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Forecasting the Fallout from AMR: Economic Impacts of Antimicrobial Resistance in Humans

A report from the EcoAMR series

The Fleming Fund

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Forecasting the Fallout from AMR: Economic Impacts of Antimicrobial Resistance in Humans

A report from the EcoAMR series

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Foreword

Less than a year ago, the Center for Global Development (CGD) published a landmark report proposing six critical recommendations to achieve a balance of innovation, access and stewardship of antimicrobials. The urgency to increase access to, and foster innovation of, new antimicrobials cannot be overstated. Annually, antimicrobial resistance (AMR) claims the lives of 1.27 million people, with an additional 4.95 million deaths associated with bacterial AMR. Inaction only promises to increase these numbers. However, what is less frequently discussed, yet equally significant, is the profound impact that rising levels of AMR will have on our global economy.

Making an economic case for investment in the fight against AMR has been a challenge across the world, partly due to competing priorities at all levels. Paramount to establishing the required business case for sustainable investment to tackle AMR is cooperation – both within and across human and animal sectors – as well as collaboration with national and global stakeholders, and engagement of private partnerships. Thus, the World Organisation for Animal Health (WOAH) is collaborating with the United Kingdom Department of Health and Social Care (UK DHSC) to pool a consortium of international partners across the human and animal health sectors, who can implement this groundbreaking EcoAMR Series. The project aims to generate the necessary evidence that will inform bold and concrete commitments to mitigate AMR by member states at the United Nations General Assembly (UNGA) High-Level Meeting on AMR in 2024 and future actions by governments and policy-makers. Among this team are global experts from the Center for Global Development and the Institute for Health Metrics and Evaluation, who have partnered with Global Research on Antimicrobial Resistance to develop the human health component. Meanwhile, RAND Europe, Animal Industry Data and WOAH have addressed the animal health component of this cross-sector initiative. The World Bank has provided quality assurance via a team of global experts serving as peer reviewers of this study's methodologies and outputs. The results from this study will guide action-oriented declarations at the UNGA High-Level Meeting on AMR, inform governments and policy-makers on effective interventions and policy-making, and facilitate sustainable financing.

To date, there have been three other studies that have quantified the global macroeconomic burden of AMR: two were commissioned by the AMR Review in 2014 and a third was published by the World Bank in 2017. Our report builds on this existing work by using more granular data on the health burden of AMR to explore a broader set of economic disruptions and measure the impact of different interventions to halt AMR. We model the future economic impact of AMR under five different scenarios on four areas of the economy: health system costs, the labour market, tourism and domestic hospitality. This is the broadest range of economic shocks ever modelled for AMR.

Our findings are profound. In a scenario where countries fail to contain drug resistance, we could face a staggering US$ 1.7 trillion annual reduction in global economic output by 2050, amounting to a 0.88% decrease in GDP. This would not only escalate hospital treatment costs, but also adversely affect tourism and domestic hospitality.

Conversely, a scenario that promotes increased access to high-quality treatment for bacterial infections, coupled with funding that spurs the development of new gram-negative antibiotics, presents a more hopeful future. Such initiatives could boost the global economy by an estimated US$ 960 billion by 2050, while simultaneously reducing health care costs by US$ 100 billion. This is in addition to the benefits of simply improving people's lives and the insurance value of reducing the risk of an AMR outbreak.

The report is explicit in its message: inaction on AMR carries a significant economic burden. However, the potential economic gains from measures that stem the rise of AMR are substantial.

The evidence also illustrates that drug resistance is not an expensive problem to fix. We estimate that it will cost US$ 63 billion dollars a year to provide quality treatment for bacterial infections and ensure innovation. These interventions offer a return on investment of 28:1, once the health benefits of the policy are taken into consideration.

As we stand on the cusp of the upcoming UNGA High-Level Meeting on Antimicrobial Resistance, we are reminded, once again, of the critical juncture at which we find ourselves in the fight against AMR. The meeting promises to yield a new political declaration – the first on AMR since 2016. New research since then has improved our understanding of AMR's devastating impacts – not just on human health but on the stability of our global economy. Member states must not only acknowledge these challenges, but also commit to the necessary measures to address them: sustained investment, improved surveillance, and greater research and development.

Mark Plant

Chief Operating Officer and Senior Policy Fellow, *Center for Global Development*

Acknowledgements

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We are very grateful to Dame Professor Sally Davies for her support and guidance throughout this process; to the 21 experts who completed a survey and were interviewed about this project; and to the peer reviewers, who provided exceptionally useful insights.

We also thank CGD's communications team for all its work on this project, particularly Emily Schabacker and Sara Viglione for their feedback, support and editing, and Stephanie Donohoe who designed several of the graphics in this paper. We are also very grateful to Barbara Karni for her work editing the paper. The paper is a much stronger piece of work thanks to the contributions of all these people.

List of abbreviations

AMR	Antimicrobial Resistance
CGE	Computable General Equilibrium
DALY	Disability-Adjusted Life Year
GDP	Gross Domestic Product
GRAM	Global Research on Antimicrobial Resistance
GTAP	Global Trade Analysis Project
HAQ	Healthcare Access and Quality Index
IHME	Institute for Health Metrics and Evaluation
ILO	International Labour Organization
MERS	Middle East Respiratory Syndrome
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Development
SARS	Severe Acute Respiratory Syndrome
TFP	Total Factor Productivity
UNICEF	United Nations International Children's Emergency Fund
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WOAH	World Organisation for Animal Health

Executive summary

KEY TAKEAWAYS

We estimate that:

1. The impact of antimicrobial resistance falls most heavily on low- and lower-middle-income countries. Antimicrobial resistance increases the cost of health care by US$ 66 billion, and this will rise to US$ 159 billion in our business-as-usual scenario where resistance rates follow historical trends.
2. If resistance rates increased at the rate of the bottom 15% of countries, AMR health costs would rise to US$ 325 billion and the global economy would be US$ 1.7 trillion smaller in 2050 (compared to the business-as-usual scenario).
3. If high-quality treatment is provided to everyone with bacterial infections and funding innovative new antibiotics, this would mean that by 2050:
   a. Health costs could be US$ 97 billion cheaper.
   b. The economy could be US$ 990 billion larger.
   c. Generated health benefits could be worth US$ 680 billion to countries.
4. Improving innovation and access to high-quality treatment would cost about US$ 63 billion per year, offering a global return on investment of 28:1.

Antimicrobial resistance (AMR) poses a significant threat to global health and economic stability. This report integrates human health burden projections with economic models to provide a comprehensive analysis of the impact of AMR on global economies and health systems.

METHODOLOGY

We adopted a multifaceted approach to estimate the economic burden of AMR. Projections of the health burden were taken from the Institute for Health Metrics and Evaluation (IHME) and five aspects of their economic impact were quantified:

1. **Health care costs:** a literature review identified cost estimates for treating resistant infections across 204 countries. We adopted a cost-of-illness methodology, mapping costs to 11 infectious syndromes, and used an imputation model to estimate costs for unknown countries, combining them with inpatient estimates derived from IHME data to project future costs.
2. **Economic resilience:** we conducted a literature review to understand the likely ways that changes in resistance might affect the economy. We then estimated how changes in AMR would lead to changes in population, direct and indirect labour force participation, tourism and hospitality.[1] Our estimates were derived from literature reviews, mathematical modelling and expert elicitation from 21 experts.
3. **Macroeconomic modelling:** we fed health and resilience inputs into a computable general equilibrium (CGE) model to simulate the wider impact on the economy.
4. **Intervention costs:** we used literature reviews and economic modelling to estimate the cost of various interventions that could tackle AMR, allowing us to compare costs and benefits.

1 These sectors were chosen based on the literature review, which is outlined in the results section.

5. **Gross Domestic Product- (GDP) based health valuation:** we estimated the health loss due to AMR, converting it into a monetary value using an established methodology.

RESULTS

Effect of AMR on mortality

All estimates of the health burden of AMR come from the IHME. Five of these scenarios were examined and compared with a business-as-usual scenario in which AMR resistance follows trends since 1990:

- Business-as-usual scenario: this assumes that resistance follows historical trends.
- Scenario 1: better treatment of bacterial infections is provided.
- Scenario 2: increased innovation and rollouts of gram-negative antibiotics.
- Scenario 3: better treatment and increased innovation is provided (combining scenarios 1 and 2).
- Scenario 4: improved access to treatments for bacterial infections; increased innovation for gram-negative bacteria; and improved access to vaccines, sanitation and clean water.
- Scenario 5 (accelerated rise in resistance scenario): this assumes resistance increases at the rate of the bottom 15% of countries.

Health burden estimates from the IHME suggest that if resistance follows trends since 1990 (the business-as-usual scenario), AMR will lead to 38.5 million deaths between 2025 and 2050. Scenario 1 would avert 90 million deaths over this period (the vast majority not from resistant infections), Scenario 2 would avert 10 million deaths, Scenario 3 would avert 100 million deaths and Scenario 4 would avert 110 million deaths. In the accelerated rise in resistance scenario (Scenario 5), an additional 6.7 million people would die as a result of AMR.

Effect of AMR on the economy

We estimate the current direct health care costs associated with AMR at US$ 66 billion per year (0.7% of global health expenditures). These costs encompass the cost of treating antibiotic-resistant infections.

The median cost of treating a resistant infection per hospital admission varies significantly, ranging from US$ 100–30,000 depending on a country's income level and the type of infection. Costs per incidence are highest in high-income countries, where more intensive treatment protocols are available, and lowest in low-income countries, where resources are highly constrained.

If resistance rates follow historical trends since 1990, the direct health care costs of AMR are projected to rise to US$ 159 billion per year by 2050 (1.2% of global health expenditure). This increase is attributed to higher treatment intensities and economic growth in regions most affected by AMR.

If nobody died from AMR, we would expect the global population to be 22.2 million larger by 2050 than it would be in a world in which resistant infections follow historical trends. This increase would add 8 million people to the labour force. Most experts consulted for this study agreed that AMR would reduce tourism and hospitality, with poorer countries particularly vulnerable and countries with robust health systems and higher GDPs more resilient. Experts also noted that relative AMR rates are crucial, as higher rates in specific countries would deter tourism more than global rates rising at a uniform rate.

Results of intervention scenarios

Effects of the five IHME scenarios were examined, and the results are summarised in Table E.1.

Lower- and middle-income countries stand to gain the most from policies that combat AMR (see Figure E.1).

Better treatment of bacterial infections

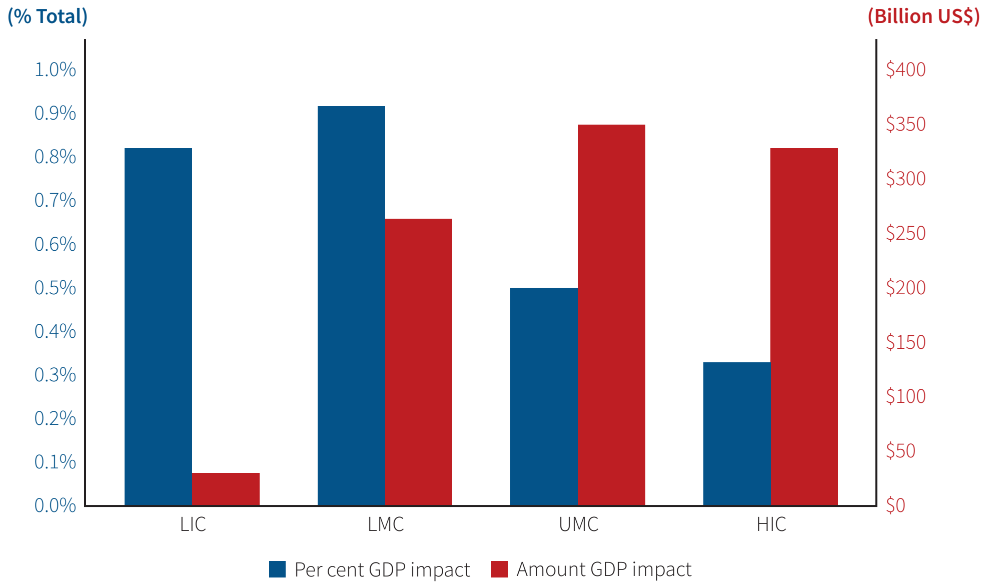
Improving treatment for bacterial infections, for example by providing better access to antibiotics, could lead to a US$ 19 billion annual reduction in health care costs by 2050 (a saving of 0.12%). This scenario would increase global GDP by US$ 269 billion (0.13%) over the business-as-usual scenario. The health benefits from this intervention would be worth half a billion dollars if disability-adjusted life years (DALYs) are valued at the GDP per capita of a given country.

TABLE E.1 Deaths averted, health care cost savings, macroeconomic benefits and a GDP-based health valuation in 2050 under five AMR scenarios (in billion US$ at 2022 value, except where otherwise indicated)

Scenario	Deaths avoided 2025–50 (millions)[a]	Health care costs saved	Change in GDP	GDP-based health valuation
Scenario 1: Better treatment of bacterial infections	89.84	19.17	269.16	506.52
Scenario 2: Innovation and rollout of effective new gram-negative antibiotics	10.23	83.28	742.85	174.06
Scenario 3: Better treatment and innovation	100.01	96.67	959.32	678.94
Scenario 4: Combined interventions	110.02	98.62	989.70	875.76
Scenario 5: Accelerated rise in resistance scenario	–6.69	–175.74	–1,671.16	–264.85

Note: [a]Data are from Vollset *et al*. (2024).

FIGURE E.1 Per cent and total GDP impact in 2050 due to improved treatment and innovation (in billion US$)



Note: LIC = Low-Income Countries, LMC = Lower-Middle-Income Countries, UMC = Upper-Middle-Income Countries, HIC = High-Income Countries.

Increased innovation and the rollout of effective new gram-negative antibiotics

Gram-negative bacteria cause about two-thirds of the world's bacterial burden and tend to be more difficult to treat than gram-positive pathogens. Most of the priority areas for new antibiotics are gram-negative (Breijyeh *et al.,* 2020). Introducing new gram-negative antibiotics could reduce health care costs by US$ 84 billion (0.54%) per year by 2050. This scenario would generate improved health outcomes worth US$ 174 billion, using a GDP-based health valuation, and would add US$ 740 billion (0.37%) to global GDP. This underscores the critical need for investment in antibiotic research and development (R&D).

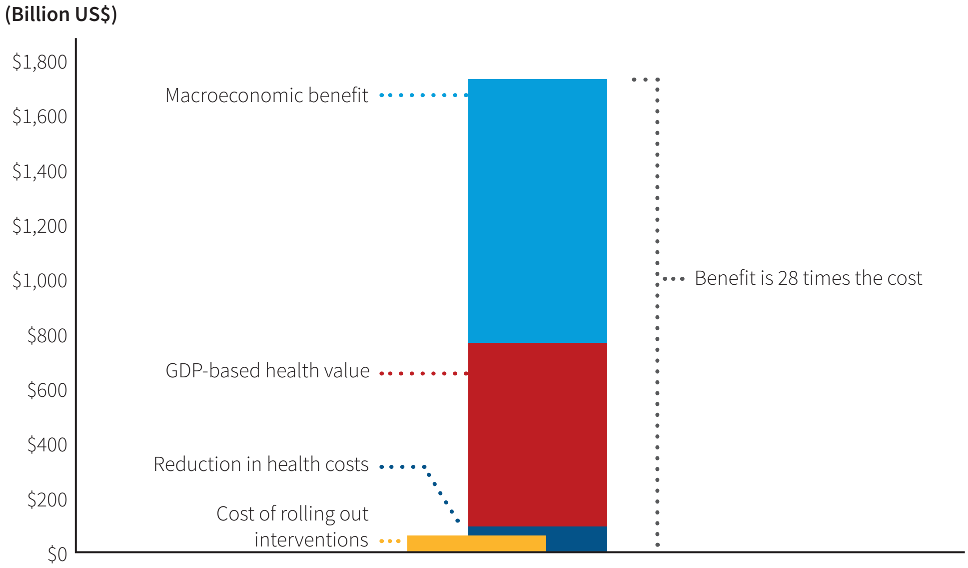
Better treatment and increased innovation

Improving antibiotic access and introducing new antibiotics could result in significant cost savings, potentially reducing health care expenditures by US$ 97 billion (0.63%) per year by 2050. Including wider macroeconomic benefits would see GDP increase by US$ 960 billion (0.48%) per year by 2050. This scenario demonstrates the compounded benefits of integrating multiple interventions to combat AMR.

Combined interventions

A comprehensive approach that combines better treatment of bacterial infections, the introduction of new antibiotics, enhanced vaccination programmes and

FIGURE E.2 Estimated annual costs (in US$) and benefits in 2050 of better treatment for bacterial infections and innovative new gram-negative drugs



Note: GDP-based health valuation is calculated by valuing each DALY at the respective country's GDP per capita.

better access to water, sanitation and hygience would result in the largest reduction in health care costs, saving up to US$ 99 billion (0.64%) per year by 2050. This scenario would add almost US$ 990 billion (0.49%) per year to global economic output.

Accelerated rise in resistance scenario

Without effective interventions, health care costs could increase by US$ 176 billion (1.14%) per year by 2050, and global output could be US$ 1.7 trillion (0.83%) lower than in the business-as-usual scenario.

COST OF INTERVENTIONS AND RETURN ON INVESTMENT

Both improved treatment for and increased access to antibiotics significantly improve health outcomes. It is also cost-effective to roll out both types of interventions.

There is no consensus on the number of new antibiotics needed, with estimates ranging from 6 to 15 drugs per decade. We assume that ten are needed per decade and that two-thirds will be for gram-negative antibiotics. With estimated R&D costs of US$ 3.3 billion per drug, this leads to an annual additional R&D cost of US$ 2.2 billion. If all high-income countries funded this R&D in proportion to their GDP, it would cost them 0.0036% of GDP in 2025. We project these costs to rise slightly more rapidly than inflation, but the cost for each country would decrease over time as more countries join the ranks of high-income countries.

For these new drugs to provide the promised health benefits, people across the world must have access to them. We estimate that it would cost US$ 59 billion to ensure that all countries have outcomes for bacterial infections that match the quality of treatment currently available in the 85th percentile of countries. Adding this to the R&D cost yields a global estimate of US$ 63 billion – less than the reduction in health costs that would accrue from implementing these interventions. When the macroeconomic and health benefits are considered, the return on investment is 28:1, highlighting the excellent value for money these interventions offer (Figure E.2).

CHAPTER 1

Introduction

Antimicrobial resistance (AMR) occurs when microorganisms such as bacteria, viruses, fungi and parasites develop the ability to withstand drugs that once effectively treated infections. This report focuses on the subset of AMR that is linked to bacterial infections, currently the largest subset of AMR and the one for which the data are richest.

The consequences of AMR are severe. Patients with resistant infections face increased mortality and prolonged illness, leading to longer hospital stays and higher medical costs. Routine medical procedures, such as surgery and chemotherapy, become riskier due to the potential for infections that are difficult or impossible to treat. This study focuses on the direct health impacts of AMR and their economic consequences.

Economically, AMR imposes a substantial burden across multiple sectors. The health care system bears the direct costs of treating resistant infections, which include extended hospital stays, additional diagnostic tests and the need for more expensive drugs. Prolonged or recurrent infections also reduce productivity and increase absenteeism, diminishing economic output.

Two large studies on the economic impact of AMR have been conducted: a study by O'Neill and the AMR Review (2014) and a study by the World Bank (2017). Both focus primarily on the labour force disruption that resistance can cause and on the cost of resistance, rather than the economic benefits of interventions that address AMR. Both were published years before the Institute for Health Metrics and Evaluation (IHME) and the University of Oxford completed their influential GRAMs study, which was the first comprehensive analysis of the burden of disease of AMR (Murray *et al.,* 2022).

This study uses the most up-to-date, granular data on the health burden of AMR, explores a broader set of economic disruptions, as well as five interventions to reduce AMR. It is organised as follows: Chapter 2 describes the methodology; Chapter 3 presents the results; and Chapter 4 offers a discussion of the results, along with policy implications and avenues for future research.

CHAPTER 2

Methodology

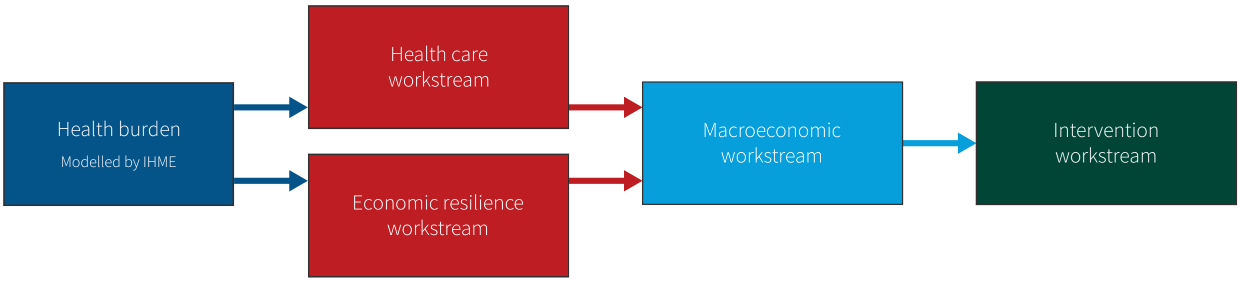
This project uses projections of the health burden of AMR, as modelled by the IHME under five scenarios (Figure 2.1). Results were analysed in two workstreams: a health-cost workstream, which examined how changes in resistance would affect the cost of health systems, and an economic resilience workstream, which examined how changes in resistance could affect specific sectors of the economy. The results informed the macroeconomic workstream, which calculates how these changes would affect the economy as a whole.

ESTIMATES OF THE BURDEN OF DISEASE ASSOCIATED WITH AMR

IHME and the University of Oxford estimated the burden of AMR for every year between 1990 and 2021.[2] The number of deaths were projected up to 2050 in two scenarios: in the first, resistance follows historical trends, and in the second, resistance remains constant but the burden changes as a result of variations in population and risk factors. The following business-as-usual scenario and five scenarios were also modelled:

- Business-as-usual scenario: assumes that resistance follows historical trends.
- Scenario 1: better treatment of bacterial infections is provided.
- Scenario 2: increased innovation and rollout of gram-negative antibiotics.
- Scenario 3: better treatment is provided, along with increased innovation.
- Scenario 4: better treatment is provided; increased innovation; and improved access to vaccines, sanitation and clean water.
- Scenario 5: an accelerated rise in resistance scenario that assumes resistance increases at the rate of the bottom 15% of countries.

FIGURE 2.1 Workstreams used to estimate the health burden of AMR



Note: IHME = Institute for Health Metrics and Evaluation.

2 Since health burden is an essential input for estimating the economic costs of AMR, we worked closely with IHME throughout this project. More details on this research can be found in IHME's EcoAMR Paper (Vollset *et al.*, 2024).

ESTIMATES OF THE ECONOMIC COST OF AMR

A literature review of studies of resistance and other infectious disease identified six priority mechanisms via which resistance could affect economic growth:

1. **Health care costs**
2. **Population change:** a reduction in consumption due to a decline in population
3. **Direct labour:** people leave the labour market due to the burden of resistance
4. **Indirect labour:** people leave the labour market or change career to avoid becoming sick from resistance
5. **Tourism:** a decline in tourism in countries with a high burden of AMR
6. **Hospitality:** a decline in the high-contact recreational service sector

We estimated the direct cost of AMR for in-patient settings using a cost-of-illness methodology.[3] A literature review identified 232 papers, which provided 896 cost estimates. These costs were mapped to eleven infectious syndromes and standardised to US$ at 2022 value.

Next, an imputation model was used to estimate the cost of a bacterial admission in each of the 204 countries tracked by IHME. IHME's data and an epidemiological review allowed for an estimation of the number of in-patients with resistant infections. These two approaches yielded a cost per hospital admission and the number of admissions per country, which were combined for an estimate of today's direct health care cost of resistance. We then projected that figure into the future using IHME's estimate scenarios and assumptions.

Two headline measures of resistant costs were estimated: (a) cost per resistant admission, which focuses on the whole cost of the infection (but may include some non-infection-related costs); and (b) the excess cost per resistant admission (the additional cost of a resistant infection over a susceptible one). The cost per resistant admission reflects actual resource usage; the excess cost better estimates the impact of resistance. We projected these costs to 2050 using various projections of the burden of resistance based on health estimates. For a detailed description of this methodology, see Laurence *et al.* (forthcoming). Confidence intervals were generated taking the intervals from estimates and different assumptions around admissions and the future cost of treating AMR.

We used the IHME's estimates of AMR-related deaths to estimate how the population would change under different AMR scenarios. Where there is a discrepancy in the number of deaths between the business-as-usual scenario and one of the scenarios, we assume that everyone who does not die will have the same probability of dying from another disease as everyone else their age in their country.

Three impacts of AMR on the labour market were explored: death, illness and bereavement. We estimated the impact of death on the workforce by combining population changes with data on how likely an individual is to be in the workforce, given their country and age. For illness, we assumed that per capita output would decline by the same amount as the person's quality of life (estimated by IHME's disease severity weighting). A literature review helped estimate the economic impact of death on family and friends.

These sectors were chosen based on a wide-ranging literature review to understand how AMR might affect the economy. This literature review took a mixed-methods approach, beginning with a broad scoping review of academic, non-academic and grey literature to establish an analytical framework to assessed the global, indirect economic burden of infectious diseases. A deductive analytical approach was used to examine other studies on AMR, as well as diseases that had similar characteristics as AMR based on their transmissibility, severity and prevalence (i.e. whether they are endemic or prone to causing outbreaks). We then looked at how different sectors of the economy were likely to be affected by these diseases in question, and decided whether the same

3 We estimate the overall cost of AMR inpatient care, from the perspective of the health care system irrespective of which party has financed the care.

mechanism could apply to AMR. This literature review indicated that tourism and hospitality were two sectors that might see disruption, alongside the labour force and health costs. However, the literature did not provide enough evidence to create inputs for our model.

Thus, expert elicitation and modelling were used to estimate the changes in indirect labour, tourism and hospitality. We invited 85 experts to take part in an interview and survey. Participants included experts on AMR, the labour force, tourism and hospitality, although the vast majority were AMR experts, including economists, policy-makers and health experts from the sectors of academia, industry and government (see Table A.1 in the annex for a list of experts). To ensure geographical distribution, experts were included from across six continents. Twenty-one of the 85 invited experts agreed to participate,[4] which is more than the number of experts recommended by Bojke *et al.* (2021). For tourism, we distinguished between changes in AMR that predominantly affected one country and situations in which all countries experienced similar rates of AMR.

Experts were asked to comment on how each economic activity would change in a country, under seven different scenarios and their changes in AMR, ranging from the death rate falling by half to increasing by a factor of eight. A regression then estimated a fit line for how a change in the death rate from AMR might change economic activity in a country. We estimated how an expert thought activity in a country would change, given the change in resistance, and used those figures to calculate the change in activity for each country in a given year, and the IHME scenario. This was used to calculate the total global change in that economic activity.

We then adjusted these figures in a given country based on how resilient the experts indicated those countries would be to an economic shock. Each expert was asked to rate up to 26 variables on a scale of 1–10 and to state whether these variables made countries more or less resilient. For example, would people from wealthier than average countries be more or less resilient to an AMR shock. For each metric, the country to receive the highest grade was given a score the same as the rating score. The country that preformed least well was assigned a zero on that metric. Every country in between was assigned a number based on how close it was to the best- and worst-performing countries. The scores across all variables were then combined to give each country a resilience score for a specific sector of the economy in a specific year. A country that had a resilience score of 33% would see twice as much economic impact from the same change in resistance as a country with a resilience score of 67%. The original shock in each country was adjusted so that this ratio was achieved while keeping the global impact constant.

This process created an estimate for how each expert's responses indicated a given country would be affected in a given year. The estimates were then combined using a trimmed mean, in which the highest and lowest 10% of estimates were removed.

The health and resilience workstreams generated a range of shocks for how different parts of the economy would be affected. A computable general equilibrium (CGE) model simulated how these changes in population, the labour force, tourism and hospitality would affect the economy as a whole. Employing the Global Trade Analysis Project (GTAP) version 7 model and version 11 database, we analysed 122 countries, covering 93.0% of the global population and 98.5% of economic output. Due to data constraints, other countries were aggregated into four regions. Simulations were run for 2030, 2040 and 2050.

Governments often assign a monetary value to the societal benefits of health to reconcile them with other benefits and costs. This helps governments maximise the overall societal benefits from any money they spend. This approach is referred to as a *GDP-based health valuation,* and we calculated this by assigning a monetary value for every DALY. A monetary value of one DALY is

4 Of the 21 interviewees, two completed a different version of the survey than the one outlined here; two others did not feel comfortable quantifying their responses. Responses from these four participants were used in the qualitative assessment, and two of them gave responses that could be used for estimating countries' resilience but not in the quantitative results.

applied as GDP per capita for that country. This assumption is based on methodology similar to that of the Towse and Bonnifield (2022) global estimate. The World Health Organization (WHO) describes a treatment that costs the equivalent of GDP per capita to avert one DALY as 'highly cost-effective', making this a conservative assumption (Claxton *et al.,* 2016; Ochalek *et al.,* 2018; Sculpher *et al.,* 2017; Towse and Bonnifield, 2022).

The resulting analysis is highly uncertain. AMR forecasts and the health impact of interventions are difficult to project, and new treatment regimens and other factors could affect health care costs. The nature of the broader economic impact at both the country and global level will depend on many factors, including the nature of AMR threats that emerge and their psychological, social and political salience. There is a very limited body of academic literature on which to draw from to understand the potential economic impact.

ESTIMATES OF THE COST OF INTERVENING TO PREVENT AMR

Next, we estimated the cost of improving medical treatment and providing better treatment of bacterial infections so that every country could achieve bacterial infection outcomes in line with the 85th percentile of countries for case fatality rate. To do so, we developed an original modelling approach, fitting a Cobb-Douglas production function to estimate how inputs of antibiotics and other health care resources are transformed into health outcomes.

To estimate the cost of new antibiotics, we reviewed the literature for evidence on the number of new antibiotics the world was likely to need and their cost. We assumed that high-income countries would bear all the research and development (R&D) costs. Literature on the global cost of vaccination was reviewed to produce novel bottom-up estimates of the cost of closing the vaccination gap globally at the country level. In addition, literature on the global cost of water, sanitation and hygiene (WASH) was reviewed to update previous estimates by the United Nations Children's Fund (UNICEF) and the World Bank on the cost of scaling up WASH at the country level (Sanitation and Water for All, 2020).

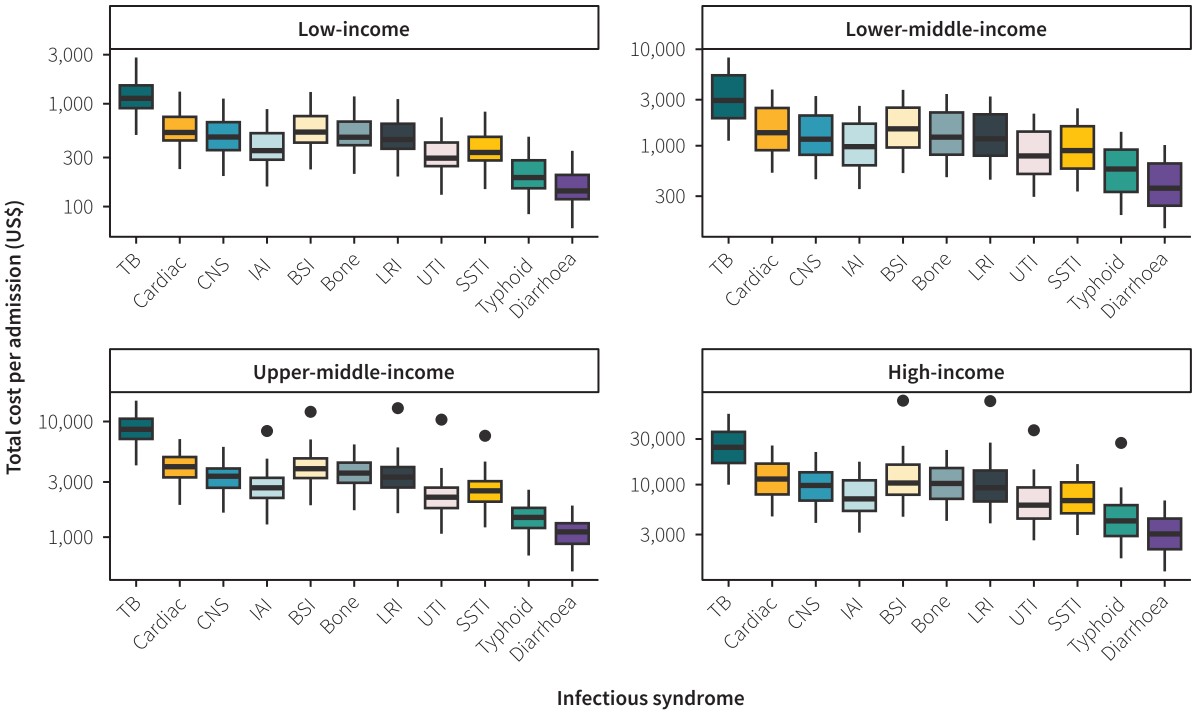
Results

Globally, we estimate that AMR costs health systems US$ 66 billion per year and projections show that these costs are likely to increase substantially in the next 25 years. This chapter reports the estimated cost per hospital admission and the estimated number of admissions associated with AMR. These results are then used to estimate overall health care costs for the present and the future.

COST PER HOSPITAL ADMISSION

The median cost per admission with a resistant infection is approx. US$ 100–1,000 in low-income countries, US$ 300–3,000 in lower-middle-income countries, US$ 1,000–10,000 in upper-middle-income countries and US$ 3,000–30,000 in high-income countries, with the costs varying by infection type (Figure 3.1).[5]

FIGURE 3.1 Cost per antibiotic-resistant admission, by syndrome and World Bank income group



Note: the horizontal (box) lines indicate the upper quartile, median and lower quartile. The vertical lines (whiskers) show the maximum point within 1.5 times the interquartile range of the upper and lower quartile, respectively. Dots are considered outliers, as they are outside this range.
Abbreviations: TB = Tuberculosis, CNS = Central Nervous System, BSI = Bloodstream Infections, IAI = Intra-Abdominal Infections, LRTI = Lower Respiratory Tract Infections, UTI = Urinary Tract Infections, SSTI = Skin and Soft Tissue Infections.

5 Throughout the report, country income groups are taken from the World Bank (2024).

Excluding tuberculosis, the excess cost per resistant infection is US$ 50–500 in low-income countries and US$ 2,000–20,000 in high-income countries (Figure 3.2). The difference in cost between treating multi-drug-resistant and drug-susceptible tuberculosis is far greater than for any other syndrome. In general, a smaller difference is observed in high-income countries, as discussed in Laurence *et al.* (forthcoming).

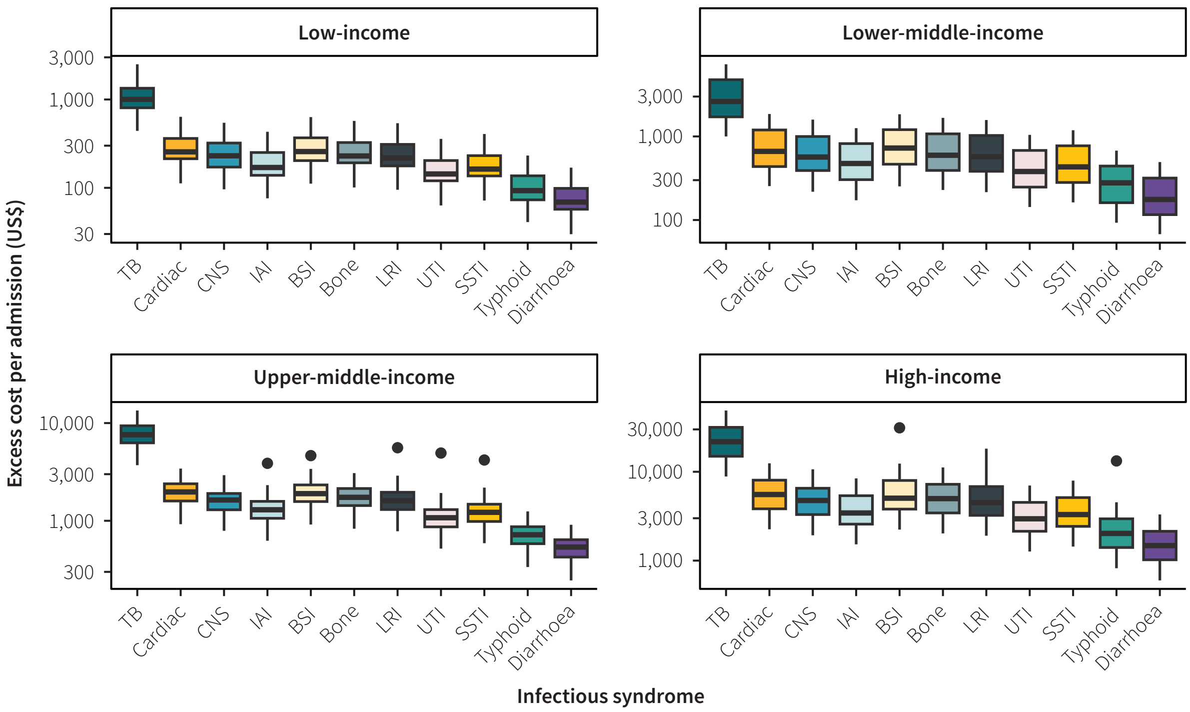
Figure 3.3 shows estimates of the excess cost of antibiotic-resistant infections. Excess costs refer to the additional cost of treating a patient who has a resistant infection; this does not include costs that would also apply if they had a drug susceptible infection. These costs are more specific to the impact of resistance itself, and the estimates are considerably lower than the total cost.

Number of hospital admissions for antibiotic-resistant infections

The total number of hospital admissions for antibiotic-resistant infections (including admissions for community-onset and hospital-acquired infections) in 2022 is estimated to be 25.4 million (11.6–48.0 million). Using per capita admission rates from Moses *et al.* (2019), we estimate the total global number of hospital admissions in 2019 at 737 million. Our estimates therefore suggest that 3.5% (1.6%–6.5%) of global admissions include a resistant infection.

Antibiotic-resistant infections represent a smaller share of total admissions as country income rises, although there are many outliers (Figure 3.4). Resistant infections impose a higher burden than susceptible infections, particularly in lower-middle-income countries, although there is a wide range within income groups.

FIGURE 3.2 Excess cost per antibiotic-resistant hospital admission, by syndrome and World Bank income group



Note: the horizontal (box) lines indicate the upper quartile, median and lower quartile. The vertical lines (whiskers) show the maximum point within 1.5 times the interquartile range of the upper and lower quartile, respectively. Dots are considered outliers because they are outside this range.
Abbreviations: TB = Tuberculosis, CNS = Central Nervous System, BSI = Bloodstream Infections, IAI = Intra-Abdominal Infections, LRTI = Lower Respiratory Tract Infections, UTI = Urinary Tract Infections, SSTI = Skin and Soft Tissue Infections.

FIGURE 3.3 Cost per hospital admission of antibiotic-resistant and antibiotic-susceptible infections, and ratio of those resistant to susceptible infections, by World Bank income group

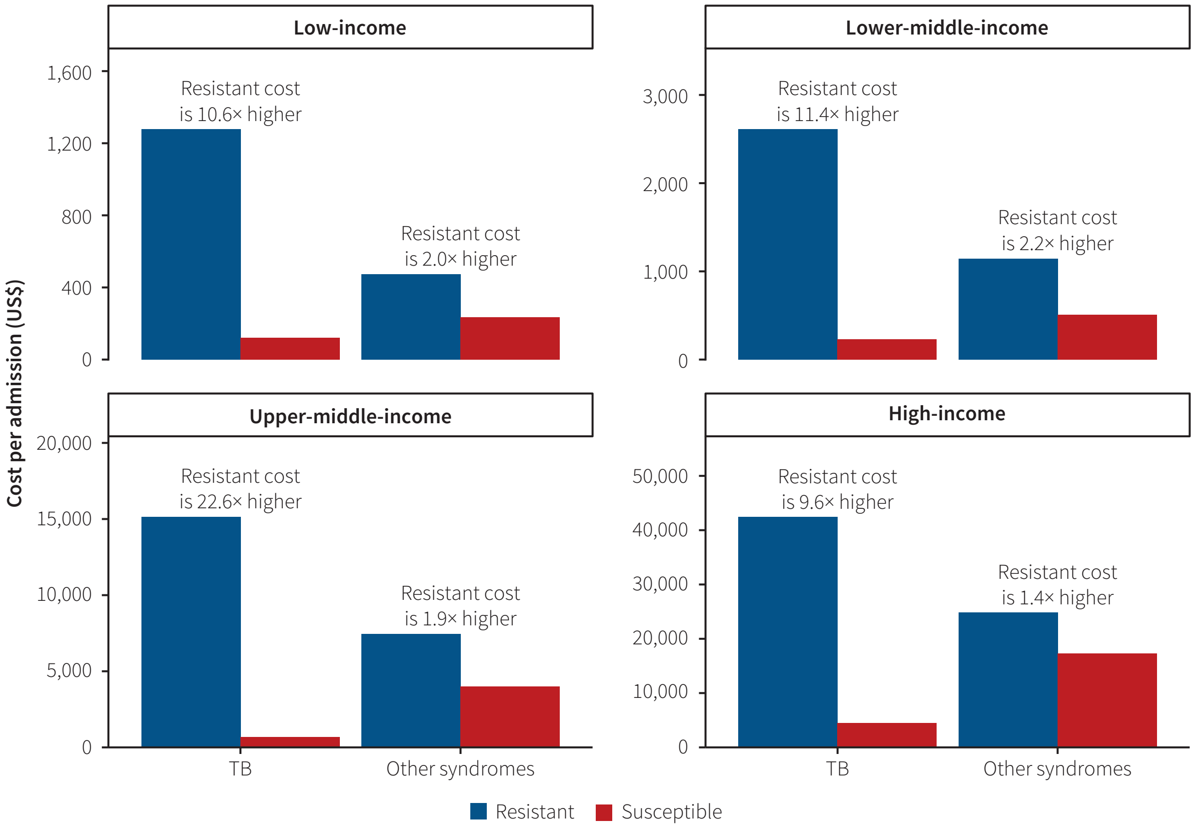
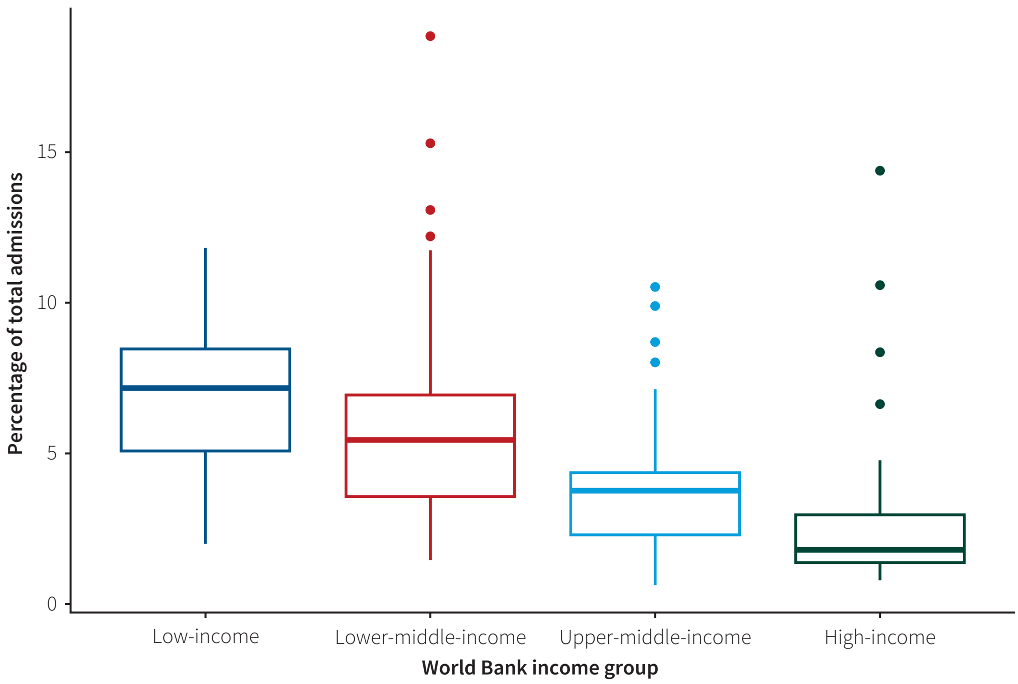


FIGURE 3.4 Percentage of hospital admissions that involve an antibiotic-resistant infection, by World Bank income group



Current cost of AMR for in-patient health care and treatment of tuberculosis

We estimate the current cost of in-patient care attributed to antibiotic resistance at US$ 66.4 billion (0.7% of annual global health care expenditure). Variations in the approach for imputing missing cost estimation and estimating hospital admissions mean that this figure can range between US$ 51.3 billion and 106.1 billion.

Figure 3.5 breaks down the total global cost by country. The lower cost of AMR outside high-income countries is indicative of resource constraints that lead to lower treatment intensity rather than a lower need for health care. Countries with the highest total spending are the most populous and have higher health care costs per capita. These figures solely account for the excess cost of resistance; the total cost of treating patients with drug-resistant infections is much higher, at an estimated US$ 168 billion (US$80.4 to $333.2 billion).

Low- and lower-middle-income countries spend more of their total health care budgets on AMR in-patients than higher-income countries do. Figure 3.6 shows the excess cost of AMR as a proportion of health care expenditure. The median excess spending associated with resistance is 2.0% of health care expenditure in low-income countries, 1.5% in lower-middle-income countries, 1.0% in upper-middle-income countries and 0.4% in high-income countries.

The study also examined the types of infections that drive costs. Bloodstream infections are the greatest contributor, followed by lower-respiratory infections. The least costly syndromes are those with the lowest estimated volumes of associated admissions (e.g. central nervous system and bone infections) or those with the lowest estimated cost per admission (e.g. typhoid and diarrhoea). (For the data breakdowns by infectious syndrome, see Laurence *et al.* [forthcoming].)

FIGURE 3.5 Estimated direct excess cost associated with hospital admissions for antibiotic-resistant infections, by World Bank income group (US$ billions)

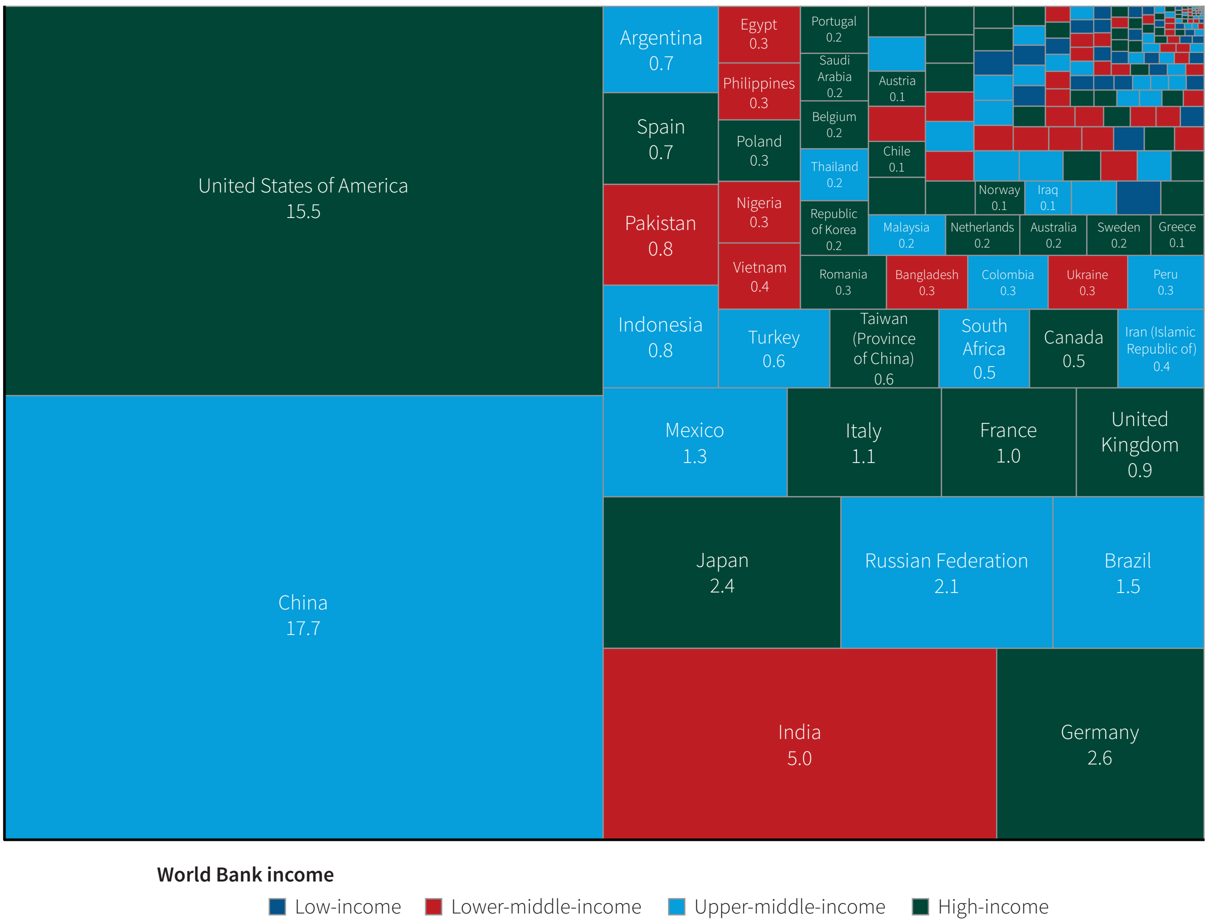
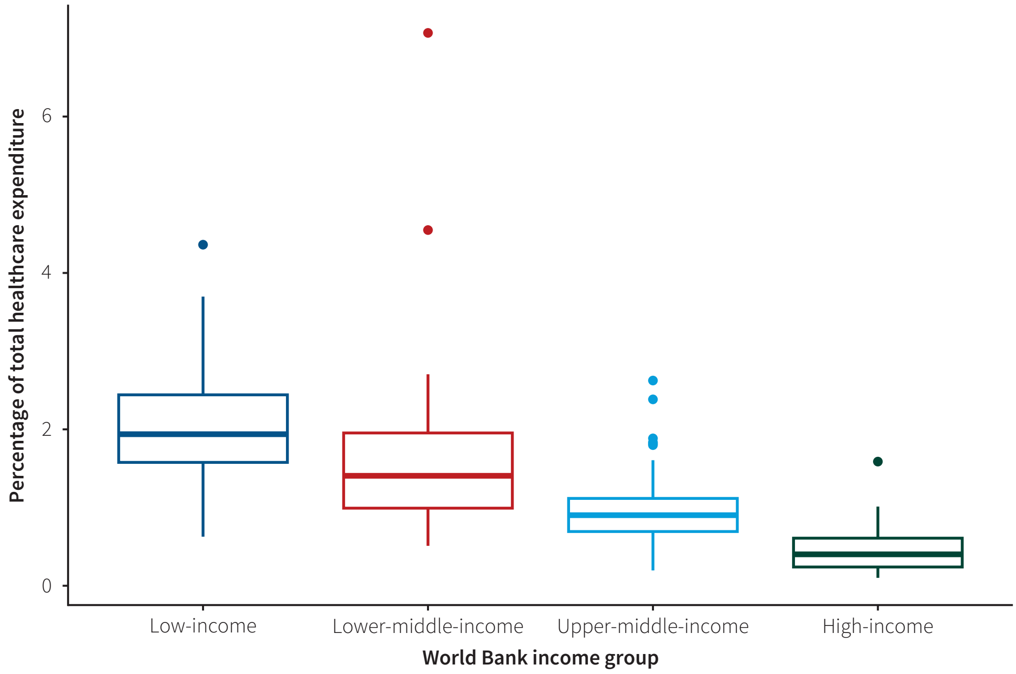


FIGURE 3.6 Percentage of in-patient health care costs associated with antibiotic-resistant infections in 2022, by World Bank income group



LITERATURE REVIEW ON RESILIENCE SECTORS TO PRIORITIES

We identified and explored about 120 studies as part of this initial scoping review. The evidence base is weak and lacks standardisation. The majority of research on the economic burden of diseases focuses on health care costs or the impact on the labour force. As mentioned in the methodology, evidence shows that AMR might cause disruption to international tourism and domestic hospitality and leisure; we therefore ruled out several other sectors of the economy.

Literature on the impacts of disease on tourism and hospitality focuses on outbreaks rather than endemic or more gradually progressing illnesses, primarily because there is a much clearer counterfactual for an outbreak, as outcomes from before and after the outbreak can be compared. The effects of outbreaks are also likely to be much larger than the effects of gradual change. Many of the tools used in econometrics would not be able to identify the small changes associated with slow-burning illnesses.

Very strong evidence links outbreaks and pandemics to significant declines in tourism, as witnessed in the cases of Ebola, COVID-19, SARS-1 and other outbreaks of disease. Further evidence suggests that Middle East Respiratory Syndrome (MERS) caused a decline in tourism (Joo *et al.,* 2019). This evidence indicates that tourism behaviour responds more strongly to new illnesses than familiar ones. The severity and suddenness of Ebola, COVID-19 and SARS-1 make it difficult to extrapolate wider lessons from those outbreaks to AMR. Evidence from these cases is therefore insufficient to establish whether AMR would reduce rates of tourism.

There is mixed evidence on the effect of malaria on tourism. Rosselló *et al.* (2017) estimate that eradicating malaria could lead to a global increase of 6.2 million tourists and US$ 3.5 billion in revenue for affected countries. In contrast, Modrek *et al.* (2012) find weak and statistically insignificant relationships between tourist arrivals and malaria cases at the national level.

Evidence on the impact of HIV/AIDS on tourism revenues is also limited. Older studies identify tourism as an area of high potential impact (Gilmore *et al.,* 1989; ILO, 2012; Lewis and Bailey, 1992). This can also affect medical tourism, a small but often very valuable segment of the tourism market (Bokhary *et al.,* 2021).

The effects of AMR may be akin to those of HIV and malaria, which are infectious diseases that are prevalent in some regions and increase slowly over time. The severity of malaria is comparable to many cases of resistance, with illnesses tending to be short but causing serious problems for select people, particularly the very young and very old. Given that the prevalence and severity of these illnesses is similar to many AMR infections, it is worth examining the hypothesis that changes in resistance might affect tourism rates. However, current literature reveals little information from which to make estimates, which is why this study relies on expert elicitation.

In addition to affecting travel, outbreaks such as Ebola, SARS-1 and COVID-19 were linked to significant declines in services that required human interaction. There is also evidence that MERS adversely affects the domestic hospitality sectors (Joo *et al.*, 2019).

Interactions with the hospitality sector do not increase the risks of contracting malaria and HIV, as they could for AMR infections. It is therefore unsurprising that there is limited evidence for these diseases. There is also limited evidence on diarrheal diseases and seasonal influenza (De Courville *et al.,* 2022).

Many AMR infections are respiratory; like the flu, their prevalence and severity can increase in the winter. They also affect people across society, causing economically productive people to miss work and alter their plans as they would with respiratory bacterial infections. Based on this, it is likely that changes in resistance may affect the hospitality sector.

Several other areas of the economy were explored but excluded for different reasons. Supply chain disruptions and large changes in retail purchasing occur during epidemics and pandemics, but this study found no indication that either is a result of non-outbreak-prone illnesses, which are more comparable to AMR. Evidence on the effect of epidemic-prone illnesses and malaria on foreign direct investment is weak and mixed; it is not strong enough to suggest a significant impact of AMR on economic growth (Tandon, 2015).

There is strong evidence that malaria disrupts education, yet this same mechanism is unlikely to hold for AMR, as malaria tends to have a higher prevalence in school-age children than bacterial infections do. Declines in education can occur during outbreaks of diseases such as swine flu, but this type of illness is not comparable to AMR. There is evidence that HIV outbreaks strain social services, but HIV has a much higher prevalence and longer duration than most bacterial infections. For these reasons, this report focuses on the effects of AMR on tourism, hospitality, labour and health care costs.[6]

DIRECT EFFECT OF AMR ON OUTPUT

Globally, only 10% of deaths occur among people aged 15–64, according to IHME health estimates. Illness among working-age people is much more common in resource-constrained settings than in wealthier countries. People in wealthier countries also tend to stay in education longer and therefore enter the labour force later in life; in essence, there is also a longer lag before their deaths affect labour participation.

Thus, even though the accelerated rise in resistance scenario sees a similar reduction in population in high- and low-income countries, about twice as many people leave the labour force in low-income countries. This greater impact in low- and lower-middle-income countries is largely hidden in data sets that focus on the global economy, since the output per worker is much smaller.

We assume that the effect of illness on GDP is proportionate to its effect on the quality of life. Therefore, if an illness is judged to cut a person's quality of life in

6 We treat all domestic expenditure, including travelling to other parts of the same country, as hospitality; we treat all foreign hospitality as tourism, partly because doing so allow us to distinguish between hospitality and tourism using export data.

TABLE 3.1 Projected morbidity caused by AMR in 2030 in all countries, in the business-as-usual scenario

Age group	Years of good health lost due to AMR (thousands)[a]	Per cent of years of healthy life lost	Days of healthy life lost per capita	Estimated days lost from workforce (millions)
Under 15	537	39.4	0.103	0[b]
15–64	438	32.1	0.029	110.3
Over 65	387	28.4	0.140	33.9
Total	1,362	100	0.059	144.2

Notes: [a]Figure includes only years lost due to morbidity. Far more years of health are lost to mortality. [b]We were unable to obtain reliable data on the number of people under the age of 15 who work. In most of the world, this figure is close to zero.

half, we assume it will also cut the person's output in half. This methodology perhaps under-estimates the effect on GDP, as people whose quality of life is halved probably produce less than half their economic output. IHME estimates show that morbidity represents a much smaller portion of the health burden than mortality, with deaths accounting for 97% of the DALY burden of resistance. Most people who contract a resistant infection will either die or recover quickly. Working-age people have less than a quarter of DALYs than the rest of the population, with the average person losing 0.03 days per year (Table 3.1). However, as the majority of the global population is aged 15–64, they still account for 32% of the years lived with disability, a far greater share than mortality, where just 10% of deaths are expected to happen to working-age people.

QUALITATIVE FINDINGS ON INDIRECT LABOUR, TOURISM AND HOSPITALITY

Based on the literature review outlined above, we focused on three sectors:

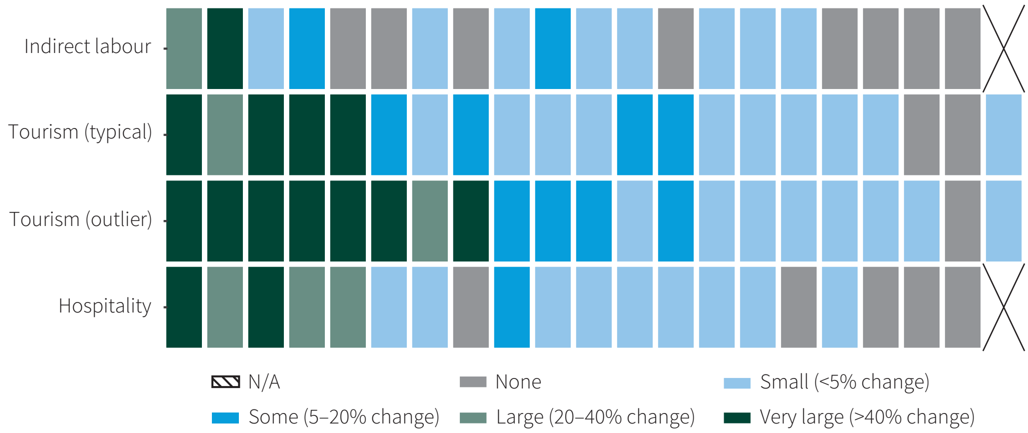
- Indirect labour: people leaving the labour market for reasons other than the mortality or morbidity that AMR causes them directly, such as wanting to avoid becoming sick.
- International tourism (tourism): economic activities of people travelling to and staying in places outside their country of residence. We limited tourism to international tourists to better align with economic data.
- Domestic hospitality and leisure (hospitality): economic activities that provide accommodation, food, entertainment, recreation and cultural experiences to residents within their own country.

Based on recent research by Jenkins *et al.* (2024) and Lohiniva *et al.* (2022) and expert interviews, we identified five broad factors affecting risk perception and corresponding action:

1. **Disease factors:** easily transmitted diseases heighten the perceptions of risk, thereby altering behaviours.
2. **Individual factors:** AMR affects the immunocompromised, very young, elderly and people in high-risk jobs, leading to higher risk perceptions and corresponding action.
3. **Contextual factors:** government policies, environmental changes and new technologies can modify risk perceptions and the impact of AMR.
4. **Social and communication factors:** media coverage, social media and personal experiences amplify risk perceptions and actions.
5. **Cognitive factors:** knowledge and familiarity with AMR shape risk appraisals and perceptions.

Figure 3.7 shows what experts view as the likely effect of a world in which deaths from AMR increase by a factor of eight. Expert answers were categorised into four levels based on their quantitative and qualitative responses. The experts predicted that the greatest

FIGURE 3.7 Experts' estimates of impact of eight-fold increase in AMR on indirect labour, tourism and hospitality



Note: each column represents a different expert. 'Typical' denotes a situation in which all countries see a similar change in resistance rates; 'outlier' indicates an estimate for a country that experiences a greater rate of resistance change than other countries. N/A (no answer) is from an expert who did not feel confident answering about a sector other than tourism.

impacts would be felt in the tourism sector, followed by hospitality and then the labour force.

All but one expert believed there would be some impact on tourism, especially if a country is an outlier in its AMR burden. The sector is likely to be affected because tourism is discretionary, and the risks can be reduced. Two-thirds of experts agreed there would be some impact on the hospitality sector, although most thought the impact would be small. While the hospitality sector is also discretionary, its activities occur in the customer's own country and are often viewed as carrying risks comparable to those of other everyday activities. Just over half of experts indicated there would be a small indirect impact on the labour force, as people reduce their work hours out of fear of contracting a drug-resistant infection. However, most indicated that few individuals would be willing or able to forgo income to reduce the risk of AMR. Only older workers and those who are immunocompromised might consider leaving the workforce, and the impact from this would be limited.

Some experts believed that resistance levels would cause activity to change in a linear fashion. Others thought that there could be a tipping point beyond which resistance would become far more impactful, or a convex curve, where additional increases in resistance cause an ever-greater impact on the economy. One expert thought that the pattern would vary by sector.

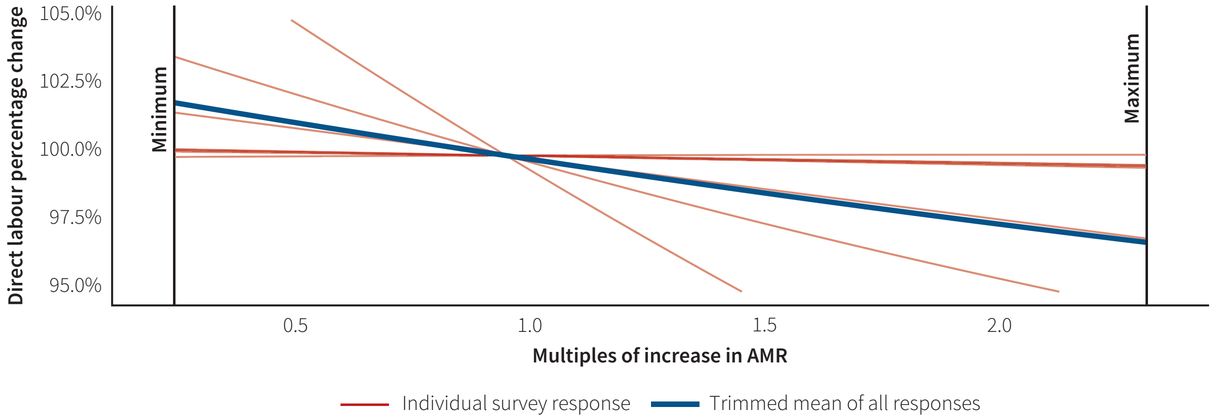
Experts' views on the effect of AMR on labour force participation

Opinions were divided on the impact of AMR on the labour force. Experts who believed AMR would disrupt the labour market drew parallels with the COVID-19 pandemic. They suggested that media coverage and first-hand experiences of AMR-related fatalities could prompt some older adults, immunocompromised individuals and people in face-to-face jobs to leave the workforce, especially if AMR rose rapidly or high-profile AMR deaths occurred. However, the impact was expected to be minimal.

Other experts argued that there would be no indirect impact on the labour market. Awareness of AMR risks is currently low, and only significant media campaigns or personal experiences might increase it. Many experts believe the rise in AMR would be gradual, allowing people to acclimatise and not see it as a sufficient reason to leave the workforce. Historical parallels are drawn with the pre-antibiotic era and the HIV epidemic, where people continued working despite health risks.

Figure 3.8 shows the possible relationship between changes in resistance and indirect labour, based on

FIGURE 3.8 Experts' estimates of the effect of AMR on labour force participation



functions created from each expert's responses. If AMR rates decline by half, the trimmed mean response is a 2% increase in the number of people in work. If AMR death rates double, the number of workers who leave work to avoid illness falls by 2.5%.

The need to work outweighs health concerns for most workers, particularly in lower-income settings. Few people in the world have the savings or support to allow them to permanently leave the workforce. Workers may temporarily leave or shift to less risky jobs rather than exit the workforce entirely.

Bereavement could also reduce hours worked, through absenteeism (time off work) and presenteeism (reduced productivity at work) (Sue Ryder, 2021; Verdery *et al.,* 2020).[7] A literature review identified 20 relevant papers. To compare them, we used inputs from the paper by Verdery *et al.* (2020), who posit that for every death, two people experience intense grief and seven experience moderate grief. On average, every person suffering moderate grief loses about eight workdays, and every person experiencing intense grief loses about 34 workdays. Combining these figures yields a figure of 212 workdays lost (93% of a work year) per death. We then multiplied this figure by the proportion of workers aged over 65 to yield a figure of 0.65 million years of work currently missed because of bereavement. This figure could rise to almost 1 million by 2050.

Experts' views on the effect of AMR on tourism

Whether perceptions of increased AMR risk affect tourism hinges on several factors, particularly media coverage and knowing someone who contracted an AMR infection. However, some experts pointed out that very few people are aware of the risks of AMR and that it could take time for people to become aware of the problem. Experts predicted that government warnings, travel advisories and border controls would play an important role in modifying behaviour, pointing to examples of travel avoidance for malaria and government border controls during the COVID-19 pandemic. Older travellers make up a significant tourism market segment and might alter their behaviour out of fear of vulnerability. The infection transmission route would also probably affect behaviour, with people less likely to travel where a resistant pathogen was contracted through food, or via waterborne or airborne bacteria. Countries with outlier AMR burdens are predicted to suffer greater impacts, as tourists choose lower-risk destinations over higher-risk ones.

Experts expect the impact of AMR on tourism to be greater than the indirect labour force impact. If AMR rates were to fall by half in every country in the world, revenue from tourism might increase by 3%; if it were to double, revenue from tourism might fall by 5% (Figure 3.9).

If one country were to experience a swing in resistance that was not experienced elsewhere, the impact on

7 Some workers may also miss work because of caregiving responsibilities. The effect is likely to be very small, however, given the short duration of illness for AMR infections.

FIGURE 3.9 Experts' estimates of the effect of AMR on tourism if all countries are affected equally

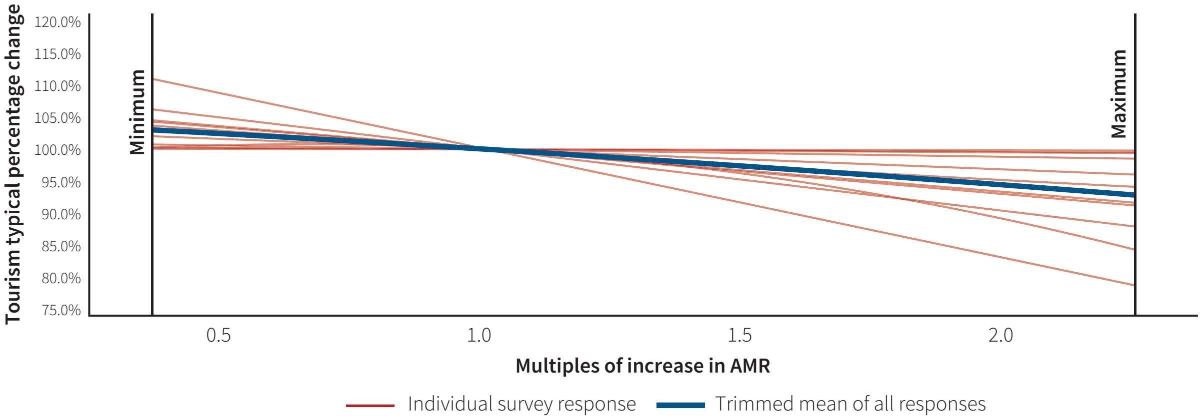
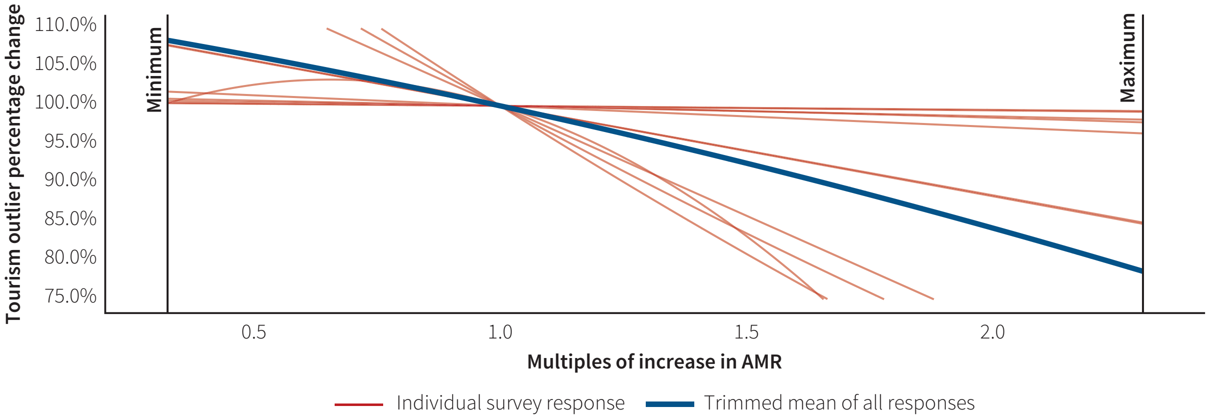


FIGURE 3.10 Experts' estimates of effect of AMR on tourism in a country in which resistance rates rise while resistance remains stable in other countries



tourism would be far greater. Cutting resistance in half could increase tourism to that country by 9%; doubling resistance could cause a 16% decline (Figure 3.10).

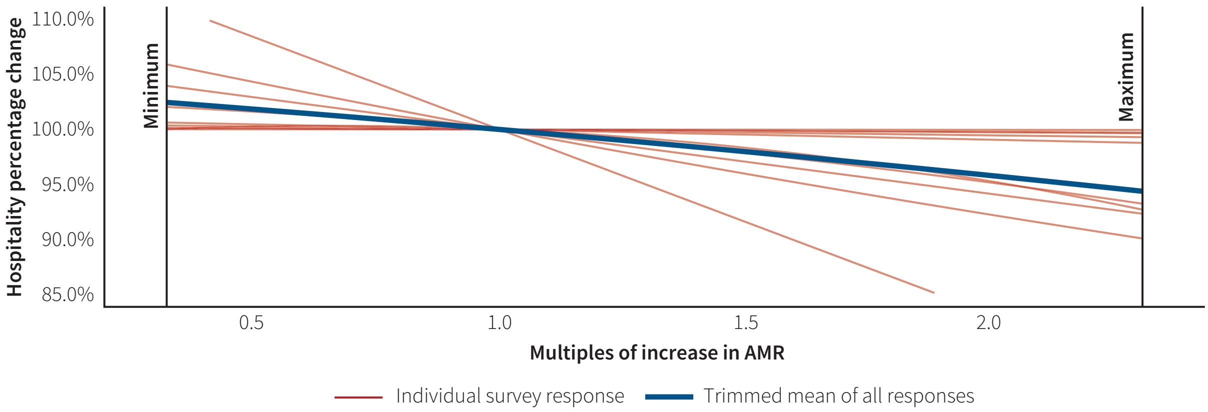
These impacts are very small compared with the impact of diseases like COVID-19 on tourism. However, international tourism was worth about US$ 6.5 trillion in 2022 – 4.8% of the global (Aguiar *et al.,* 2022). Even small shifts in demand can thus have a large impact on the economy.

Experts' views on the effect of AMR on hospitality

Experts indicated that increased media exposure or personal encounters with AMR cases might cause people to change their risk calculus and behaviour. Most of them expected the response to hospitality to be similar to but more muted than the effect on tourism because people are likely to be more comfortable with the level of risk near where they live. Several experts indicated that over the long term, impacts may plateau or even fall back toward baseline levels, as businesses adopt mitigation measures and people acclimatise to new risks and become less willing to forgo leisure activities, especially if the risk is comparable to that of other necessary everyday activities (such as working). This effect has been seen with COVID-19, where people are much more willing to risk infection than they were in 2020 (although hospitality has still not returned to pre-COVID levels in some countries (Mosolova, 2024; Shi and Xu, 2024).

Cutting AMR rates in half is projected to lead to a 2.5% increase in hospitality; doubling resistance rates would cause hospitality rates to fall by 4% (Figure 3.11). Although this expected rate of change is smaller than for tourism, the impact on the economy would be greater, as hospitality accounts for twice the share of the global economy as tourism does, at US$ 12.8 trillion (9.5% of global GDP), based on our analysis of data from Aguiar *et al.* (2022).

FIGURE 3.11 Experts' estimates of the effect of AMR on hospitality

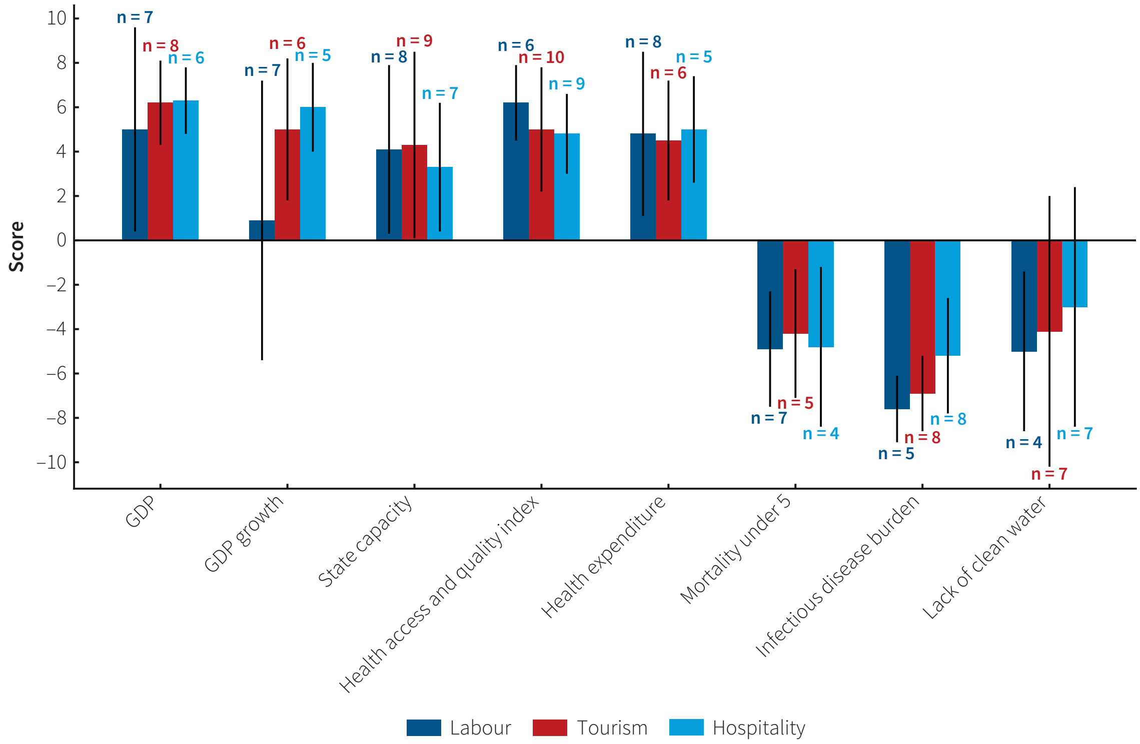


Factors affecting a country's resilience to an AMR shock

Experts were asked how 26 variables would affect labour, tourism and hospitality. Figure 3.12 shows the 12 most important variables they identified.

Wealthier countries and countries with better health care systems were widely seen as being more resilient to economic shocks. All experts but one thought these factors would make countries much more resilient (the outlier believed that there would be greater labour disruption in wealthy countries, since greater personal wealth or government support means that people can afford to take time off work). GDP growth resulted in the most divergent responses from experts. Several thought it was very important, as it gave countries increased fiscal space and flexibility to deal with a crisis. Others thought that only the level of income matters, not the rate of growth.

FIGURE 3.12 Twelve variables that experts view as most important for determining how resilient a country is to an AMR shock



Note: scores range from +10 (very large positive impact) to −10 (very large negative impact). *n* = number of people who answered a question, *S* = standard deviation of responses, bars indicate average response, whiskers show range between lowest and highest scores.

Under-five mortality and higher infectious disease burden were generally seen as negatively correlated with resilience because they indicate that a country might not have the capacity to support health needs. Most experts thought decisions around behaviour would often be driven by perception of disease, and that this perception was likely to be worse in countries that are already perceived as performing poorly.

Experts were asked about six disease transmission types (airborne, blood-borne, direct contact, faecal-oral, sexual and via tuberculosis). Airborne diseases and tuberculosis (which were separated from other airborne diseases) were seen as having the largest impact. Faecal-oral transmission was seen as important for hospitality and tourism because it might discourage people from eating out or going to unfamiliar places; it was not seen as important for labour.

Experts were asked about five different types of climate (arid, continental, polar, temperate and tropical). Countries with tropical climates were expected to be more affected by a change in resistance rates. One expert noted, 'I think the hotter, stickier climates will have the biggest impact, the tropical areas of the world.'

Most experts viewed demographic variables, such as population density, the urban–rural divide and age, as not very important.

Responses from each expert were combined with country data to give each country a resilience score. The results show general agreement on the countries that were more or less resilient, although there was wide variation in the responses given by experts to the importance of specific variables (see Figure 3.12). The median correlation for a resilience score from different experts was 0.80, 0.76 and 0.82 for labour, tourism and hospitality, respectively. The correlation between the mean resilience number for each of the three sectors of the economy is almost perfect (Table 3.2).

TABLE 3.2 Correlation between resilience responses generated from different experts, using 2030 data

	Hospitality	Tourism	Labour
Labour	Mean resilience: 0.986 Correlation of experts: Median = 0.82 Mean = 0.71 Min = 0.17 Max = 0.98	Mean resilience: 0.976 Correlation of experts: Median = 0.83 Mean = 0.78 Min = 0.24 Max = 0.99	Within-sector correlation: Median = 0.80 Mean = 0.74 Min = 0.13 Max = 0.96
Tourism	Mean resilience: 0.979 Correlation of experts: Median = 0.95 Mean = 0.8 Min = –0.13 Max = 1	Within-sector correlation: Median = 0.76 Mean = 0.71 Min = –0.06 Max = 0.98	
Hospitality	Within-sector correlation: Median = 0.82 Mean = 0.64 Min = –0.17 Max = 0.98		

Notes: mean resilience measures the correlation between mean country resilience in two sectors. Correlation of experts measures the correlation between responses for every expert who gave an opinion on two different sectors. Within-sector correlation measures the correlation of all experts who gave opinions on the same sector.

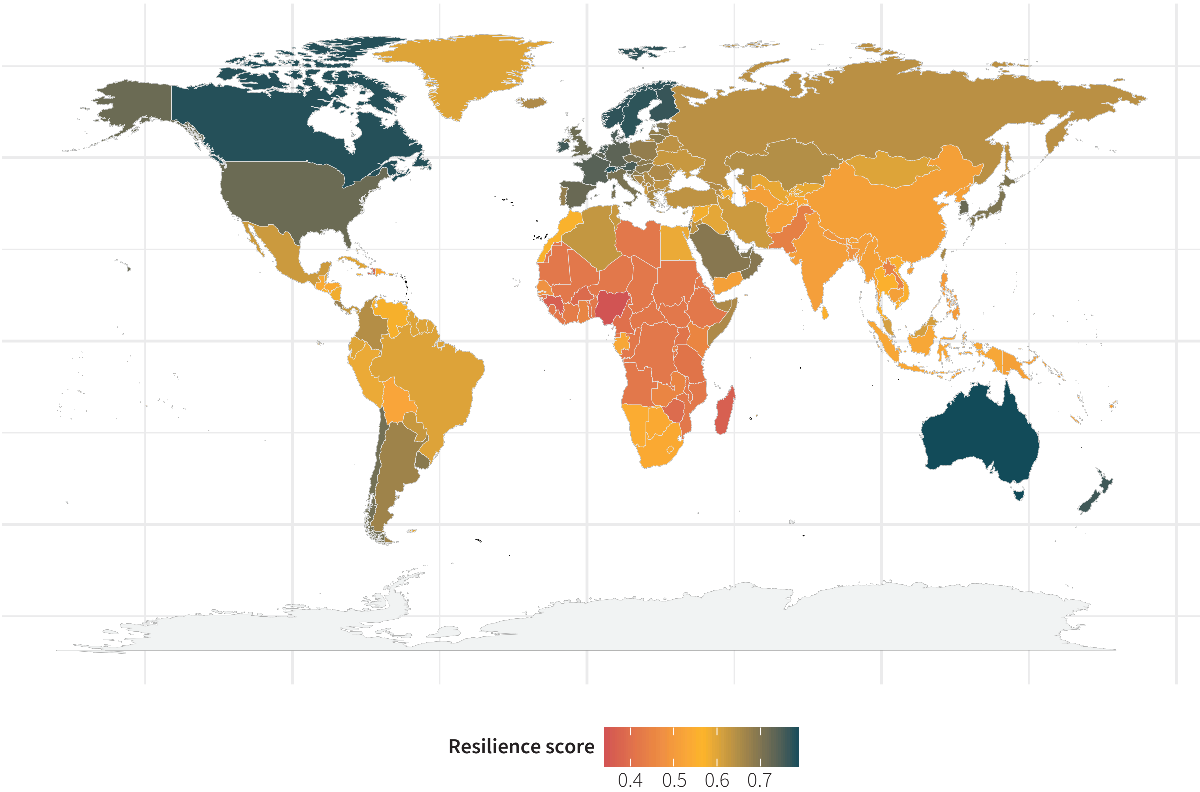
Resilience is weakly correlated with changes in mortality rates in the accelerated rise in resistance scenario and very highly correlated with changes in the intervention scenario (Table 3.3), suggesting that the countries that would benefit most from access to innovative antibiotics, improvements treatment quality, vaccination and WASH are those most at risk from economic disruption caused by resistance.

Australia is most resilient in each of the three sectors (Figure 3.13); Nigeria is the least resilient for labour and hospitality and second to least resilient (after Madagascar) for tourism. Combining the results from all experts, for tourism, Australia's score is 79.1 and Nigeria's is 34.6.[8] These figures suggest that for every 1% change in hospitality from a given AMR shock in Australia, one would expect the same change in resistance in Nigeria to lead to a 3.13% change in hospitality. The economic risks from AMR – and the benefits of reducing resistance – are thus far greater in Nigeria than Australia. Expert results also suggested that a change in AMR that led to a 1% shock in direct labour force in Australia would lead to a 2.97% and 3.13% shock, respectively, in the least resilient country.

TABLE 3.3 Correlation between changes in AMR death rate and resilience, by sector

	Scenario	
Sector	**Combined interventions**	**Accelerated AMR**
Labour	0.852	0.299
Tourism	0.840	0.319
Hospitality	0.855	0.291

FIGURE 3.13 Average resilience scores for labour, tourism and hospitality, by country, 2030



8 Scores are based on how close a country's resilience scores is to 100 (no change). Nigeria's 65.4 divided by Australia's 20.9 equals 3.13.

All the most resilient countries are high-income; the least resilient countries tend to be low- or lower-middle-income (Figure 3.14). Countries with more deaths from AMR are also more likely to have lower resilience scores.

IMPACT OF AMR UNDER DIFFERENT SCENARIOS

The business-as-usual scenario assumes that AMR will follow recent historical trends. Under this scenario, 38.5 million (32.0–45.3 million) people are projected to die from AMR infections between 2025 and 2050. Were this to happen, annual AMR in-patient costs could increase to US$ 159 billion (US$ 60–229) by 2050 in the business-as-usual scenario, driven largely by the fact that the parts of the world with the highest levels of AMR are expected to become much richer over the next 25 years and will thus spend more on health care. In the majority of countries, we expect the percentage of a health care budget spent on AMR to fall, but because a greater portion of global health spending will be in countries with high AMR rates, we expect the global budget to increase. The overall financial burden of resistance is expected to rise from 0.7% (0.6–1.1%) to 1.0% (0.4%–1.5%) of health budgets. Although the amount spent on AMR will increase in real terms in every income group, middle-income countries are responsible for almost all the global increase, as spending in high-income countries will remain comparatively stable, and this is too low in low-income countries to affect global averages (Figure 3.15).

Our modelling suggests that, in the business-as-usual scenario, the global population will be 21 million lower in 2050 than in a world in which nobody dies of AMR, yet deaths from other bacterial infections remain unchanged. This scenario would lead to a reduction in the labour force of almost 7.3 million people. The largest change in population in both absolute and relative terms occurs in lower-middle-income countries, though the relative change to the labour force is slightly larger in low-income countries, due to the higher proportion of young people who die. The impact on high-income countries is much smaller (Figure 3.16).

Overview of intervention scenarios

Twenty-five years is a long time away; policy-makers have plenty of time to enact policies that reduce the risk from resistance, and the decisions that are taken will have a large impact on both human health and the economy.

FIGURE 3.14 Correlation between average sector resilience and AMR death rate, by World Bank income group, 2030

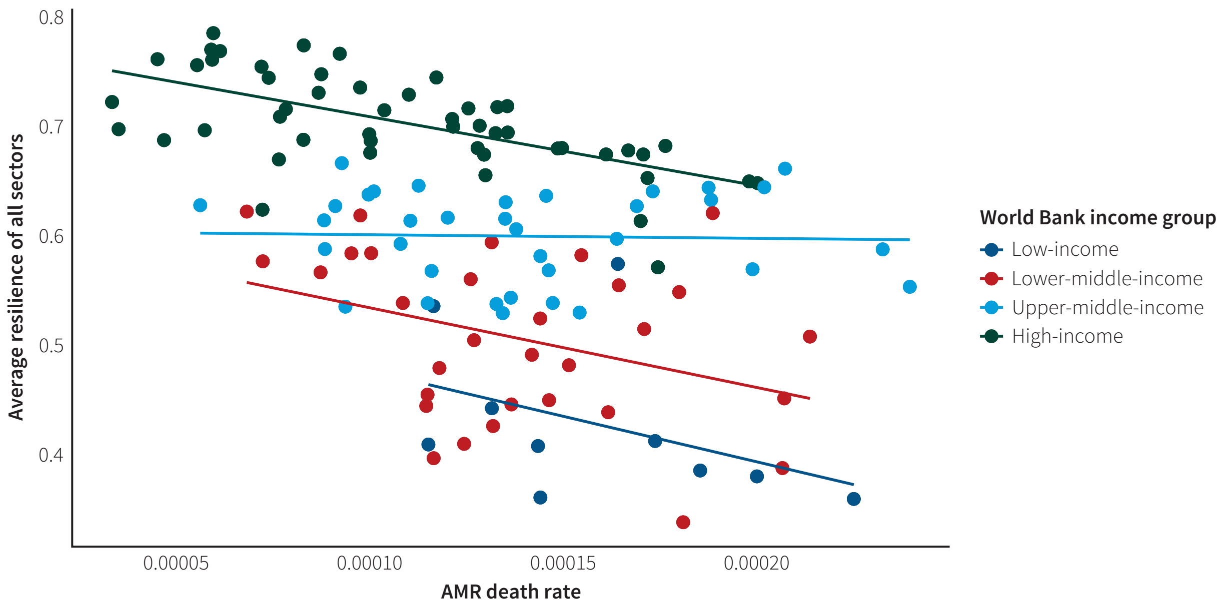


FIGURE 3.15 Global increase in excess in-patient health care costs associated with AMR, by World Bank income group, 2020–2050

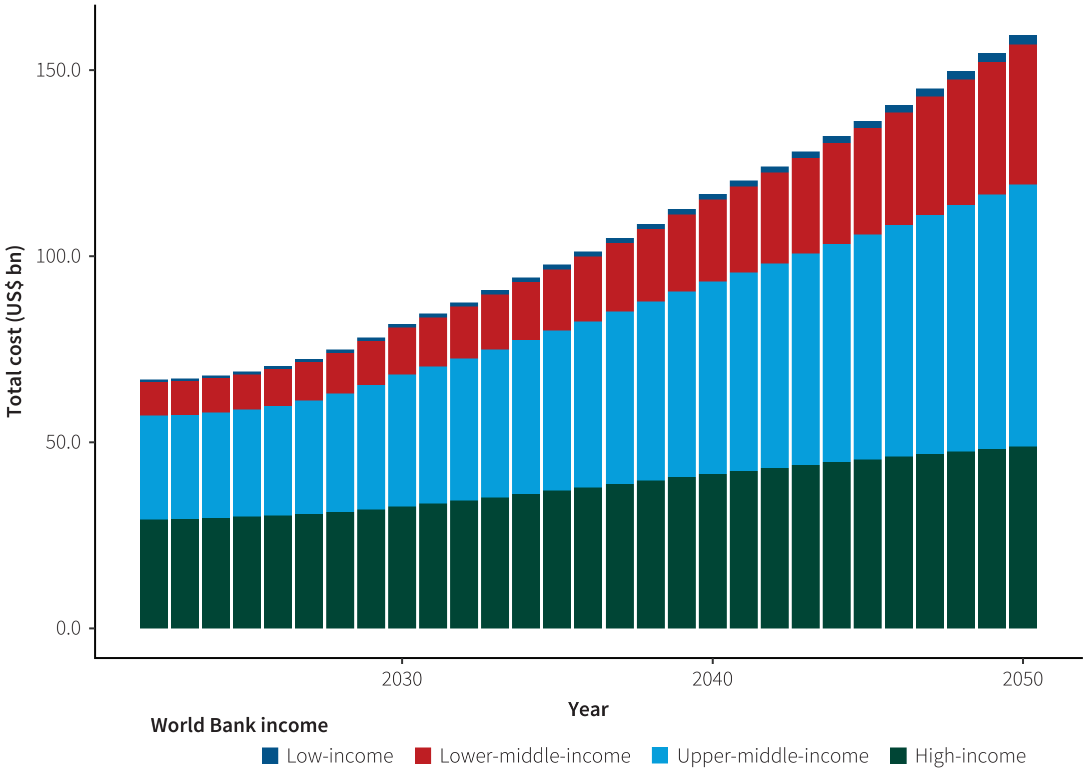
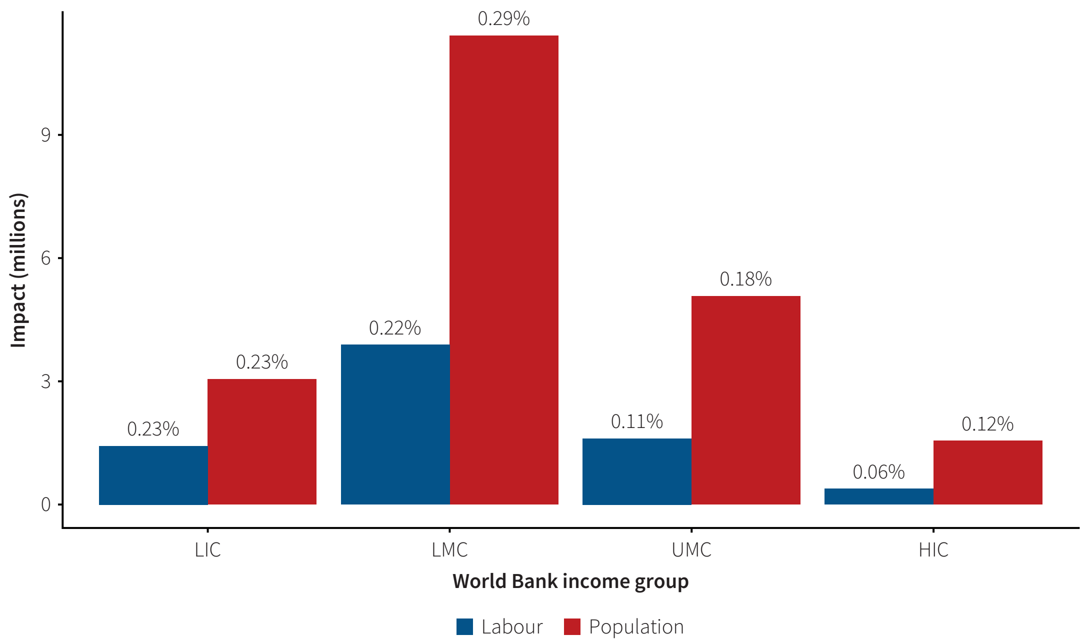


FIGURE 3.16 Population and labour force changes by 2050 relative to the business-as-usual scenario in a world without AMR, by World Bank income group



Note: LIC = Low-Income Countries, LMC = Lower-Middle-Income Countries, UMC = Upper-Middle-Income Countries, HIC = High-Income Countries.

The first column in Table 3.4 shows how different interventions will affect cumulative mortality between 2025 and 2050. The second column captures the global change in expenditure on in-patient treatment in 2050 compared with the business-as-usual scenario. Column 3 measures how much larger (or smaller) the economy would be in 2050 compared with the business-as-usual scenario. The last column depicts the amount health systems would spend to achieve the health outcomes in IHME's model. We equate a country's GDP per capita as equal to one DALY, in line with WHO recommendations (Claxton *et al.,* 2016). The impact on health costs and GDP are shown in Figures 3.17 and 3.18.

IHME estimates that, if all countries follow an AMR trend in line with the accelerated rise in resistance scenario (i.e. AMR progresses in line with the performance of the bottom 15th percentile of countries), there would be an additional 6.7 (6.1–7.3) million deaths over the next 25 years. However, it is possible for things to get better as well as worse. Improvements in the treatment of bacterial infections, vaccinations and WASH can save the lives of many people who die of drug-susceptible infections; the three scenarios that include these interventions all reduce global fatalities by a far greater number than the expected deaths from resistance. As this report focuses on understanding the macroeconomic benefits from changes in AMR, much of the economic improvement that would likely come from this reduction in non-AMR deaths is not captured by the methodology.

In absolute terms, the health and macroeconomic benefits are similar in lower-middle-, upper-middle- and high-income countries, and the benefits are much larger than in low-income countries. However, the relative benefits of rolling out the better treatment and innovation scenario are much larger in low- and

TABLE 3.4 Deaths averted, health care cost savings, macroeconomic benefits and a GDP-based health valuation in 2050 under five AMR scenarios (in billion US$ at 2022 value, except where otherwise indicated)

Scenario	Deaths avoided 2025–2050 (millions)[a]	Health care costs saved	Change in GDP	GDP-based health valuation
Scenario 1: Better treatment of bacterial infections	89.84	19.17	269.16	506.52
Scenario 2: Innovation and rollout of effective new gram-negative antibiotics	10.23	83.28	742.85	174.06
Scenario 3: Better treatment and innovation	100.01	96.67	959.32	678.94
Scenario 4: Combined interventions	110.02	98.62	989.70	875.76
Scenario 5: Accelerated rise in resistance scenario	–6.69	–175.74	–1,671.16	–264.85

Note: [a]Data are from Vollset *et al*. (2024).

FIGURE 3.17 Health care cost savings of five AMR intervention scenarios in 2050

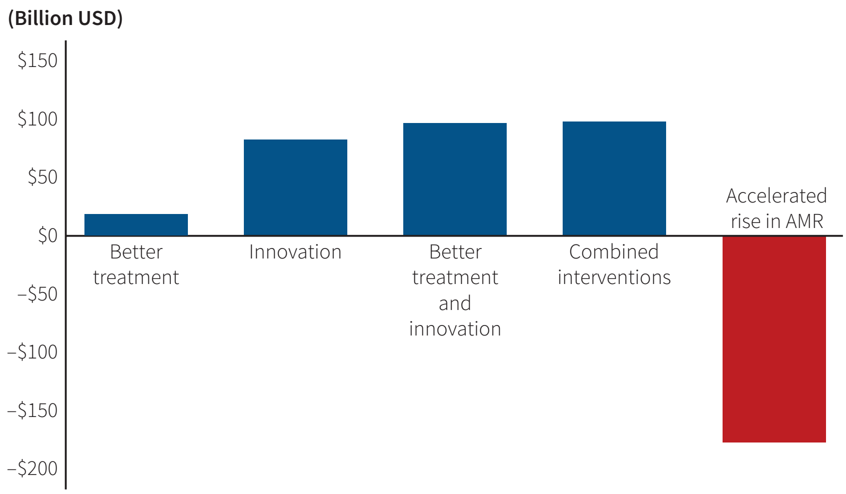
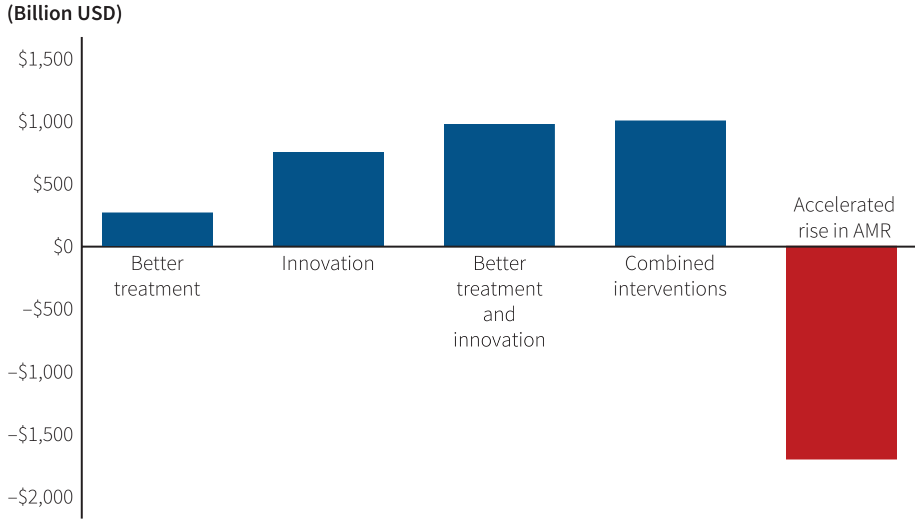


FIGURE 3.18 Macroeconomic impact (change in GDP) of five AMR intervention scenarios in 2050

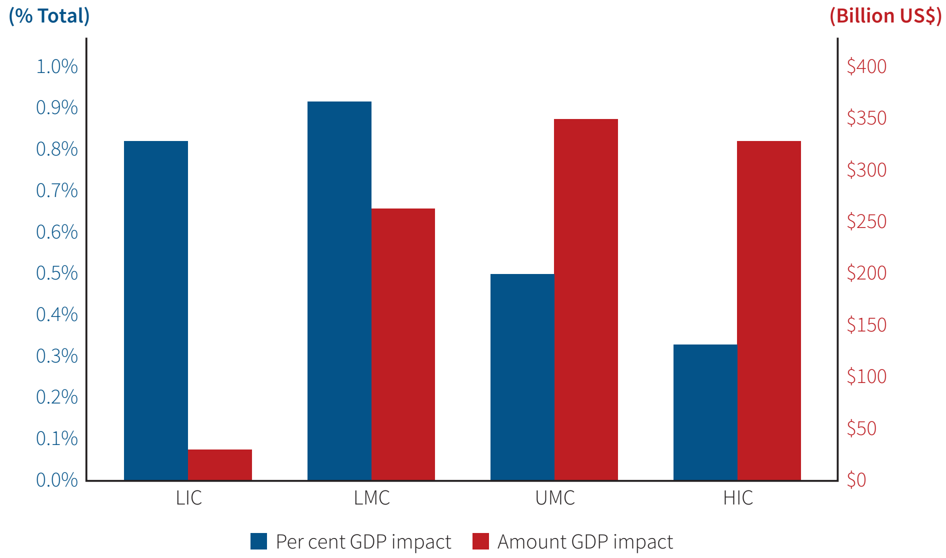


lower-middle-income countries (Figure 3.17). This discrepancy is evident in all the intervention scenarios, as shown in the following subsections. In contrast, the accelerated rise in resistance scenario has a larger effect on the two wealthier income groups.

Better treatment of bacterial infections

This scenario projects a world in which improvements in case-fatality rates of infectious syndromes reach the levels observed in settings with a Healthcare Access and Quality[9] (HAQ) Index measure in the 85th percentile across all locations (Vollset *et al.*, 2024). IHME estimates that doing so would save 90 million (81–100 million) lives between 2025 and 2050 compared with the business-as-usual scenario (Table 3.5). Only 5.6% of the averted deaths are from drug-resistant infections; the rest are from drug-susceptible infections. Many of the benefits of this policy are outside the scope of the economic burden of AMR. We estimate that there would be an additional 54 million people alive in 2050 in this scenario, who

FIGURE 3.19 Per cent and total GDP impact in 2050 due to improved treatment and innovation (in billion US$)



Note: LIC = Low-Income Countries, LMC = Lower-Middle-Income Countries, UMC = Upper-Middle-Income Countries, HIC = High-Income Countries.

9 The Health and Quality Index (HAQ) assesses health care system performance by measuring mortality rates from preventable or treatable causes. Scores range from 0 to 100, with higher values indicating better outcomes, based on data from the Global Burden of Disease study (Haakenstad *et al.*, 2022).

TABLE 3.5 Economic impacts in 2030, 2040 and 2050 of better treatment of bacterial infections

Type of impact	2030	2040	2050				
			All countries	Low-income countries	Lower-middle-income countries	Upper-middle-income countries	High-income countries
In-patient costs (US$ billions)	−8.0	−12.4	−19.2	−0.8	−10.0	−7.4	−1.1
Per cent of all health care costs	−0.08	−0.10	−0.12	−0.55	−0.76	−0.14	−0.01
Population							
Per cent	0.155	0.400	0.583	0.855	0.787	0.395	0.093
Millions of people	11.7	35.1	54.0	11.0	30.7	11.1	1.2
Change in economic activity							
Direct labour (millions)	4.17	12.52	20.71	5.36	11.17	3.85	0.32
Total labour (%)	0.07	0.11	0.15	0.60	0.44	0.18	0.03
Tourism (%)	0.28	0.31	0.34	1.61	1.18	0.39	−0.05
Hospitality (%)	0.10	0.11	0.12	0.41	0.35	0.15	0.03
Economic impact							
GDP-based health valuation (US$ billions)	319.5	403.3	506.5	46.8	241.8	190.0	27.9
Direct GDP impact (%)	0.014	0.034	0.053	0.202	0.162	0.055	0.014
Direct GDP impact (US$ billions)	19.2	56.4	106.5	7.4	46.6	38.2	14.3
Total GDP impact (%)	0.080	0.106	0.133	0.463	0.425	0.162	0.016
Total GDP impact (US$ billions)	107.2	178.4	269.2	16.9	122.3	113.5	16.4

would have already died in the business-as-usual scenario, and this would increase the size of the global labour force by 21 million people. As more people are expected to travel to low- and middle-income countries, the results show a very small decline (0.05%) in tourism to high-income countries; this is equivalent to about US$ 1.5 billion – spread across 50 countries – when all sectors are combined. We still expect this to increase GDP in these countries by US$ 16 billion.

We estimate that the annual in-patient cost of treating resistant infections will fall by US$ 19.2 billion (0.12%) by 2050, as access to and the quality of medical treatment for bacterial infections rises (see Table 3.5). This figure does not include the costs associated with increasing access to treatment. Global GDP would reach US$ 269 billion (an increase of 0.013%) because of this policy's impact on AMR (this estimate excludes the benefits of reducing the burden from susceptible infections). Changes in the

TABLE 3.6 Sectors driving the macroeconomic shock in 2050 from better treatment of bacterial infections in all countries (per cent)

Measure	Direct impact only	Direct and indirect impact	Share of change in GDP
Change in GDP	0.053	0.133	100.0
Population	0.007	0.007	5.3
Health	0.009	0.009	6.6
Labour	0.037	0.06	45.3
Tourism	0	0.034	25.2
Hospitality	0	0.023	17.6

labour force are by far the biggest driver of this policy's impact (Table 3.6).

Improved innovation and the rollout of effective new gram-negative antibiotics

In this scenario, IHME modelled the benefits of a healthy pipeline of gram-negative antibiotics and universal access to them.[10] It projects 10.2 million fewer deaths in the world between 2025 and 2050 than under the business-as-usual scenario. All these deaths are attributable to AMR; thus, the economic impact per death averted is higher per death averted than in other scenarios.

We expect innovative antibiotics to reduce the cost of in-patient health care by US$ 83 billion compared with the business-as-usual scenario, a saving of 0.54% per year by 2050 (Table 3.7). Low- and lower-middle-income countries disproportionately benefit from this change in health care costs, with the change in these countries as a percentage of GDP being four times greater than the change in high-income countries. This is partly because high-income countries spend much larger shares of their health budget treating AMR infections. The amount spent on AMR falls in every country but goes up globally because countries that are less well-off today tend to have a much higher burden of resistance. These countries are also expected to account for a far greater share of global health spending in 2050.

An additional 6 million people would be alive, and 2 million additional people would be working if this intervention were rolled out. Globally, spending on tourism would increase by about 1%, with even faster growth in low-income (1.8%) and lower-middle-income (1.9%) countries. This spending would increase the GDP-based health valuation by US$ 174 billion and add

TABLE 3.7 Economic impacts in 2030, 2040 and 2050 of improving innovation and rolling out gram-negative antibiotics

Type of impact	2030	2040	2050				
			All countries	Low-income countries	Lower-middle-income countries	Upper-middle-income countries	High-income countries
In-patient costs (US$ billions)	−27.2	−65.1	−83.3	−1.6	−23.1	−28.8	−29.7
Per cent of all health care costs	−0.26	−0.50	−0.54	−1.14	−1.75	−0.53	−0.35
Population							
Per cent	0.011	0.041	0.066	0.071	0.095	0.042	0.023
Millions of people	0.9	3.6	6.1	0.9	3.7	1.2	0.3
Change in economic activity							
Direct labour (millions)	0.28	1.17	2.11	0.42	1.24	0.38	0.07
Total labour (%)	0.16	0.28	0.27	0.31	0.37	0.25	0.26
Tourism (%)	0.54	0.95	0.96	1.79	1.89	0.98	0.59
Hospitality (%)	0.32	0.54	0.52	0.57	0.66	0.48	0.50
Economic impact							
GDP-based health valuation (US$ billions)	62.2	137.5	174.1	8.4	68.3	54.3	43
Direct GDP impact (%)	0.035	0.067	0.069	0.109	0.085	0.040	0.084
Direct GDP impact (US$ billions)	46.8	112	139.8	4	24.5	27.8	83.5
Total GDP impact (%)	0.213	0.374	0.367	0.432	0.570	0.358	0.312
Total GDP impact (US$ billions)	286.8	628.7	742.9	15.7	164.0	251.2	311.8

10 It may not be technically feasible to ensure that there are sufficient new antibiotics to replace those lost to resistance.

TABLE 3.8 Sectors driving the macroeconomic shock associated with increased innovation and the rollout of effective new gram-negative antibiotics in all countries in 2050 (per cent)

Measure	Direct impact only	Direct and indirect impact	Share of change in GDP
Change in GDP	0.069	0.367	100
Population	0.001	0.001	0.2
Health	0.063	0.063	17.1
Labour	0.005	0.111	30.3
Tourism	0	0.101	27.5
Hospitality	0	0.091	24.8

US$ 740 billion to global GDP in 2050, making the economy 0.37% larger. The macroeconomic benefits would be larger in low- and lower-middle-income countries.

The labour force is the biggest driver of GDP growth, increasing GDP by 0.005% directly and by 0.11% when indirect benefits are considered. About 30% of the GDP benefit from this intervention comes from an increase in the labour force, which would add an estimated 0.14% to global GDP (Table 3.8). Tourism and hospitality are the other two big drivers of GDP growth. Health has less of an effect, and the increase in population does not meaningfully affect growth.

Better treatment and increased innovation

In this scenario, IHME modelled the combination of increasing access to both innovative gram-negative antibiotics and high-quality treatment.

TABLE 3.9 Economic impacts in 2030, 2040 and 2050 of improving treatment and innovation

Type of impact	2030	2040	2050				
			All countries	Low-income countries	Lower-middle-income countries	Upper-middle-income countries	High-income countries
In-patient costs (US$ billions)	−33.7	−73.8	−96.7	−2.1	−29.3	−34.7	−30.6
Per cent of all health care costs	−0.32	−0.57	−0.63	−1.49	−2.22	−0.64	−0.36
Population							
Per cent	0.167	0.441	0.651	0.928	0.884	0.438	0.116
Millions of people	12.6	38.8	60.3	11.9	34.6	12.4	1.5
Change in economic activity							
Direct labour (millions)	4.45	13.73	22.93	5.81	12.48	4.24	0.4
Total labour (%)	0.22	0.38	0.41	0.85	0.75	0.42	0.29
Tourism (%)	0.77	1.17	1.20	3.08	2.80	1.30	0.49
Hospitality (%)	0.4	0.62	0.6	0.8	0.85	0.58	0.52
Economic impact							
GDP-based health valuation (US$ billions)	381.6	539.8	678.9	55.2	309.3	243.8	70.7
Direct GDP impact (%)	0.048	0.098	0.119	0.296	0.236	0.093	0.097
Direct GDP impact (US$ billions)	64.7	165	241.1	10.8	68	64.9	97.4
Total GDP impact (%)	0.280	0.458	0.474	0.808	0.902	0.494	0.324
Total GDP impact (US$ billions)	377.7	768.8	959.3	29.5	259.7	346.3	323.9

TABLE 3.10 Sectors driving the macroeconomic change associated with improving treatment and innovation (per cent)

Measure	Direct impact only	Direct and indirect impact	Share of change in GDP
Change in GDP	0.119	0.474	100
Population	0.008	0.008	1.7
Health	0.069	0.069	14.6
Labour	0.042	0.166	35
Tourism	0	0.125	26.4
Hospitality	0	0.106	22.3

It estimates that combining these scenarios would avert 100 million deaths between 2025 and 2050 compared with the business-as-usual scenario. As in the better treatment scenario, most of the averted deaths are not from drug-resistant infections, so many of the economic benefits are not captured (as our focus is on quantifying the economic impact of AMR). This scenario is projected to reduce the cost of in-patient care by US$ 97 billion, which is equivalent to a reduction in health spending of 0.63%, an increase in tourism rates by 1.2% and a rise in GDP of US$ 959 billion per year by 2050 (Table 3.9). This scenario would increase global economic output by 0.47% over the business-as-usual scenario.

The labour force is the biggest driver of growth, leading to a 0.17% increase in economic output over the business-as-usual scenario, with tourism and hospitality both increasing the GDP by a little over 0.1% each (Table 3.10).

Combined interventions scenario

In this scenario, IHME combined the better treatment and innovation scenarios with improved access to vaccination and WASH. It estimates that this scenario would prevent 110 million deaths between 2025 and 2050 compared with the business-as-usual scenario. As in the access to better treatment scenarios, many of the lives saved through vaccination and WASH are not directly attributed to AMR and so are not fully captured by this study. In the business-as-usual scenario, IHME also model the gradual elimination of WASH risk factors plus 100% vaccine coverage by 2050 for the modelled vaccines (Vollset *et al.*, 2024). In the business-as-usual scenario, it predicted that risk factors from WASH and the number of people who lack access to vaccines will fall by almost half between 2025 and 2050.

Implementing this scenario would reduce the cost of health care by US$ 99 billion, which is a 0.63% reduction in annual health care spending by 2050 (Table 3.11). This scenario is projected to increase tourism by more than 3% in low- and lower-middle-income countries and add almost 27 million workers to the workforce directly. It is projected to add US$ 990 billion per year to global output, an increase of 0.49%. The expected benefits in low- and lower-middle-income countries are more than twice as large as the benefits in high-income countries.

The combined scenario is the combination of four interventions: providing better treatment, increasing innovation, improving access to vaccines, and improving access to sanitation and clean water.

As in other interventions that include better access to treatment, the largest share of the GDP increase is from changes in the labour force (Table 3.12), in part because the modelling does not capture the non-AMR-related benefits from health, tourism and hospitality.

Accelerated rise in resistance scenario

This scenario assumes that, instead of following historic trends, countries progress at the same historical rate as a country in the 15th percentile. Were this scenario to come to pass, IHME projects that there would be an estimated 6.7 million additional deaths between 2025 and 2050, raising the total number of deaths attributable to AMR to 45.2 million. In-patient health care costs are projected to rise by US$ 176 billion, a 1.14% increase; this would bring the total excess cost of treating resistant infections to US $325 billion. We estimate

TABLE 3.11 Economic impacts in 2030, 2040 and 2050 of the combined scenario

Type of impact	2030	2040	2050 All countries	2050 Low-income countries	2050 Lower-middle-income countries	2050 Upper-middle-income countries	2050 High-income countries
In-patient costs (US$ billions)	−34.3	−74.8	−98.6	−2.2	−30.5	−35.2	−30.7
Per cent of all health care costs	−0.32	−0.58	−0.64	−1.59	−2.31	−0.65	−0.36
Population							
Per cent	0.188	0.508	0.775	1.266	1.039	0.479	0.109
Millions of people	14.2	44.7	72.0	16.4	40.7	13.5	1.4
Change in economic activity							
Direct labour (millions)	5.03	15.80	27.45	7.42	14.72	4.94	0.38
Total labour (%)	0.23	0.39	0.43	1.01	0.83	0.43	0.29
Tourism (%)	0.79	1.20	1.24	3.58	3.05	1.31	0.46
Hospitality (%)	0.41	0.62	0.61	0.89	0.89	0.60	0.53
Economic impact							
GDP-based health valuation (US$ billions)	513.0	689.4	875.8	116.1	520	319.8	−80.1
Direct GDP impact (%)	0.049	0.101	0.125	0.354	0.265	0.095	0.096
Direct GDP impact (US$ billions)	66.6	169.7	252.3	12.9	76.4	66.9	96.1
Total GDP impact (%)	0.286	0.467	0.489	0.939	0.975	0.504	0.322
Total GDP impact (US$ billions)	386.2	784.8	989.7	34.2	280.5	353.4	321.6

TABLE 3.12 Sectors driving the macroeconomic changes associated with improving treatment and innovation (per cent)

Measure	Direct impact only	Direct and indirect impact	Share of change in GDP
Change in GDP	0.125	0.489	100
Population	0.009	0.009	1.9
Health	0.070	0.07	14.4
Labour	0.045	0.173	35.3
Tourism	0	0.128	26.3
Hospitality	0	0.108	22.2

that this scenario would lead to declines in labour force participation (0.5%), in revenue from tourism (2.1%) and hospitality (1.3%). The burden is expected to be highest in high- and upper-middle-income countries, partly because these countries have historically had lower AMR rates. This outcome is expected despite the fact that our experts generally thought that wealthy countries would be far more resilient to the economic impact of AMR than poorer countries; the disparity would be far greater without this assumption. We estimate that global output would be US$ 1.7 trillion lower in 2050 than in the business-as-usual scenario, a 0.83% reduction in GDP.

Tourism is the largest driver of results in this scenario, reducing global output by 0.26% compared with the business-as-usual; labour and hospitality led to further reductions of 0.21% and 0.23%, respectively; the impacts of changes in health costs and particularly population are smaller (Table 3.14). This scenario has a much smaller impact on mortality than any of the others and less impact on mortality attributable to AMR than any scenario except better access to treatment (where the scale is similar). Nevertheless, it has the greatest impact on GDP, for two main reasons. First, many of the experts believed that tourism, hospitality and the indirect labour impact of a change in resistance would be far greater if resistance declines. Second, the change in mortality is much greater in wealthy countries, which spend more on health care and by definition have larger economies. As a result, the shock is larger, reinforcing the need to disaggregate results by income group.

TABLE 3.13 Economic impacts in 2030, 2040 and 2050 of the accelerated rise in resistance scenario

Type of impact	2030	2040	2050				
			All countries	Low-income countries	Lower-middle-income countries	Upper-middle-income countries	High-income countries
In-patient costs (US$ billions)	24.3	78.5	175.7	1.6	10.9	93.6	69.7
Per cent of all health care costs	0.23	0.61	1.14	1.16	0.83	1.72	0.82
Population							
Per cent	–0.005	–0.019	–0.043	–0.042	–0.032	–0.059	–0.040
Millions of people	–0.4	–1.7	–4.0	–0.5	–1.2	–1.7	–0.5
Change in economic activity							
Direct labour (millions)	–0.12	–0.55	–1.37	–0.24	–0.47	–0.53	–0.13
Total labour (%)	–0.13	–0.30	–0.51	–0.23	–0.16	–0.61	–0.55
Tourism (%)	–0.47	–1.18	–2.13	–0.59	–0.17	–3.78	–1.26
Hospitality (%)	–0.30	–0.71	–1.25	–0.64	–0.50	–1.48	–1.34
Economic impact							
GDP-based health valuation (US$ billions)	–40.7	–122.0	–264.8	–7.3	–34.0	–117.5	–106.2
Direct GDP impact (%)	–0.031	–0.078	–0.137	–0.120	–0.039	–0.122	–0.177
Direct GDP impact (US$ billions)	–42.1	–131.2	–278.3	–4.4	–11.1	–85.6	–177.2
Total GDP impact (%)	–0.194	–0.471	–0.825	–0.342	–0.221	–1.261	–0.712
Total GDP impact (US$ billions)	–261.7	–790.3	–1671.2	–12.4	–63.7	–883.8	–711.2

TABLE 3.14 Sectors driving the macroeconomic changes associated with the accelerated rise in resistance scenario (per cent)

Measure	Direct impact only	Direct and indirect impact	Share of change in GDP
Change in GDP	–0.137	–0.825	100
Population	–0.001	–0.001	0.1
Health	–0.131	–0.130	15.7
Labour	–0.007	–0.210	25.4
Tourism	0.000	–0.259	31.4
Hospitality	0.000	–0.227	27.4

RETURN ON INVESTMENT

Return on investment in improved treatment of bacterial infections

It is difficult to estimate the inputs needed to achieve good outcomes against bacterial infections. Some countries that have outcomes in the top quartile use relatively few antibiotics and have low health care utilisation (e.g. Costa Rica). Some countries with above-average levels of antibiotics have outcomes in the bottom quartile (e.g. Tanzania).

Both improving health care and increasing access to antibiotics appeared to have a significant impact on health outcomes. Countries need a combination of better treatment of bacterial infections and better access to health systems to achieve good outcomes against AMR infections.

Table 3.15 shows that the global cost of improving in- and out-patient antibiotics and health care is US$ 59 billion. Low-income countries have the largest gap in access to make up; however, costs are higher in middle income countries. This is partly driven by the fact that nine times as many people live in middle-income countries as in low-income ones, and partly because health care is much less expensive in low-income countries. Although the average and country approaches yield similar results overall, the country productivity model yields much higher estimates for low-income countries, partly because some health systems in these countries are not very productive. Without improving productivity, a much larger increase in inputs would be needed to improve treatment.

Return on investment in increased access to new drugs

There is no consensus on how many new antibiotics the world needs. The number depends on the quality of the drugs, the number of pathogens they can treat and how quickly bacteria develop resistance to the new drugs. The UK Independent Review on AMR (2016) recommends that 15 new antibiotics should be discovered over the next ten years (O'Neill, 2016). The Infectious Diseases Society of America (2013) recommended ten drugs per decade (Boucher *et al.*, 2013). Towse and Bonnifield (2022) suggest that six drugs be developed per decade.

We assume that ten drugs will be developed per decade, two-thirds of them for gram-negative infections. Outterson and Rex (2020) estimate that it would cost US$ 3.3 billion to develop each drug, or about US$ 2.2 billion per year. We expect these costs to rise more rapidly than inflation, for several reasons. First, research costs tend to rise slightly more rapidly than inflation.[11] Second, getting a new treatment approved is costly, partly because of higher regulatory standards and partly because new products must be better than existing ones, which becomes more challenging the better treatments become. The tendency for the cost of drug R&D to rise more quickly than inflation is known as Eroom's law (Scannell *et al.*, 2012). Third, it seems likely that a large portion of natural antibiotic

TABLE 3.15 Average cost of in-patient and out-patient antibiotics and health care, by World Bank income group (US$ at 2022 value, in millions)

World Bank income group	Antibiotics		Health care		Total
	In-patient	Out-patient	In-patient	Out-patient	
Low	294	242	2,488	1,100	4,125
Lower-middle	1,183	1,414	22,428	10,378	35,403
Upper-middle	4,539	1,243	5,120	3,591	14,493
High	333	126	1,923	2,555	4,936
Total	6,349	3,025	31,959	17,624	58,957

11 For example, the US National Institutes of Health estimate that research costs rise about 0.5% faster than US inflation (NIH, 2024).

compounds have already been discovered; as the number of new treatments left to discover dwindles, the cost of discovery is likely to rise (Brown and Wright, 2016; McDonnell *et al.,* 2024). For these reasons, we assume that research costs will rise at 2% above inflation.

R&D would cost 0.0036% of GDP in 2025, to be borne entirely by high-income countries.[12] We assume that as middle-income countries become high-income countries, they, too, will start funding R&D on antibiotics. The cost for countries that are currently considered high-income could fall to 0.0022% of GDP in 2050, as most upper-middle-income countries are expected to become high-income countries by then. The annual cost of R&D is projected to reach US$ 3.7 billion (in US$ at 2022 value) by 2050. If this cost is shared by high-income countries in proportion to their own wealth, we would expect countries that are currently classified as high-income to have very stable expenses at US$ 2.3 billion in 2050, with countries that are expected to become high-income paying the remaining US$ 1.4 billion, essentially funding the rise in research costs.

Return on investment in vaccination and intervention

Using IHME's vaccine coverage assumptions for 2022–2050 and the costs per dose in Laurence and McDonnell (forthcoming), we estimate the additional costs of vaccinating more infants and moving to higher-valency vaccines. Increasing vaccination coverage to the level of IHME's business-as-usual scenario is projected to cost US$ 2 billion. This cost would rise to US$ 4.6 billion in the combined intervention scenario.

Return on investment in WASH interventions

Improving WASH is crucial for reducing AMR. Ensuring access to clean water in hospitals is particularly important. WASH interventions do much more than prevent the spread of most infectious diseases; they have also been shown to improve education, nutrition and growth in children (Arnold *et al.,* 2013; Pickering *et al.,* 2019). Action is expensive, however: the global cost of scaling up WASH to meet Sustainable Development Goal (SDG) targets 6.1 and 6.2 is estimated at US$ 263 billion per year (US$ 114 billion in capital costs and US$ 129 billion in operational costs); this is US$ 116 billion more per year than the world spent in 2022.[13]

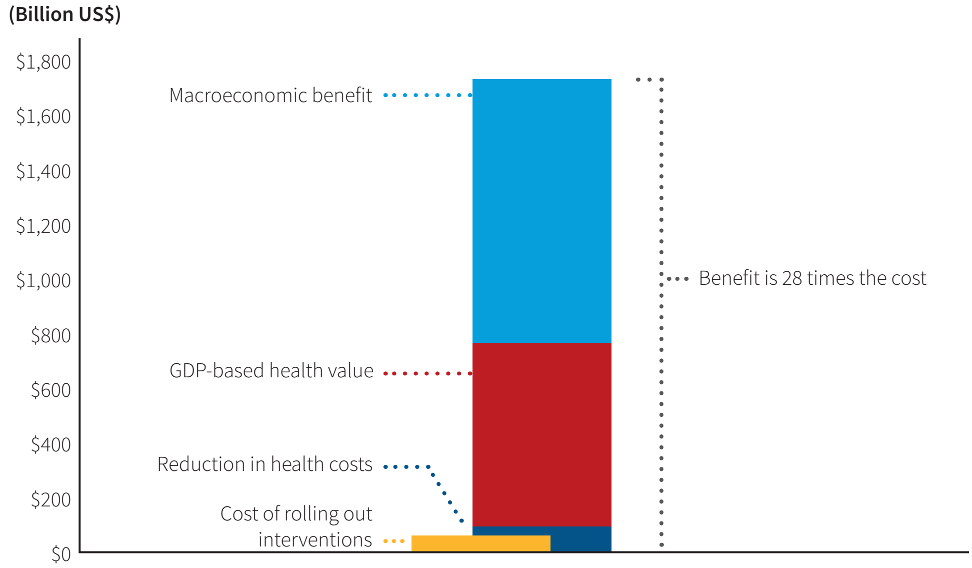
Benefits outside the area of AMR are beyond the scope of this report, which assesses only whether WASH is a cost-effective intervention for preventing resistance. We find that the AMR benefits alone are not large enough to make a comprehensive WASH intervention cost-effective. Some more specific WASH interventions, such as providing clean water to health clinics, are likely to be cost-effective in reducing AMR (McDonnell and Klemperer, 2022). Doing so would also yield large benefits to other patient groups (Water Aid, 2021).

Cost-effectiveness of improving health treatment and innovation of new antimicrobials

Of the four interventions scenarios modelled by IHME, the better access and innovation scenario is the one we were best able to cost. This scenario is comprehensive, covering two of the three pillars of access, innovation and stewardship that are often identified as key to combating AMR (McDonnell *et al.,* 2023). This scenario is very cost-effective, generating health and economic benefits that greatly exceed the cost of rolling out the intervention (Figure 3.20). Globally, this policy is projected to yield massive savings in health care costs in the long-term, as it would cost US$ 63 billion per year and generate savings of US$ 97 billion for health systems. The policy is expected to generate health savings of US$ 34 billion by 2030, just over half the expected costs; not until the mid-2030s will health systems start to see their costs fall by more than the cost of rolling out the policy (see Table 3.9 for a breakdown of benefits in 2030 and 2040). Using GDP per capita to value the health benefits, they would be worth US$ 670 billion globally by 2050

12 These costs cover only R&D. Additional spending would be needed to increase access to the new drugs to achieve the benefits outlined in this report.
13 SDG targets 6.1 and 6.2 commit to achieving universal and equitable access to safe and affordable drinking water and access to adequate and equitable sanitation and hygiene for all, and ending open defecation by 2030 (UN, 2015).

FIGURE 3.20 Estimated annual costs (in US$) and benefits in 2050 of better treatment for bacterial infections and innovative new gram-negative drugs



and US$ 350 billion in 2030. Health costs would fall by US$ 97 billion, and global GDP would be US$ 960 billion larger by 2050 and US$ 380 billion in 2030. Combining these estimates, we find that by 2030 the health and economic benefits from the policy would be more than ten times greater than the cost of the intervention; by 2050, the return on investment (ROI) would be 28:1 (Figure 3.18).

The benefits to these interventions are not evenly spread across the world: The greatest benefits accrue in low- and lower-middle-income countries. The costs are also highest in these countries because more work is needed to improve the quality of health care, particularly in lower-middle-income countries, where health inputs cost significantly more than in low-income countries. Even in lower-middle-income countries, the ROI is 17:1 in 2050 (Table 3.16). The cost of these interventions is greater than the savings from in-patient health care in low- and lower-middle-income countries, bolstering the argument that wealthier countries should provide funding to help people in poorer countries access high-quality treatment, including innovative and effective antibiotics.

TABLE 3.16 Estimated annual costs and benefits of improving treatment and innovation in 2050, by World Bank income group (US$ at 2022 value, in billions, except where otherwise indicated)

World Bank income group	Cost of rolling out intervention	Reduction in health care costs	Macroeconomic benefit	GDP-based health valuation	Combined benefits	Return on investment
Low	4.1	2.1	29.5	55.2	86.7	21:1
Lower-middle	35.4	29.3	259.7	309.3	598.3	16.9:1
Upper-middle	15.9	34.7	346.3	243.8	624.8	39.3:1
High	7.2	30.6	323.9	70.7	425.1	58.8:1
All countries	62.7	96.7	959.3	678.9	1,734.9	27.7:1

Notes: combined benefits are from a reduction in health care costs, increase in macroeconomic output and GDP-based health valuation of health benefits. This is compared to the cost of the intervention to estimate the return on investment.

Discussion

Several studies have examined the ways in which AMR might affect the economy. Although these studies differ from ours in both methodology and approach, where possible we have tried to compare our findings with the literature. This section also identifies some weaknesses of this study.

COMPARISON WITH OTHER STUDIES

Health care costs

Our cost-per-admission estimates for diarrhoea in lower-middle-income countries align with those of Baral *et al.* (2020). Using IHME's global burden of disease estimates, we find that 3.5% of hospital admissions involved a resistant infection; we could find no comparable global estimate. Our estimates for the European Union and the United States of America (US) are higher than those of Cassini *et al.* (2019) and Jernigan *et al.* (2020).

Our cost estimates are lower than the estimates of the most comparable study (OECD and WHO, 2024). The methodologies and years are not directly comparable: the WHO and OECD study looks at the cost of resistance between 2015 and 2035 and at the full cost of infection rather than excess cost of resistance. Our estimate of the total average cost of infection is US$ 187.2 billion in the business-as-usual scenario and US$ 201.8 billion in the accelerated rise in resistance scenario – less than half the US$ 461 billion[14] estimated by WHO and OECD. Differences may arise from varying methodologies in estimating admissions volumes, different scenarios for future volumes and costing methodologies. WHO and OECD use full economic costs based on a standardised methodology using WHO-Choice.[15] Our review uses estimates from the literature, which are based on a more diverse set of methodologies.

Our cost estimates are higher than those of OECD (2023) for 34 OECD countries. Primarily because of differences in resistant admissions, we estimate there are more people in hospital with resistant infections. Adjusting our costs to align with admissions in the WHO and OECD study would bring our estimate in line with their central estimate. For the US, our estimates are higher than those of the US Centers for Disease Control and Prevention (CDC, 2019) and Nelson *et al.* (2021), likely because of differences in the number of AMR admissions underlying our estimates. In a follow-up paper (Laurence *et al.,* forthcoming), we will include a table on how our results compare with other estimates of cost per admission, number of admissions with a resistant infection and the total cost of AMR.

Macroeconomic burden

Three other studies have quantified the global macroeconomic burden of AMR. Two were commissioned by the AMR Review in 2014, and a third was published by the World Bank in 2017 (Ahmed *et al.,* 2017; O'Neill, 2014). All these studies compared a world in which there was no AMR with one in which there was a high level of resistance, similar to IHME's accelerated rise in resistance scenario. They also analysed disruption over a longer time period, making comparison difficult. The AMR Review estimated a 2.5% decline in GDP after 25 years as a result of AMR; the World Bank estimated a decline of 1.1–3.8% after 33 years. Under the accelerated rise in resistance scenario, we estimate that the 2050 world economy would be 0.9% smaller than in the business-as-usual scenario.

14 We inflated the WHO and OECD's figure of US $412 billion to 2022 USD to make it contestant with the numbers in this report.
15 WHO CHOICE (Choosing Interventions That Are Cost-Effective) is a WHO programme that provides data on the cost and effectiveness of health interventions to help policy-makers prioritise strategies based on their efficiency and impact.

This paper focuses on bacterial resistance. The AMR Review included malaria and HIV, which together accounted for about 25% of their estimated burden.

All the studies assumed a 1:1 relationship between a decline in population as a result of AMR and a decline in the labour force. This assumption was based on previous research that was carried out before there were good global estimates of the age profile of people dying from AMR. Work by GRAMs[16] and the IHME projections used in this study suggest that most people who die from AMR will be over the age of 65 and no longer in the workforce (Murray *et al.,* 2022). The population decline caused by AMR will therefore be far greater in the non-working population and our estimate of the labour shock from AMR is lower than that of previous studies, particularly in high-income countries, where very few people die before 65.

GDP-based health valuation

The research that is closest to our estimates of the amount governments might be willing to pay to achieve a given level of health improvement is a series by Bonnifield and Towse looking at the cost and ROI of generating new drugs (Bonnifield and Towse, 2022; Towse and Bonnifield, 2022). Our study looks only at gram-negative antibiotics; Bonnifield and Towse also examine gram-positive antibiotics. The difference should have little bearing on the results as it reduces both the costs and benefit of any intervention.

For G7 countries and the European Union, Bonnifield and Towse use estimates of the opportunity cost of health expenditure. This measure is more accurate than our GDP-based proxy, but data constraints make it challenging to apply this on a global scale.

The biggest difference between the two studies is around cost delivery. They assume that some portion of existing antibiotics in use will be replaced with new ones and that the cost of these existing drugs includes a cost of distribution, which will instead be spent distributing the new drugs. Our costs are based on the expectation that supply and treatment will need to improve in some countries; however, because we have combined this cost with rolling out better treatment more generally for resistant infections, it is difficult to make comparisons. When we remove these costs, as well as the macroeconomic benefits from the intervention, we get very similar results for ten-year ROI (Table 4.1), though our results tend to be a little smaller over a longer time horizon.

STRENGTHS AND LIMITATIONS OF THIS STUDY

Scope

This study is the first that we are aware of that estimates the future global burden of AMR at the national level. Antibiotics do not just treat bacterial infections, they also provide a safety net in medicine, allowing doctors

TABLE 4.1 Comparison of returns on investment of interventions in Bonniefield and Towse (2022) and this report

Item	Bonnifield and Towse	This paper[b]
G7 countries and the European Union		
10-years	5:1	6:1
Long-term[a]	23:1	9:1
Global		
10-years	27:1	34:1
Long-term[a]	125:1	56:1

Notes: [a]The long term is 30 years in Bonnifield and Towse and 26 years in this paper. [b]Costs and benefits from this paper only come from innovative gram-negative antibiotics and exclude macroeconomic benefits.

16 The Global Research on Antimicrobial Resistance (GRAM) Project is a partnership between IHME and the University of Oxford, to provide rigorous quantitative estimates of AMR burden.

to perform surgery with the knowledge that if a patient contracts a bacterial infection, it can be treated. The health and economic implications of AMR for wider health care could be profound. Understanding this wider impact was beyond the scope of this project. Thus, our results for the accelerated rise in resistance scenario are likely an under-estimation of the actual result. Future studies should seek to understand this wider risk from resistance.

Our resilience and health models were designed to understand the impact of AMR on the economy. Many of the other benefits that accrue from some of the interventions – such as a reduction in deaths from drug susceptible infections – are thus not captured by our approach, which therefore under-estimates the value of some interventions. Future work should try to understand the totality of benefits that come from improving treatment for bacterial infections, WASH and access to vaccines.

Health cost model

This study is the first to use bottom-up country estimates of costs per hospital admission combined with admission numbers to estimate the global direct health care costs associated with AMR. This approach ensures that overall health care cost estimates align with relevant micro-costing evidence from the literature, provides insights into the distribution of global costs across countries and allows for health care cost scenarios that align with disease burden scenarios. Managing the global variation in AMR treatment – including different illness presentations, bacterial pathogens and health system structures – poses significant challenges. Producing consistent global estimates is much more complex than producing national estimates; where discrepancies arise, more specific studies with narrower research focuses should be preferred.

A major limitation of this study is that it uses death estimates to estimate hospital admissions in order to maintain consistency with evidence from other sources. Future research should aim to develop these estimates further, ideally using large primary admissions datasets.

Resilience model

Our direct labour force participation estimates are based on a very simple methodology, in which people who are sick or die leave the labour market. By using much more granular health estimates than previous studies of AMR, we gain better insight into how the labour market might change because of AMR.

Few studies have attempted to understand the economic consequences of endemic infectious diseases beyond the impact of treatment costs and labour participation, partly because of the lack of a good counterfactual and the likely small size of the effect. We overcame these challenges by using a combination of expert elicitation and modelling. We are not aware of another study that examines the impact of AMR on other sectors of the economy.

Our initial findings give reason to believe that increased AMR could affect tourism, hospitality and the labour force. However, our results are based on expert elicitation, and it was it difficult to find experts who felt able to discuss both AMR and the economic sectors of interest.

Macroeconomic model

The Global Trade Analysis Project (GTAP) model is widely used for economic research, particularly in analysing economic shocks and their global impacts. The global economic impact of AMR has been studied using a CGE model, which we believe is the most comprehensive framework for analysing its impact. With five different shocks (changes in population, labour, health care costs, hospitality and tourism) this study simulates more shocks to the economy than previous work. The methodology and modelling assumptions are widely accepted and used for global economic analysis.

Like any economic model, ours has limitations related to data availability, parameterisation and modelling assumptions that have been well-documented elsewhere (Bekkers *et al.*, 2018; Burfisher, 2021; Dixon and Jorgenson, 2013; Hertel, 1996; Valenzuela *et al.*, 2008). Future research on the economy-wide effects of AMR could include impacts that were not considered in this analysis, including potential changes in the demand for goods and services beyond the hospitality and tourism sectors.

Implementation cost model

The approach for costing new antibiotics, new vaccines and improvements to WASH were based on the literature but tailored to match the details of the scenarios explored. To estimate the cost of providing access to new antibiotics, we used a production function, an approach that, to our knowledge, has not been used elsewhere.

Our results are highly uncertain because of data limitations, oversimplifications in treating different health care services as interchangeable and the use of arbitrary weightings for health outcomes. We overlooked key differences within categories and assumed that no antibiotics are distributed without appointments, potentially underestimating out-patient gaps. Implicit in the production function are assumptions about dosing and service mixes that may not apply universally. We also took no account for better resource stewardship. Our approach assumes a highly elastic supply of health care resources, which could lead to inflated costs in the short term.

POLICY IMPLICATIONS

AMR imposes a huge cost on society. It was responsible for 1.27 million deaths worldwide in 2019, and that figure could rise to more than 1.8 million by 2050.

AMR also imposes enormous economic costs, with health systems currently spending an additional US$ 64 billion per year treating AMR infections. Through mortality and morbidity, AMR also reduces the size of the labour force. Almost all the experts we interviewed believe that it is likely to affect tourism, now or in the future. The experts also believed that demand for hospitality services could decline as a result of an increase in AMR. Even if these effects are very small in terms of percentage changes, these sectors make up such a large portion of the economy that changes could have substantial impacts on it.

Increasing the number of new antibiotics and ensuring access to high-quality treatment for bacterial infection will yield significant benefits. Although doing so would be expensive, in the long run it would save health systems far more than it costs, providing societal and macroeconomic benefits that exceed their costs by a factor of 20. There does not need to be a trade-off between what is best for the economy and what is best for people's health; both can be optimised at the same time.

All countries would see huge benefits from reduced AMR, with the largest gains accruing to people in low- and upper-middle-income countries. However, the cost of tackling resistance is also far higher in resource-constrained settings. If the better treatment and innovation scenario were implemented, with high-income countries funding all innovation and each country funding its own improvements in the treatment of bacterial infections, the ROI would be more than twice as high in high-income countries than in low- and lower-middle-income countries. This finding suggests that equitable solutions need to be sought, in which wealthier countries do more to ensure widespread access to treatments in the world's poorest countries.

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Annex A. Experts who completed the study survey and interview

TABLE A.1 Experts who completed the study survey and interview

Name	Affiliation
Dr Fernando Antoñanzas Villar	Professor of Economics, Department of Economics and Business, University of La Rioja, Spain
Dr Marco Boeri	Director of Preference Research at Open Health; Honorary Professor of Health Economics at Queen's University Belfast, United Kingdom
Dr Juan Gabriel Brida	Professor of Economic Dynamics, Departamento de Metodos Cuantitativos, Universidad de la República de Uruguay
Prof Carlos Carrillo-Tudela	Professor of Economics, Department of Economics, University of Essex, United Kingdom
Dr Michele Cecchini	Head of the Public Health Unit, Organisation for Economic Co-operation and Development, Paris, France
Prof Clare Chandler	Professor of Medical Anthropology, London School of Hygiene and Tropical Medicine, United Kingdom
Dr Sujith J. Chandy	Executive Director, International Centre for Antimicrobial Resistance Solutions, Copenhagen, Denmark
Dr Jason Gordon	Co-Founder and Chief Commercial Officer, Health Economics and Outcomes Research Limited, London, United Kingdom
Mr Marco Hafner	Senior Economist, RAND Europe, Cambridge, United Kingdom
Ms Abigail Herron	Global Head of ESG Strategic Partnerships, Aviva Investors, Manchester, United Kingdom
Dr Nadine Therese Hillock	Research Associate, School of Public Health, University of Adelaide, Australia
Dr Aidan Hollis	Professor of Economics, Department of Economics, University of Calgary, Canada
Dr Ramanan Laxminarayan	Founder and President, One Health Trust, New Delhi, India
Dr Yoel Lubell	Head of Economics and Implementation Research Group (EIRG), Mahidol Oxford Tropical Medicine Research Unit, Bangkok, Thailand
Dr Arindam Nandi	Researcher (Associate II), Population Council, and visiting fellow, One Health Trust, Washington DC, United States of America
Lord Jim O'Neill	Former Chair of Independent Review on Antimicrobial Resistance, London, United Kingdom
Mr Israel Osorio Rodarte	Economist, World Bank, Washington DC, United States of America
Prof David Paterson	Professor of Medicine, Saw Swee Hock School of Public Health and the Yong Loo Lin School of Medicine, National University of Singapore; Honorary Professor at the University of Queensland, Australia
Dr John Rex	Editor-in-Chief, AMR Solutions; Chief Medical Officer, F2G Ltd; Operating Partner, Advent Life Sciences; Adjunct Professor of Medicine, McGovern Medical School, Houston, Texas, United States of America
Prof Richard Smith	Deputy Pro Vice Chancellor and Professor of Health Economics, University of Exeter, United Kingdom
Dr Shinya Tsuzuki	AMR Clinical Reference Center, National Center for Global Health and Medicine, Tokyo; Disease Control and Prevention Center, National Center for Global Health and Medicine, Tokyo; Faculty of Medicine and Health Sciences, University of Antwerp, Belgium

This report is part of the EcoAMR series. As of September 2024, the series features these other publications:

- Forecasting the Fallout from AMR: Economic Impacts of Antimicrobial Resistance in Food-Producing Animals
- Forecasting the Fallout from AMR: Human Health Impacts of Antimicrobial Resistance
- Forecasting the Fallout from AMR: Averting the Health and Economic Impacts through One Health Policy and Investment

World Organisation for Animal Health

AID Animal Industry Data

CGD Center for Global Development

Institute for Health Metrics and Evaluation

RAND Europe

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