 months of the pandemic found that LTCF residents had a 24-fold higher death rate, compared to community-dwelling older adults (Sepulveda, Stall and Sinha, 2020[83]). By February 2021, an estimated 40% of all deaths from COVID-19 in participating OECD countries had occurred in LTC settings, ranging from 4% in Greece to 75% in Australia (Rocard, Sillitti and Llena-Nozal, 2021[84]).

Numerous outbreaks have been reported in LTCFs and, in some countries, outbreaks in LTCFs were larger and more severe than outbreaks in acute care hospitals (Suwono et al., 2022[85]; Thompson et al., 2020[86]). The size of outbreaks and large number of deaths from COVID-19 in LTCFs have been attributed to several factors, including asymptomatic healthcare workers, multi-occupancy rooms shared by residents and shared bathrooms, and insufficient staff to conduct effective IPCs (Hoxha et al., 2021[87]; Olmos et al., 2021[88]). For example, a study found that in Ontario, Canada, multi-occupancy rooms in LTCFs contributed to the spread of infection and converting 4-bed rooms to 2-bed rooms in LTCFs could have averted 998 COVID-19 cases and 263 deaths (Brown et al., 2021[89]).

Note: Data from Rocard, Sillitti and Llena-Nozal (2021[84]) include LTCFs, community care settings and home-based care. The vast majority of recipients were aged 65 and older.

Source: D'ascanio, M. et al. (2021[82]), "Age is not the only risk factor in COVID-19: The role of comorbidities and of long staying in residential care homes", https://doi.org/10.1186/S12877-021-02013-3/TABLES/5; Sepulveda, E., N. Stall and S. Sinha (2020[83]), "A comparison of COVID-19 mortality rates among long-term care residents in 12 OECD countries", https://doi.org/10.1016/j.jamda.2020.08.039; Rocard, E., P. Sillitti and A. Llena-Nozal (2021[84]), "COVID-19 in long-term care: Impact, policy responses and challenges", https://doi.org/10.1787/b966f837-en; Suwono, B. et al. (2022[85]), "SARS-CoV-2 outbreaks in hospitals and long-term care facilities in Germany: A national observational study", https://doi.org/10.1016/J.LANEPE.2021.100303; Thompson, N. et al. (2020[86]), "Prevalence of antimicrobial use and opportunities to improve prescribing practices in U.S. nursing homes", https://doi.org/10.1016/j.jamda.2016.08.013; Hoxha, A. et al. (2021[87]), "Asymptomatic SARS-CoV-2 infection in Belgian long-term care facilities", https://doi.org/10.1016/S1473-3099(20)30560-0; Olmos, C. et al. (2021[88]), "SARS-CoV-2 infection in asymptomatic healthcare workers at a clinic in Chile", https://doi.org/10.1371/JOURNAL.PONE.0245913; Brown, K. et al. (2021[89]), "Association between nursing home crowding and COVID-19 infection and mortality in Ontario, Canada", https://doi.org/10.1001/jamainternmed.2020.6466.

The pandemic also had an impact on vaccination campaigns in 36% of countries (10 out of 28 countries), it affected AMR awareness campaigns in 19% of countries (5 out of 27 countries), ASP practices in 39% of countries (11 out of 28 countries) of countries and IPC in LTCFs in 64% of countries (18 out of 28 countries). France reported a one-year delay in implementing national ASP campaigns targeting the public and professionals and Greece reported a delay in the development of campaigns. In Germany, during the pandemic, immunisation campaigns targeted nurses and LTCF residents. In Luxembourg and Poland, there was an improved uptake of influenza vaccines. In Greece, Ireland, Luxembourg, Portugal and the United States, there was an increase in rapid testing of LTCF residents to help with early diagnosis and screening for COVID-19 infection, which potentially helped reduce the spread of infection in LTCFs. In Australia, progress on some AMR Strategy implementation activities was temporarily impacted to some extent by the prioritisation of resources to address the COVID-19 pandemic, particularly when specific expertise or areas were needed, such as epidemiologists, modellers, general practitioners, communicable disease specialists and laboratories.

The COVID-19 pandemic has raised awareness of the need for IPC measures but has delayed or even stopped ASPs

Many countries reported a positive impact on the adoption of IPC components, such as hand hygiene, in LTCFs because of the pandemic. In Canada, Germany, Ireland, Italy, Japan, Portugal, Spain and the United States, education and IPC protocols increased awareness of the importance of hand hygiene. In Lithuania, intensive training, national and regional meetings, consultations in outbreak control and additional external inspections were targeted at LTCFs. In Belgium, free education on IPC and centralised e-learning sessions were offered in LTCFs. Luxembourg improved IPC implementation, and Greece and Poland enhanced hand hygiene through better access to disinfectants and protective cloths.

The impact of the pandemic on ASPs was significant. In France, ASPs were slowed down due to the pandemic. Greece and Luxembourg experienced implementation delays on ASPs and, in Spain, a development framework for ASPs was stopped because all resources were focused on COVID-19. However, in Ireland, there were increased webinars, delivered by the Irish Health Service Antimicrobial Resistance and Infection Control programme, and webinars on education and guidance on COVID-19 for LTCFs.

Policy options to tackle AMR in LTCFs

Countries recognise that national action plans on AMR need to acknowledge inappropriate antibiotic use and AMR in LTCFs but there is some way to go to fill important gaps in the design, adoption and effective use of ASP, IPC and surveillance in LTCFs.

With 28 countries (out of 28 countries) reporting that they plan to include references to LTC in their next national action plan on AMR, it is clear that EU/EEA and OECD countries recognise that tackling AMR and inappropriate antibiotic use in LTCFs requires targeted policy actions. However, as illustrated in the previous sections, there are a number of important gaps in the design, adoption and effective use of ASP, IPC and surveillance in LTCFs. Policy options for countries seeking to reduce the threat of inappropriate antibiotic use and AMR in LTCFs include:

- Setting up routine surveillance systems that can collect and report data on antibiotic use and AMR in LTCFs. Routine surveillance is needed to establish a baseline situation, design policies that are fit for LTCFs and monitor and evaluate the impact of those policies.
- Promoting the design, implementation and effective use of ASPs that are fit for LTCFs, including more integration with prescribers (e.g. general practitioners), better feedback on antibiotic use and AMR profiles, regular training and a budget specifically dedicated to ASP.
- Incentivising adoption and compliance with IPC practices that are tailored to LTCFs, emphasising the need for budgets specifically earmarked for IPC, creation of IPC committees and adoption of procedures for surveillance and auditing of IPC processes in LTCFs.

Guidelines and centralised policy advice are helpful but may be insufficient to ensure change at scale. Many LTCFs face enormous challenges, from staff shortages to limited financial resources, to significant and complex demands from their residents (Box 7.5). A survey of over 1 000 LTCFs in the United States concluded that LTCFs may not follow voluntary IPC guidelines if doing so requires significant financial investment, such as recruiting staff or investing in infrastructure (Ye et al., 2015[90]). Without appropriate financial and technical support, it is unlikely that all LTCFs will be able to implement the surveillance, ASP and IPC protocols that can make a difference in the fight against AMR.

A combination of well-funded mandates and financial incentives may be a way forward. Financial strategies targeting healthcare providers to promote the prudent use of antibiotics have been shown to improve the appropriateness of antibiotic prescribing in various healthcare settings (Yoshikawa et al., 2021[91]). Both financial penalties and rewards can be effective and the choice of whether to use financial rewards or penalties should be informed by the context (Yoshikawa et al., 2021[91]). More research is needed on whether such strategies could work in LTCFs, so pilot projects and experimentation could be useful.

Routine surveillance of AMR in LTCFs

Despite efforts to improve surveillance of antibiotic prescribing and AMR in LTCFs by EU/EEA countries, Australia and Canada, among others, comparable data on the prevalence of HAIs, antibiotic consumption and AMR in LTCFs are not yet widely available. Routine surveillance of AMR in LTCFs is limited in most countries (Haenen et al., 2019[27]).

Routine surveillance of both antibiotic use and AMR in LTCFs can promote benchmarking, auditing and goal setting. When combined with other interventions, routine surveillance can be an effective way to promote the use of ASPs and IPC practices and is associated with reduced rates of HAIs (Daneman et al., 2012[92]; Fleming et al., 2014[93]; Furuno and Mody, 2020[15]). Routine data on AMR in LTCFs can also help to determine susceptibility rates within a given community or country and to guide the development of antibiotic restrictive lists, and specific antibiograms that can reduce the rates of inappropriate prescribing in LTCFs (Furuno et al., 2014[94]). Unlike PPSs, routine surveillance provides ongoing monitoring of infections in LTCF residents admitted to acute care hospitals or other healthcare settings and provides a comprehensive, integrated approach to tackling AMR within the healthcare system.

Almost half of countries (13 out of 24 countries) require LTCFs to register residents infected or colonised with multidrug-resistant organisms and 63% (15 out of 24 countries) have a designated person responsible for reporting and managing outbreaks. Moreover, a few countries are starting to implement annual PPSs for HAIs and antibiotic use in LTCFs (Public Health Agency of Canada, 2019[95]; Ministry of Health/Ministry for Primary Industries, 2017[96]). However, these types of reporting provide only a picture in time and are not well suited to characterise antibiotic use and AMR over time. Furthermore, findings from PPS indicate the majority of infections in LTCFs originate in the residents' own LTCF. Yet, existing systems of routine surveillance would identify these infections when residents are admitted to acute care hospitals and these findings may not be shared back with the LTCF. Setting up routine surveillance systems that can capture these details is instrumental to fighting AMR in LTCFs.

Establishing routine LTCF-specific surveillance systems may be challenging because LTCFs often use several laboratories and many countries aggregate surveillance data from LTCFs with samples from GP clinics in the community. This challenge may be circumvented by collecting LTCF postcodes to help identify and disaggregate samples from LTCFs in surveillance databases (Raban et al., 2021[97]; Rosello et al., 2017[23]). Despite the challenges associated with LTCF-specific surveillance, setting up surveillance systems for LTCFs is feasible and can be integrated into existing healthcare systems (Nicolle et al., 2000[13]; El Emam et al., 2014[98]).

ASPs that are fit for LTCFs

Educating healthcare workers, prescribers, LTCF residents and their family members is an important element of successful ASP (Holmes et al., 2003[99]). Only 1 in 5 countries (4 out of 21 countries) report having guidelines, protocols or requirements for the provision of regular training on appropriate antibiotic prescribing in LTCFs. Initial and continuous ASP education and training are lacking in many LTCFs, and healthcare workers in LTCFs often do not have sufficient knowledge of ASP. Prescriber education is important because knowledge gaps may influence physician prescribing behaviour and decision-making (Kassett et al., 2016[100]), yet prescriber education implemented in isolation may be ineffective to reduce inappropriate prescribing in LTCFs. To improve the effectiveness of educational ASP, ASP strategies should be integrated into existing LTCF systems of healthcare delivery using behavioural incentives such as monitoring, surveillance, goal setting, feedback and audits (Fleming, Browne and Byrne, 2013[101]; Nguyen, Tunney and Hughes, 2019[102]).

Establishing clear communication channels between stakeholders in LTCFs and other healthcare settings within the community is also important to the success of ASPs. A common barrier to effective implementation of ASPs in LTCFs is the fragmented nature of healthcare delivery in LTCFs, where residents have multiple caregivers and prescribers working in other healthcare settings are often based off site and prescribe antibiotics over the phone (Crnich et al., 2015[103]). This model contributes to the lack of continuity of care often experienced by LTCF residents, which can lead to inappropriate antibiotic prescribing and emphasises the need for a co-ordinated and collaborative approach to ASP in LTCFs (Pulia et al., 2018[69]). Improved collaboration between LTCF stakeholders and other healthcare settings is important because of the potential for LTCFs to spread multidrug-resistant organisms across healthcare networks (Kahvecioglu et al., 2014[28]). Collaboration also creates opportunities for Acute care hospitals to share expertise with neighbouring LTCFs which can in turn tailor interventions to suit their specific needs (Kullar et al., 2018[104]).

To illustrate, a community-wide campaign “Do bugs need drugs?” was implemented in LTCFs in Alberta and British Columbia in Canada. The campaign, aimed at LTCFs, sought to provide a consistent approach to the management of urinary tract infections and nursing home-acquired pneumonia; and to facilitate the communication of signs and symptoms between LTCFs and physicians. Reductions in antibiotic prescribing were achieved with staff education and feedback in Alberta (Carson and Patrick, 2015[105]; Do Bugs Need Drugs?, 2016[106]).

Incentives for effective use of IPC measures

As most IPC programmes are designed for closed systems such as hospital wards in acute care hospitals, without modification and careful planning, these interventions can be challenging to implement in LTCFs, as these often have multiple areas for socialisation and fewer resources for IPC compared to acute care hospitals. These challenges can be tackled by targeting interventions to residents who are at a high risk of acquiring infections, such as those with indwelling devices (e.g. feeding tubes and urinary catheters) and those with pressure ulcers (Blanco et al., 2018[107]; Mody et al., 2015[7]). A few examples of best practices in preventing urinary tract infections and reducing the unnecessary use of antibiotics in LTCFs are shown in Box 7.7 below.

Many LTCFs have limited resources and cost may be a barrier to implementing IPC measures and employing staff with experience or specialised training in IPC practices. In smaller LTCFs, a member of staff could be adequately trained in IPC, assume responsibility for the co-ordination of activities in the facility and have access to expert advice at a more central level if needed. Adherence to IPC measures is likely a cost-effective way to reduce the use of antimicrobials in healthcare settings (OECD, 2018[14]) and may also be cost-effective from the perspective of the healthcare payer (Hutton et al., 2018[108]). Moreover, the potential costs of controlling an outbreak, the costs of longer hospital stays and more intensive treatment, and the costs associated with morbidity and mortality for residents and healthcare workers can be significantly higher than implementing effective IPCs in LTCFs. Therefore, it is likely beneficial for payers to provide incentives to LTCFs to implement IPC programmes.

Box 7.7. Examples of best practices in preventing urinary tract infections and reducing the unnecessary use of antibiotics in LTCFs

To Dip or Not to Dip

Infection prevention can lead to lower use of antibiotics. In the United Kingdom, a quality improvement programme "To Dip or Not to Dip" was used to improve the diagnosis and management of urinary tract infections in LTCFs. Instead of using dip-stick urinalysis to diagnose urinary tract infections, which can lead to misleading results, LTCF staff were trained to use an evidence-based clinical algorithm for diagnosis, recording and sharing resident symptoms with general practitioners. The change in practice reduced both treatment and prophylactic antibiotic prescriptions for urinary tract infections and hospital admissions among LTCF residents, without recorded adverse effects (UK Government, 2019[109]). The programme has been adopted by the Australian Aged Care Quality and Safety Commission to improve the diagnosis and management of urinary tract infections in LTCFs (Australian Government, 2022[110]).

Good Hydration! initiative

Dehydration is common among LTCF residents, can increase the risk of urinary tract infections, disorientation, falls and is a common cause of hospital admission among LTCF residents (Schols et al., 2009[111]). This initiative involved staff and resident training on hydration, posters and introducing a "7 structured drinks round" for residents each day (Lean et al., 2019[112]; Booth and Agnew, 2019[113]). The intervention successfully reduced the incidence of urinary tract infections requiring antibiotics and hospital admissions with a primary diagnosis of urinary tract infections among LTCF residents. The programme has won multiple awards and has been adopted in other LTCFs in England (United Kingdom) (Oxford Patient Safety Collaborative, 2019[114]). Improving hydration in LTCF residents is a relatively low-cost intervention, as the direct and indirect costs of antibiotic treatment and hospitalisation are high.

A national project to prevent catheter-associated urinary tract infections in LTCFs

The use of indwelling urinary catheters is a risk factor for urinary tract infections and, in LTCFs, the urine of residents with chronic (>30 days) indwelling catheters is the most common site for isolation of resistant gramme-negative organisms (Mody et al., 2007[115]; Nicolle, 2014[116]). In the United States, an evidence-based programme to tackle catheter-associated urinary tract infections, adapted from a similar programme in acute care hospitals, was implemented in over 400 LTCFs. The intervention involved education, surveillance, change champions and an evidence-based tool to assist with the correct diagnosis, in an effort to reduce the inappropriate use of antibiotics for asymptomatic urinary tract infections. The intervention also targeted residents with indwelling urinary catheters and included guidance for catheter removal, aseptic insertion, regular assessments, training and incontinence planning. After adjusting for LTCF characteristics (e.g. ownership, number of beds, having an infection preventionist), the incidence of catheter-associated urinary tract infections dropped from 6.42 at the beginning of the project to 3.33 per 1 000 catheter-days at the end of the project. Furthermore, 75% of the nursing homes (276 in 368) reported at least a 40% reduction in the rates of catheter-associated urinary tract infections and a reduction in the frequency of orders for urine cultures (Mody et al., 2007[115]). Cost-effectiveness analysis showed that the intervention was likely to have net cost savings of USD 34 000 per year (Hutton et al., 2018[108]).

Source: UK Government (2019[109]), *Tackling Antimicrobial Resistance 2019-24: The UK's Five-year National Action Plan*, Department of Health and Social Care, London; Australian Government (2022[110]), *To Dip or Not to Dip flyer*, https://www.agedcarequality.gov.au/resources/dip-or-not-dip-flyer (accessed on 4 April 2022); Schols, J. et al. (2009[111]), "Preventing and treating dehydration in the elderly during periods of illness and warm weather", https://doi.org/10.1007/s12603-009-0023-z; Lean, K. et al. (2019[112]), "Reducing urinary tract infections in care homes by improving hydration", https://doi.org/10.1136/bmjoq-2018-000563; Booth, J. and R. Agnew (2019[113]), "Evaluating a hydration intervention (DRInK Up) to prevent urinary tract infection in care home residents: A mixed methods exploratory study", https://doi.org/10.22540/jfsf-04-036; Oxford Patient Safety Collaborative (2019[114]), *Good Hydration!*, http://bit.ly/good-hydration (accessed on 4 April 2022); Mody, L. et al. (2007[115]), "Indwelling device use and antibiotic resistance in nursing homes: Identifying a high-risk group", https://doi.org/10.1111/j.1532-5415.2007.01468.x; Nicolle, L. (2014[116]), "Catheter associated urinary tract infections", *Antimicrobial Resistance and Infection Control*, Vol. 3/1, https://doi.org/10.1186/2047-2994-3-23; Hutton, D. et al. (2018[108]), "Economic evaluation of a catheter-associated urinary tract infection prevention programme in nursing homes", https://doi.org/10.1111/jgs.15316.

Conclusion

Many factors come together to make AMR in LTCFs an especially challenging threat, not only to residents and staff of LTCFs but also to broader communities in which these facilities are located. When staff, visitors and residents move in and out of LTCFs, so do organisms, including resistant pathogens.

Residents of LTCFs are at a higher risk of HAIs and infections from resistant pathogens, compared to community-dwelling older adults. Many residents of LTCFs receive multiple courses of antibiotics each year. Despite it being crucial to ensure that antibiotics are used wisely, many antibiotic prescriptions in LTCFs are unnecessary or inappropriate and are often given without laboratory or diagnostic testing, not always in alignment with evidence-based guidelines.

Many countries have legislation and policies to tackle AMR in LTCFs but there are important gaps in the effective use of ASPs and IPC measures. According to a new OECD survey, just over half of reporting EU/EEA and OECD countries report having a national action plan on AMR that specifically references LTCFs. In most countries, there are no guidelines, protocols or requirements for the adoption of ASPs in LTCFs. A majority of countries do report having guidelines, protocols or requirements for the adoption of IPC programmes or protocols in LTCFs but far fewer report having a process of surveillance/audit of IPC policies in LTCFs. Finally, data on antibiotic consumption and AMR in LTCFs are not widely available and routine surveillance is still limited in most countries. Only around a third of countries conduct surveillance of antibiotic consumption and AMR in LTCFs and around one in five report having surveillance of indicators of ASP or IPC in LTCFs.

Tackling AMR in LTCFs is a key part of addressing the threat of AMR more broadly but responses to this challenge must acknowledge that LTCFs have different needs and face different risks compared to acute care hospitals. It is positive that 28 countries report that they plan to include references to LTC in their next national action plan on AMR. Policy options for countries to consider include:

- Setting up routine surveillance systems that can collect and report data on antibiotic use and AMR in LTCFs. Routine surveillance is essential to establish a baseline situation, design policies that are fit for LTCFs, and monitor and evaluate the impact of those policies.
- Promoting the design, implementation and effective use of ASPs that are fit for LTCFs, including more integration with prescribers (e.g. general practitioners), better feedback on antibiotic use and AMR profiles, regular training and a budget dedicated to ASPs.
- Incentivising adoption and compliance with IPC practices that are tailored to LTCFs, emphasising the need for budgets specifically earmarked for IPC, creation of IPC committees and adoption of procedures for surveillance and auditing of IPC processes in LTCFs.

Many countries do not mandate, incentivise or monitor the adoption of ASPs and IPC measures in LTCFs. Because LTCFs face enormous challenges, ASPs and IPC practices may be underutilised. Financial strategies targeting healthcare providers to promote the prudent use of antibiotics have been shown to improve the appropriateness of antibiotic prescribing in various healthcare settings. A combination of well-funded mandates and financial incentives may be a way forward.

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Annex 7.A. Country participation in data collection

Annex Table 7.A.1. Country participation in the OECD Survey on Antibacterial Resistance in LTCFs (2021-22), as of 1 March 2022

Country	Participation in policy survey
Australia	Participated
Austria	Participated
Belgium	Participated
Canada	Participated
Chile	Participated
Cyprus	Participated
Costa Rica	Participated *
Colombia	Did not participate
Czech Republic	Participated *
Denmark	Participated
Estonia	Participated *
Finland	Participated
France	Participated
Germany	Participated
Greece	Participated
Hungary	Participated
Iceland	Participated
Ireland	Participated
Israel	Participated
Italy	Participated
Japan	Participated
Korea	Did not participate
Latvia	Participated *
Lithuania	Participated
Luxembourg	Participated
Mexico	Did not participate
Netherlands	Participated
New Zealand	Did not participate
Norway	Participated
Poland	Participated
Portugal	Participated
Slovak Republic	Participated
Slovenia	Participated
Spain	Participated
Sweden	Participated
Switzerland	Did not participate
Türkiye	Participated
United Kingdom	Participated
United States	Participated

* Responded to a shorter version of the questionnaire.

Annex 7.B. Country responses to selected questions in the OECD survey

Country responses to selected questions in the OECD Survey on Antibacterial Resistance in Long-Term Care Facilities (2021-22) are presented in Tables 7.B.1 through 7.B.13.

Annex Table 7.B.1. Overview of policies and legislation from central governments to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	Does your country's national action plan on AMR refer specifically to long-term care?	Do you plan to include references to long-term care in your next national action plan on AMR?	Besides a national action plan, does your country have legislation, policies and/or programmes aimed at addressing antibacterial resistance in LTCFs?	Do the national action plan, legislation, policies and/or programmes you referenced in previous questions include monitoring and evaluation plans focusing specifically on LTCFs?	Does your country have a process for auditing the quality of care provided in LTCFs, which includes indicators related to antibacterial resistance?
Australia	Yes	Yes	Yes	Yes	No
Austria	Yes	Yes	Yes	No	Yes
Belgium	No	Yes	No	No answer	No
Canada	Yes	Yes	Yes	No answer	No
Chile	Yes	Yes	Yes	No	No
Costa Rica	No answer	Yes	No answer	No answer	No
Cyprus	Yes	No answer	Yes	Yes	No
Czech Republic	No	Yes	No answer	No answer	No
Denmark	No	No answer	Yes	Yes	No
Estonia	No	Yes	No	No answer	No
Finland	Yes	Yes	Yes	Yes	Yes
France	No	No answer	Yes	No	No answer
Germany	Yes	Yes	Yes	No	No
Greece	No	Yes	Yes	Yes	No answer
Iceland	Yes	Yes	Yes	Yes	Yes
Ireland	Yes	Yes	Yes	Yes	Yes
Israel	No	Yes	Yes	No	No
Italy	Yes	Yes	Yes	Yes	No
Japan	No	Yes	No answer	No answer	No answer
Latvia	No	Yes	Yes	No	Yes
Lithuania	No	Yes	Yes	No answer	No
Luxembourg	Yes	Yes	Yes	Yes	No
Malta	Yes	Yes	Yes	Yes	Yes
Netherlands	Yes	Yes	Yes	Yes	Yes
Norway	No	No answer	No	No	No
Poland	Yes	Yes	No	No	No
Portugal	No	Yes	No	No	No
Slovak Republic	Yes	Yes	No	No	No

Country	Does your country's national action plan on AMR refer specifically to long-term care?	Do you plan to include references to long-term care in your next national action plan on AMR?	Besides a national action plan, does your country have legislation, policies and/or programmes aimed at addressing antibacterial resistance in LTCFs?	Do the national action plan, legislation, policies and/or programmes you referenced in previous questions include monitoring and evaluation plans focusing specifically on LTCFs?	Does your country have a process for auditing the quality of care provided in LTCFs, which includes indicators related to antibacterial resistance?
Slovenia	No	Yes	No	No	Yes
Spain	No	Yes	No	No	Yes
Sweden	Yes	No answer	No answer	No answer	No answer
Türkiye	No	Yes	No	No	No
United Kingdom	No	No answer	No answer	No	No answer
United States	Yes	Yes	Yes	Yes	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.2. Use of ASP budgeting and committees to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	A budget dedicated to ASP in LTCFs	Antimicrobial committee in LTCFs
Australia	No answer	No answer
Austria	No	No
Belgium	No	Yes, at institutional level
Canada	Do not know	Do not know
Chile	No	No
Costa Rica	No answer	No answer
Cyprus	No	No
Czech Republic	No answer	No answer
Denmark	No	No
Estonia	No answer	No answer
Finland	No	Do not know
France	Yes, at subnational level	No
Germany	No	No
Greece	No	No
Iceland	No	No
Ireland	Yes, at central level	Yes, at institutional level
Israel	No	Yes, at institutional level
Italy	No answer	No answer
Japan	No	No
Latvia	No answer	No answer
Lithuania	No answer	No answer
Luxembourg	No	No
Malta	Yes, at central level	Do not know
Netherlands	No answer	No answer
Norway	No	No
Poland	No	No
Portugal	No answer	No answer
Slovak Republic	No	Yes, at institutional level
Slovenia	No answer	No answer
Spain	No	No
Sweden	No answer	No answer
Türkiye	No answer	No answer
United States	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.3. Use of ASP written guidelines to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	Written guidelines for the appropriate use of antimicrobials in LTCFs	Written guidelines for the appropriate use of antimicrobials for residents with cognitive impairments or advanced dementia	Written guidelines on antimicrobial treatment for respiratory tract infections in LTCFs	Written guidelines on antimicrobial treatment for urinary tract infections in LTCFs	Written guidelines on antimicrobial treatment for wound and soft tissue infections in LTCFs
Australia	No answer	No answer	No answer	No answer	No answer
Austria	No	No	No	No	Yes, at institutional level
Belgium	Yes, at central level	Do not know	Yes, at central level	Yes, at central level	Yes, at central level
Canada	Do not know	Do not know	Do not know	Do not know	Do not know
Chile	No	No	No	No	No
Costa Rica	No answer	No answer	No answer	No answer	No answer
Cyprus	No	No	No	No	No
Czech Republic	No answer	No answer	No answer	No answer	No answer
Denmark	No	No	No	No	No
Estonia	No answer	No answer	No answer	No answer	No answer
Finland	Do not know	Do not know	Yes, at central level	Yes, at central level	Yes, at central level
France	Yes, at subnational level	No	Yes, at central level	Yes, at central level	Yes, at central level
Germany	No	No	No	No	No
Greece	No	No	Yes, at central level	Yes, at central level	Yes, at central level
Iceland	No	No	No	No	No
Ireland	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
Israel	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Italy	No	No	No	No	No
Japan	No	No	No	No	No
Latvia	No answer	No answer	No answer	No answer	No answer
Lithuania	No answer	No answer	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Luxembourg	No	No	No	No	No
Malta	Do not know	Do not know	Do not know	Do not know	Do not know
Netherlands	No answer	No answer	No answer	No answer	No answer
Norway	Yes, at central level	No	Yes, at central level	Yes, at central level	Yes, at central level
Poland	No	No	No	No	No
Portugal	Yes, at central level	No answer	Yes, at central level	Yes, at central level	No answer
Slovak Republic	Yes, at central level	No	Yes, at central level	Yes, at central level	Yes, at central level
Slovenia	No answer	Do not know	No answer	No answer	No answer
Spain	No	No	Yes, at central level	Yes, at central level	Yes, at central level
Sweden	No answer	No answer	No answer	No answer	No answer
Türkiye	Yes, at institutional level	No answer	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
United States	No answer	No answer	No answer	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.4. Use of ASP components to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	A therapeutic formulary, comprising a list of antimicrobials in LTCFs	A restrictive list of antimicrobials to be prescribed in LTCFs	A system that requires permission from a designated person(s) for prescribing restricted antimicrobials, not included in the local formulary in LTCFs	A system to remind healthcare workers of the importance of microbiological samples to inform the best antimicrobial choice in LTCFs
Australia	No answer	No answer	No answer	No answer
Austria	No	No	No	No
Belgium	Yes, at institutional level	Yes, at institutional level	No	Yes, at institutional level
Canada	Do not know	Do not know	Do not know	Do not know
Chile	Do not know	No	No	No
Costa Rica	No answer	No answer	No answer	No answer
Cyprus	No	No	No	No
Czech Republic	No answer	No answer	No answer	No answer
Denmark	No	No	No	No
Estonia	No answer	No answer	No answer	No answer
Finland	Do not know	Do not know	Do not know	Do not know
France	Yes, at institutional level	Yes, at institutional level	No	No
Germany	No	No	No	No
Greece	Yes, at central level	Yes, at central level	Yes, at institutional level	No
Iceland	No	No	No	No
Ireland	Do not know	Yes, at central level	No	Yes, at central level
Israel	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Italy	No answer	No answer	No answer	No answer
Japan	No	No	No	No
Latvia	No answer	No answer	No answer	No answer
Lithuania	No answer	No answer	No answer	No answer
Luxembourg	No	No	No	No
Malta	Do not know	Yes, at institutional level	Do not know	No
Netherlands	No answer	No answer	No answer	No answer
Norway	Yes, at central level	No	No	Yes, at central level
Poland	No	No	No	No
Portugal	Yes, at central level	Yes, at central level	No answer	No answer
Slovak Republic	Yes, at institutional level	Yes, at central level	Yes, at institutional level	No
Slovenia	No answer	No answer	No answer	No answer
Spain	No	No	No	No
Sweden	No answer	No answer	No answer	No answer
Türkiye	No answer	No answer	No answer	No answer
United States	No answer	No answer	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.5. Use of ASP monitoring, feedback and training to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	Data available on annual antimicrobial consumption by antimicrobial class at the LTCF level	Subnational AMR profile summaries available in LTCFs or local primary care practices	Annual regular training on appropriate antimicrobial prescribing in LTCFs	Advice on antimicrobials not included in the formulary in LTCFs	Feedback to the local general practitioner on antimicrobial consumption in the facility in LTCFs
Australia	No answer	No answer	No answer	No answer	No answer
Austria	No	No	No	No	Yes, at institutional level
Belgium	No	No	Yes, at institutional level	Do not know	Do not know
Canada	Do not know	Do not know	Do not know	Do not know	Do not know
Chile	No	No	No	No	No
Costa Rica	No answer	No answer	No answer	No answer	No answer
Cyprus	No	No	No	No	No
Czech Republic	No answer	No answer	No answer	No answer	No answer
Denmark	No	No	No	No	No
Estonia	No answer	No answer	No answer	No answer	No answer
Finland	Do not know	Do not know	Do not know	Do not know	Do not know
France	Yes, at central level	Yes, at central level	No	No	No
Germany	No	No	No	No	No
Greece	No	Do not know	No	Yes, at central level	No
Iceland	No	No	No	No	No
Ireland	No	No	Yes, at institutional level	Do not know	Yes, at institutional level
Israel	Yes, at central level	Do not know	Yes, at institutional level	Yes, at institutional level	Yes, at central level
Italy	No answer	No answer	No answer	No answer	No answer
Japan	No	No	No	No	No
Latvia	No answer	No answer	No answer	No answer	No answer
Lithuania	No answer	No answer	Yes, at institutional level	No answer	Yes, at institutional level
Luxembourg	No	No	No	No	No
Malta	No	Do not know	Do not know	Do not know	Do not know
Netherlands	No answer	No answer	No answer	No answer	No answer
Norway	Yes, at central level	Yes, at central level	No	Yes, at central level	Yes, at central level
Poland	No	No	No	No	No
Portugal	No answer	No answer	No answer	No answer	No answer
Slovak Republic	No	Yes, at institutional level	No	Yes, at institutional level	No
Slovenia	No	No answer	No answer	No answer	No answer
Spain	No	No	No	No	No
Sweden	No answer	No answer	No answer	No answer	No answer
Türkiye	No answer	No answer	Yes, at subnational level	No answer	Yes, at institutional level
United States	No answer	No answer	No answer	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.6. Use of infection prevention and control budgeting and committees to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	An infection prevention and control programme or protocol in LTCFs	An infection prevention and control focal point in LTCFs	A budget dedicated to infection prevention and control in LTCFs	Internal or external infection control committee in LTCFs
Australia	No answer	No answer	No answer	No answer
Austria	No	No	No	No
Belgium	Yes, at subnational level	Yes, at institutional level	Do not know	Yes, at subnational level
Canada	Yes, at central level	Do not know	Yes, at central level	Do not know
Chile	No	No	No	No
Costa Rica	No answer	No answer	No answer	No answer
Cyprus	No	No	No	No
Czech Republic	No answer	No answer	No answer	No answer
Denmark	Yes, at central level	No	Yes, at institutional level	Yes, at institutional level
Estonia	No answer	No answer	No answer	No answer
Finland	Yes, at central level	Yes, at subnational level	No	Do not know
France	Yes, at central level	Yes, at central level	Yes, at central level	No
Germany	Yes, at central level	Yes, at central level	Yes, at central level	Do not know
Greece	Yes, at institutional level	No	No	No
Iceland	Yes, at central level	Yes, at institutional level	No	Yes, at institutional level
Ireland	Yes, at central level	Yes, at institutional level	Yes, at central level	Yes, at institutional level
Israel	Yes, at central level	Yes, at central level	No	Yes, at institutional level
Italy	Yes, at institutional level	Do not know	Do not know	Yes, at institutional level
Japan	Yes, at subnational level	Yes, at central level	Yes, at central level	Yes, at central level
Latvia	No answer	No answer	No answer	No answer
Lithuania	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	No
Luxembourg	Do not know	Do not know	No	No
Malta	Yes, at central level	Yes, at subnational level	Yes, at central level	No
Netherlands	Yes, at central level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Norway	Yes, at central level	Yes, at subnational level	Yes, at institutional level	No
Poland	No	No	No	No
Portugal	Yes, at central level	Yes, at central level	No	No
Slovak Republic	Yes, at central level	No	No	Yes, at institutional level
Slovenia	No answer	No answer	No answer	No answer
Spain	Yes, at institutional level	No	No	No
Sweden	No answer	No answer	No answer	No answer
Türkiye	No answer	No answer	No answer	No Answer
United Kingdom	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
United States	Yes, at institutional level	No answer	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.7. Use of infection prevention and control written guidelines to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	Management of MRSA and/or other multidrug-resistant microorganisms in LTCFs	Hand hygiene in LTCFs	Management of urinary catheters in LTCFs	Management of venous catheters/lines in LTCFs	Management of enteral feeding in LTCFs
Australia	No answer	No answer	No answer	No answer	No answer
Austria	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Belgium	Yes, at subnational level	Yes, at subnational level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Canada	Yes, at subnational level	Yes, at central level	Do not know	Do not know	Do not know
Chile	No	Do not know	Yes, at central level	Yes, at central level	Yes, at central level
Costa Rica	No answer	No answer	No answer	No answer	No answer
Cyprus	No	No	No	No	No
Czech Republic	No answer	No answer	No answer	No answer	No answer
Denmark	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Do not know
Estonia	No answer	No answer	No answer	No answer	No answer
Finland	Yes, at central level	Yes, at central level	Yes, at central level	Do not know	Do not know
France	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
Germany	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Greece	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	No
Iceland	Yes, at central level	Yes, at central level	Do not know	Do not know	Do not know
Ireland	Yes, at central level	Yes, at central level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Israel	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
Italy	No	Do not know	No	No	No
Japan	Yes, at central level	Yes, at central level	No	No	No
Latvia	No answer	No answer	No answer	No answer	No answer
Lithuania	Do not know	Yes, at central level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Luxembourg	No	Yes, at central level	No	No	Yes, at institutional level
Malta	Yes, at central level	Yes, at central level	Yes, at central level	No	Yes, at central level
Netherlands	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	No answer
Norway	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	No
Poland	Do not know	Do not know	Do not know	Do not know	Do not know
Portugal	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
Slovak Republic	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
Slovenia	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
Spain	No	No	No	No	No answer
Sweden	No answer	No answer	No answer	No answer	No answer
Türkiye	No answer	Yes, at central level	No answer	No answer	No answer
United Kingdom	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
United States	No answer	No answer	No answer	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.8. Use of infection prevention and control components to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	Registration of residents colonised/infected with multi-resistant microorganisms in LTCFs	Decisions on isolation and additional precautions for residents colonised with resistant microorganisms in LTCFs	Designation of a person responsible for reporting and management of outbreaks in LTCFs	Supervision of disinfection and sterilisation of medical and care material in LTCFs	Organisation, control, feedback on hand hygiene in the LTCF on a regular basis	Organisation, control, feedback of a process of surveillance/audit of IPC policies in LTCFs
Australia	Yes, at central level	Yes, at central level	Yes, at institutional level	Yes, at subnational level	Yes, at central level	No answer
Austria	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at institutional level	Yes, at institutional level	No
Belgium	No	Yes, at central level	Yes, at central level	Yes, at subnational level	Yes, at central level	Yes, at institutional level
Canada	Yes, at central level	Yes, at central level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at subnational level
Chile	No	Yes, at central level	Yes, at central level	Yes, at institutional level	Yes, at institutional level	No
Costa Rica	Yes, at institutional level	Yes, at subnational level	Yes, at subnational level	Yes, at institutional level	Yes, at subnational level	No answer
Cyprus	No	Yes, at central level	No	Yes, at central level	Yes, at institutional level	No
Czech Republic	Yes, at institutional level	Yes, at institutional level	Yes, at subnational level	Yes, at institutional level	Yes, at subnational level	No answer
Denmark	Yes, at central level	Yes, at central level	Yes, at institutional level	Do not know	Yes, at institutional level	Yes, at institutional level
Estonia	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at central level	Yes, at institutional level	No answer
Finland	No answer	No answer	No answer	No answer	No answer	Yes, at central level
France	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at central level	Yes, at subnational level
Germany	Yes, at institutional level	Yes, at central level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Greece	No	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at subnational level	No
Iceland	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	No
Ireland	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	No	No
Israel	No	No answer	No	Yes, at institutional level	Yes, at central level	Yes, at institutional level
Italy	Yes, at subnational level	Yes, at subnational level	Do not know	Do not know	No	Do not know
Japan	No	Do not know	No	Yes, at central	Do not know	No

Country	Registration of residents colonised/infected with multi-resistant microorganisms in LTCFs	Decisions on isolation and additional precautions for residents colonised with resistant microorganisms in LTCFs	Designation of a person responsible for reporting and management of outbreaks in LTCFs	Supervision of disinfection and sterilisation of medical and care material in LTCFs	Organisation, control, feedback on hand hygiene in the LTCF on a regular basis	Organisation, control, feedback of a process of surveillance/audit of IPC policies in LTCFs
				level		
Latvia	Yes, at institutional level	No	No	Do not know	No	No answer
Lithuania	Do not know	Do not know	Yes, at central level	Do not know	No	Yes, at institutional level
Luxembourg	Do not know	Yes, at institutional level	Do not know	Do not know	Do not know	No
Malta	Do not know	Do not know	Do not know	No	No	No
Netherlands	Do not know	Do not know	Do not know	Yes, at institutional level	Do not know	Yes, at subnational level
Norway	Do not know	Do not know	Do not know	Do not know	Do not know	Yes, at central level
Poland	No answer	No answer	No answer	No answer	No answer	No
Portugal	No answer	No answer	No answer	No answer	No answer	No
Slovak Republic	No answer	No answer	No answer	No answer	No answer	Yes, at institutional level
Slovenia	No answer	No answer	No answer	No answer	No answer	No answer
Spain	No answer	No answer	No answer	No answer	No answer	No
Sweden	No answer	No answer	No answer	No answer	No answer	No answer
Türkiye	No answer	No answer	No answer	No answer	Yes, Subnational	No answer
United Kingdom	No	Yes, at institutional level	Yes, at subnational level	Yes, at institutional level	Yes, at central level	Yes, at central level
United States	No answer	No answer	No answer	No answer	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.9. Use of infection prevention and control training to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	Regular infection prevention and control training of the nursing and paramedical staff in LTCFs	Regular infection prevention and control training for general practitioners working with LTCFs
Australia	No answer	No answer
Austria	Yes, at subnational level	No
Belgium	Yes, at institutional level	Yes, at institutional level
Canada	Do not know	Do not know
Chile	Do not know	Do not know
Costa Rica	No answer	No answer
Cyprus	No	No
Czech Republic	No answer	No answer
Denmark	Yes, at institutional level	No
Estonia	No answer	No answer
Finland	Yes, at central level	Yes, at central level
France	Yes, at institutional level	Yes, at institutional level
Germany	Yes, at institutional level	Yes, at institutional level
Greece	No	No
Iceland	Yes, at institutional level	No
Ireland	Yes, at central level	Yes, at central level
Israel	Yes, at central level	Yes, at central level
Italy	Do not know	Do not know
Japan	Yes, at central level	Do not know
Latvia	No answer	No answer
Lithuania	Yes, at institutional level	Yes, at institutional level
Luxembourg	Do not know	Do not know
Malta	Yes, at central level	Yes, at central level
Netherlands	Yes, at institutional level	Do not know
Norway	Yes, at institutional level	Yes, at central level
Poland	No	No
Portugal	Yes, at institutional level	Yes, at institutional level
Slovak Republic	Yes, at institutional level	Yes, at institutional level
Slovenia	Yes, at institutional level	Yes, at institutional level
Spain	No	No
Sweden	No answer	No answer
Türkiye	No Answer	No Answer
United Kingdom	Yes, at subnational level	Yes, at central level
United States	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.10. Use of infection prevention and control protocols to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	Offer of annual influenza vaccination to all LTCF residents	Offer of annual influenza vaccination to all staff in LTCFs	Development of care protocols in LTCFs
Australia	No answer	No answer	No answer
Austria	Yes, at subnational level	Yes, at subnational level	No
Belgium	Yes, at subnational level	Yes, at institutional level	Yes, at institutional level
Canada	Yes, at subnational level	Yes, at subnational level	Yes, at central level
Chile	Yes, at central level	Yes, at central level	Yes, at central level
Costa Rica	No answer	No answer	No answer
Cyprus	Yes, at central level	Yes, at central level	Do not know
Czech Republic	No answer	No answer	No answer
Denmark	Yes, at central level	Do not know	Yes, at institutional level
Estonia	No answer	No answer	No answer
Finland	Yes, at central level	Yes, at central level	Yes, at central level
France	Yes, at institutional level	Yes, at institutional level	Yes, at subnational level
Germany	Yes, at institutional level	Yes, at institutional level	Yes, at central level
Greece	Yes, at central level	Yes, at central level	Yes, at institutional level
Iceland	Yes, at central level	Yes, at central level	Do not know
Ireland	Yes, at central level	Yes, at central level	Yes, at institutional level
Israel	Yes, at central level	Yes, at central level	Yes, at central level
Italy	Yes, at central level	Yes, at central level	Do not know
Japan	No	No	Do not know
Latvia	No answer	No answer	No answer
Lithuania	Yes, at central level	Yes, at central level	Yes, at institutional level
Luxembourg	Yes, at institutional level	Yes, at institutional level	Do not know
Malta	Yes, at central level	Yes, at central level	Yes, at central level
Netherlands	Yes, at central level	Yes, at institutional level	Yes, at central level
Norway	Yes, at institutional level	Yes, at institutional level	Yes, at central level
Poland	Yes, at central level	Yes, at central level	No
Portugal	Yes, at central level	Yes, at central level	Yes, at institutional level
Slovak Republic	Yes, at central level	No	No
Slovenia	Yes, at institutional level	No answer	No answer
Spain	Yes, at central level	Yes, at central level	Yes, at institutional level
Sweden	No answer	No answer	No answer
Türkiye	Yes, at central level	Yes, at central level	No Answer
United Kingdom	Yes, at central level	Yes, at central level	Yes, at subnational level
United States	Yes, at central level	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.11. Use of surveillance and monitoring to tackle AMR in LTCFs in the EU/EEA and OECD, 2021-22

Country	Antimicrobial consumption in LTCFs	AMR in LTCFs	HAIs in LTCFs	Multidrug-resistant organisms in LTCFs	Indicators of ASP in LTCFs	Indicators of infection prevention and control in LTCFs
Australia	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
Austria	Yes, at institutional level	No	Yes, at institutional level	Yes, at institutional level	No	Do not know
Belgium	No	No	No	Yes, at central level	No	No
Canada	No answer	No answer	No answer	No answer	No answer	No answer
Chile	No	No	No	No	No	No
Costa Rica	No answer	No answer	No answer	No answer	No answer	No answer
Cyprus	No	No	No	No	No	No
Czech Republic	No answer	No answer	No answer	No answer	No answer	No answer
Denmark	No	No	No	No	No	No
Estonia	No answer	No answer	No answer	No answer	No answer	No answer
Finland	Do not know	Do not know	Do not know	Yes, at central level	Do not know	Do not know
France	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	No	Yes, at central level
Germany	No	No	No	No	No	No
Greece	No answer	No answer	No answer	No answer	No answer	No answer
Iceland	No	No	No	No	No	No
Ireland	Yes, at institutional level	No	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level
Israel	Yes, at central level	Yes, at central level	No	Yes, at central level	No	No
Italy	No	No	No	No	No	No
Japan	No	No	No	No	No	No
Latvia	No answer	No answer	No answer	No answer	No answer	No answer
Lithuania	No	No	Yes, at institutional level	No	No	No
Luxembourg	No	No	No	No	No	No
Malta	Do not know	Yes, at subnational level	Yes, at subnational level	Yes, at subnational level	Do not know	No
Netherlands	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
Norway	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level	Yes, at central level
Poland	No	No	No	No	No	No
Portugal	No	No	No	No	No	No
Slovak Republic	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	Yes, at institutional level	No	No
Slovenia	No	No	No answer	No	No answer	No answer
Spain	No	No	No	Yes, at subnational level	No	Yes, at subnational level
Sweden	No answer	No answer	No answer	No answer	No answer	No answer
Türkiye	No	No	No	No	No	No
United States	Yes, at institutional level	Yes, at institutional level	No answer	No answer	No answer	No answer

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.12. Overview of the impact of the COVID-19 pandemic on surveillance of AMR in LTCFs in the EU/EEA and OECD, 2021-22

Did the COVID-19 pandemic affect the following country actions?

Country	Surveillance of antimicrobial consumption in LTCFs	Surveillance of AMR in LTCFs	Surveillance of HAIs in LTCFs	Rapid testing of residents in LTCFs to determine whether they have viral or bacterial infections
Australia	No	No	No	No
Austria	Yes	Yes	Yes	No
Belgium	Yes	Yes	Yes	No
Canada	No	No	No	No
Chile	No	No	No	No
Costa Rica	No answer	No answer	No answer	No answer
Cyprus	Yes	Yes	Yes	No
Czech Republic	No answer	No answer	No answer	No answer
Denmark	No	No	No	No
Estonia	No answer	No answer	No answer	No answer
Finland	Yes	Yes	Yes	Yes
France	Yes	No	No	No
Germany	No	No	Yes	Yes
Greece	Yes	Yes	Yes	Yes
Iceland	No	No	No	No
Ireland	Yes	No	Yes	Yes
Israel	No	No	No	No
Italy	No	No	No	No
Japan	No	No	No	No
Latvia	No answer	No answer	No answer	No answer
Lithuania	No	No	No	No
Luxembourg	No	No	No	Yes
Malta	Yes	Yes	Yes	Yes
Netherlands	Yes	Yes	Yes	Yes
Norway	No	No	No	No
Poland	No	No	No	No
Portugal	No	No	No	Yes
Slovak Republic	Do not know	Do not know	Do not know	Do not know
Slovenia	Yes	Yes	Yes	No
Spain	No	Yes	Yes	No
Sweden	No	No	No	No
Türkiye	No	No	No	No
United States	No	No	No	Yes

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Annex Table 7.B.13. Overview of the impact of the COVID-19 pandemic on policy actions related to AMR in LTCFs in the EU/EEA and OECD, 2021-22

Did the COVID-19 pandemic affect the following country actions?

Country	Developing, approving or operationalising the national action plan on antimicrobial resistance	Audits of antibiotic prescribing behaviours in LTCFs	ASP in LTCFs (e.g. education)	Infection prevention and control in LTCFs (e.g. hand hygiene)	Activities to improve awareness and understanding of antibacterial resistance in LTCFs in the general public (e.g. social media campaigns)	Vaccination campaigns for non-COVID-19 related diseases (e.g. influenza) in LTCFs
Australia	No answer	No	No	No	No	No
Austria	Yes	No	No	Yes	No	Yes
Belgium	Yes	No	Yes	Yes	No	Yes
Canada	Yes	No	No	Yes	No	No
Chile	Yes	No	No	No	No	No
Costa Rica	Yes	No answer	No answer	No answer	No answer	No answer
Cyprus	Yes	Yes	Yes	No	No	No
Czech Republic	Yes	No answer	No answer	No answer	No answer	No answer
Denmark	No	No	No	No	No	No
Estonia	No answer	No answer	No answer	No answer	No answer	No answer
Finland	Yes	Yes	Yes	Yes	Yes	Yes
France	Yes	Yes	Yes	No	Yes	No
Germany	Yes	No	No	Yes	No	Yes
Greece	Yes	Yes	Yes	Yes	Yes	Yes
Iceland	No	No	No	No	No	No
Ireland	Yes	No	Yes	Yes	No	No
Israel	Yes	No	No	Yes	No	No
Italy	Yes	No	No	Yes	No	Yes
Japan	No	No	No	Yes	No	No
Latvia	Yes	No answer	No answer	No answer	No answer	No answer
Lithuania	Yes	No	No	Yes	No	No
Luxembourg	Yes	No	Yes	Yes	No	Yes
Malta	No answer	Yes	Yes	Yes	Yes	Yes
Netherlands	Yes	Yes	Yes	Yes	Yes	Yes
Norway	Yes	No	No	No	No	No
Poland	No answer	No	No	Yes	No	Yes
Portugal	No	No	No	Yes	No	No
Slovak Republic	Yes	Do not know	Do not know	Do not know	Do not know	Do not know
Slovenia	Yes	Yes	Yes	No	No	No
Spain	Yes	No	Yes	Yes	No	No
Sweden	No answer	No	No	No	No	No
Türkiye	Yes	No			No	Yes
United Kingdom	No	No answer	No answer	No answer	No answer	No answer
United States	Yes	Yes	No	Yes	No	No

Note: Countries are sorted alphabetically.
Source: OECD analysis of Survey on Antibacterial Resistance in LTCFs (2021-22).

Notes

[1] The first level markers used in the ECDC Composite Index of AMR are: *Staphylococcus aureus* resistant to methicillin (MRSA), *Enterococcus faecium* and *Enterococcus faecalis* resistant to vancomycin, *Enterobacteriaceae* resistant to third-generation cephalosporins and *Pseudomonas aeruginosa* and *Acinetobacter baumannii* resistant to carbapenems. *Enterobacteriaceae* selected for the AMR markers: *Escherichia coli*, *Klebsiella* spp., *Enterobacter* spp., *Proteus* spp., *Citrobacter* spp., *Serratia* spp. and *Morganella* spp.

[2] Frequencies and percentages for specific questions in the policy survey are based on countries that responded to each specific question in the policy survey. Countries that did respond to a specific question are excluded from analyses of that specific question.

OECD Health Policy Studies

Embracing a One Health Framework to Fight Antimicrobial Resistance

Antimicrobial resistance (AMR) – the ability of microbes to resist antimicrobials – remains an alarming global health threat. This is despite the efforts made by OECD and EU/EEA countries to curtail it. Unless additional effective interventions are scaled up quickly, AMR rates are forecasted to increase in the next three decades across OECD and EU/EEA countries, with costs exceeding the healthcare expenditure on the COVID-19 pandemic. Using microsimulation and machine-learning techniques, this report analyses critical policy levers to inform the next generation of AMR initiatives. It shows that tackling the detrimental health and economic impact of AMR requires embracing a One Health framework – a collaborative, trans-disciplinary and multi-sectoral approach that promotes close co-operation and collaboration across human health, animal health, agrifood systems and the environment. This report identifies 11 One Health "best buys" that, if implemented systematically, would improve population health, reduce health expenditure and generate positive returns for the economy.

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