Food and Agriculture
Organization of the
United Nations

THE FUTURE OF ANTIMICROBIAL USE IN LIVESTOCK

The economic cost of action or inaction

THE FUTURE OF ANTIMICROBIAL USE IN LIVESTOCK

The economic cost of action or inaction

Alejandro Acosta[1] | Wondmagegn Tirkaso[1] | Francesco Nicolli[1] | Sergio R. Araujo[1] | Marco Artavia[1]
Thomas Chatzopoulos[1] | Martin Cicowiez[1,2] | Shaikh Eskander[3,4] | Kátia Cardinal[5,6] | Fabiola Onofrio[7]
Jozimo Santos-Rocha[1] | Antonio Valcarce[1] | Emmanuel Kabali[1] | Rachel Dalton[1] | Carmen Bullon[1]
Giuseppina Cinardi[1] | Alejandro Dorado Garcia[1] | David W. Roland-Holst[8] | Thomas P. Van Boeckel[9]
Ramanan Laxminarayan[10,11] | Junxia Song[1]

[1] Food and Agriculture Organization of the United Nations | [2] National University of La Plata | [3] London School of Economics
[4] University of Alabama | [5] Federal University of Rio Grande do Sul | [6] Farroupilha Federal Institute | [7] University of Ferrara
[8] University of California, Berkeley | [9] University of Zurich | [10] Princeton University | [11] One Health Trust

Food and Agriculture Organization of the United Nations
Rome, 2026

REQUIRED CITATION
Acosta, A., Tirkaso, W., Nicolli, F., Araujo, S., Artavia, M., Chatzopoulos, T., Cicowiez, M., Eskander, S., Cardinal, K., Onofrio, F., Santos-Rocha, J., Valcarce, A., Kabali, E., Dalton, R., Bullon, C., Cinardi, G., Dorado Garcia, A., Roland-Holst, D.W., Van Boeckel, T.P., Laxminarayan, R. & Song, J. 2026. *The future of antimicrobial use in livestock – The economic cost of action or inaction*. Rome, FAO. https://doi.org/10.4060/cd9571en

ISBN: 978-92-5-140684-7

Contents

Figures

Tables

Contributors

A One Health framework to assess the economic return on investment in livestock antimicrobial stewardship
Alejandro Acosta, Francesco Nicolli, David Wells Roland-Holst, Jozimo Santos-Rocha, Wondmagegn Tirkaso, Junxia Song

The future of antimicrobial use in livestock
Alejandro Acosta, Wondmagegn Tirkaso, Francesco Nicolli, Thomas P. Van Boeckel, Giuseppina Cinardi, Junxia Song

Global impact of antimicrobial growth promoters on livestock productivity
Alejandro Acosta, Kátia Cardinal, Francesco Nicolli, Fabiola Onofrio, Junxia Song

Antimicrobial use in livestock – The economic cost of action or inaction
Alejandro Acosta, Wondmagegn Tirkaso, Marco Artavia, Francesco Nicolli, Thomas Chatzopoulos, Sergio René Araujo, Martin Cicowiez, Shaikh Eskander, Ramanan Laxminarayan, Junxia Song

Reframing livestock antimicrobial use as a global public good
Alejandro Acosta, Francesco Nicolli, Rachel Dalton, Antonio Valcarce, Emmanuel Kabali, Alejandro Dorado Garcia, Carmen Bullon, Wondmagegn Tirkaso, Junxia Song

The authors declare they have no conflict of interest.

Acknowledgements

This publication was prepared by a multidisciplinary team of experts at FAO, under the direction of Thanawat Tiensin (Assistant Director-General, Director of the Animal Production and Health Division, and Chief Veterinarian), Junxia Song (Chief of the One Health and Disease Control Branch), and Alejandro Acosta (Livestock Economist Policy Officer). Strategic guidance was provided by Badi Besbes (Chief of the Sustainable Animal Production, Feed and Genetics Branch).

The research and writing team, coordinated by Alejandro Acosta and Junxia Song, was composed of Wondmagegn Tirkaso, Francesco Nicolli, Antonio Valcarce, Alejandro Dorado Garcia, Emmanuel Kabali, Rachel Dalton, Giuseppina Cinardi, Sergio R. Araujo, Marco Artavia, Thomas Chatzopoulos, Carmen Bullon, Jozimo Santos-Rocha, Martin Cicowiez (National University of La Plata), Thomas P. Van Boeckel (University of Zurich), Fabiola Onofrio (University of Ferrara), Shaikh Eskander (London School of Economics and University of Alabama), David W. Roland-Holst (University of California, Berkeley), Kátia Cardinal (Federal University of Rio Grande do Sul and the Farroupilha Federal Institute), and Ramanan Laxminarayan (Princeton University and One Health Trust).

The report benefited from the valuable contributions of FAO colleagues, including those who provided inputs through the FAO AMR Working Group, the FAO Reference Centres on Antimicrobial Resistance, and other FAO mechanisms: Daniela Battaglia, Paul Boettcher, Anica Buckel, Mark Caudell, Giuliano Cecchi, Leopoldo del Barrio, Madhur Dhingra, Fanette Fontaine, Anamaria Garcia Diaz, William Garthwaite, Maria Gatica, Andres Gonzalez Serrano, Bin Hao, Martin Heilmann, Ozge Kara, Nicolas Keck, Jieun Kim, Tabitha Kimani, David Laborde, Francesca Latronico, Jeffrey LeJeune, Grégoire Leroy, Marialia Lucio Restrepo, Melissa Marin Cabrera, Holger Matthey, Cristian Morales, Nelea Motriuc, Beatrice Mouille, Scott Newman, Ugo Pica Ciamarra, Jorge Pinto Ferreira, Melba Reantaso, John Ruane, Ahmed Saad, Damian Tago Pacheco, Felix Teillard, Michael Treilles, Aimable Uwizeye, German Vasquez Nino, Teemu Viinikainen, Nicolas Winter, Dominik Wisser and Larissa Zanette.

We further appreciate the insightful feedback received through external reviews, particularly from experts at the Quadripartite Joint Secretariat: Jean Pierre Nyemazi (World Health Organization), Chantal Morel (World Health Organization), and Morgan Jeannin (World Organisation for Animal Health).

We gratefully acknowledge the financial support provided by the Fleming Fund, which contributed to the development and completion of this report, as well as to the open-access publication of its background papers in various peer-reviewed journals. The Fleming Fund programme is managed by the United Kingdom of Great Britain and Northern Ireland's Department of Health and Social Care.

Finally, we would like to thank the FAO communications and operations teams, the editor, and the design team that supported the drafting and publication process: Claudia Ciarlantini, Cristiana Giovannini, Lucia De Canio, Enrico Masci, Ludovica Nela, Yerkem Sembayeva, Denise Martinez Breto and Se-Woong Koo. Jill E. Mazzetta provided professional English-language editing and proofreading of the manuscript and page proofs.

Foreword

Antimicrobials have long played an important role in protecting livestock health, animal welfare and productivity. Yet their overuse and misuse accelerate antimicrobial resistance (AMR), weakening the effectiveness of medicines that underpin animal health, public health, livelihoods and food security. This report places that challenge within its economic and policy context and provides decision-makers with evidence to guide action.

Shaping the future of antimicrobial use (AMU) in livestock requires looking beyond the farm. Patterns of use are shaped by economic incentives and constraints across production systems, value chains and markets. Reducing unnecessary AMU therefore requires an economy-wide One Health approach that aligns incentives, reduces barriers to prevention, and makes responsible use and viable alternatives feasible at scale.

Despite growing political commitment, global AMU in livestock could continue to rise without further intervention, particularly in regions where demand for animal source foods is increasing and production systems are intensifying. This trajectory is not inevitable, but changing it will require decisive action to reshape incentives, strengthen animal health systems and expand access to viable alternatives.

Phasing out antimicrobial growth promoters (AGPs) is an important part of this agenda. The evidence in this report shows that AGPs have been associated, on average, with measurable productivity gains, although effects vary across species, systems and contexts. Adjustment pressures will therefore not be uniform. Restrictions on AGPs should be accompanied by practical measures that accelerate the adoption of alternatives, strengthen veterinary and advisory services, and reduce disease pressure at the farm level.

The long-term economic burden of rising AMR is expected to exceed the costs of action. Yet the main policy challenge lies in the short-term transition, as the costs of reducing AMU are often immediate and concentrated, while the benefits of preserving antimicrobial effectiveness emerge gradually and are widely shared. This imbalance is compounded by the fact that antimicrobial effectiveness has the key characteristics of a global public good. Its benefits extend across borders, while the costs of action are often local, immediate and unevenly distributed.

The Food and Agriculture Organization of the United Nations (FAO) is committed to supporting Members in translating these insights into action. Through RENOFARM, FAO's 10-year flagship initiative to Reduce the Need for Antimicrobials on Farms for Sustainable Agrifood Systems Transformation, its Farm 5Gs framework of good practices, and the International FAO Antimicrobial Resistance Monitoring system (InFARM), FAO will continue to serve as a convening and technical partner.

AMR underscores the importance of acting early, before risks intensify and become far more costly to reverse. Timely and coordinated action can reduce the need for antimicrobials, strengthen livestock systems and avoid higher economic and social costs in the future. By acting decisively now, we can protect food security, safeguard public health and preserve the effectiveness of antimicrobials for future generations.

Thanawat Tiensin
Assistant Director-General, Director of the Animal Production and Health Division, and Chief Veterinarian
Food and Agriculture Organization of the United Nations

Abbreviations

ADG	average daily gain
Aglink-Cosimo	Agricultural Linkage – Commodity Simulation Model
AGP	antimicrobial growth promoter
AMR	antimicrobial resistance
AMU	antimicrobial use
AMUI	antimicrobial use intensity
AMUQ	antimicrobial use quantity
ANIMUSE	global database on Animal Antimicrobial Use
BAU	business as usual
CGE	computable general equilibrium
CI	confidence interval
CIA	critically important antimicrobials
FAO	Food and Agriculture Organization of the United Nations
FCR	feed conversion ratio
FE	feed efficiency
GDP	gross domestic product
GISSA	Global Integrated System for Surveillance of AMR and AMU (Quadripartite)
GLASS	Global Antimicrobial Resistance and Use Surveillance System
GPG	global public good
HIC	high-income country
InFARM	International FAO Antimicrobial Resistance Monitoring
IPEA	Independent Panel on Evidence for Action Against AMR
LBC	livestock biomass conversion
LBIO	livestock biomass
LIC	low-income country
LMIC	lower-middle-income country
LPSM-G	Livestock Policy Simulation Model – Global
Mt	million tonnes
OECD	Organisation for Economic Co-operation and Development
PCU	population correction unit
PE	partial equilibrium
ROI	return on investment
UNEP	United Nations Environment Programme
UNGA	United Nations General Assembly
UMIC	upper-middle-income country
WHO	World Health Organization
WOAH	World Organisation for Animal Health

Key messages

Shaping the future of antimicrobial use in livestock requires looking beyond livestock production to the wider food system.

Antimicrobial use (AMU) in livestock generates interlinked effects that extend across value chains, governance, and macroeconomic performance. Understanding these connections is essential to designing interventions that sustain productivity while safeguarding long-term societal welfare. This report sets out an integrated framework showing how microeconomic factors, governance capacity, and macroeconomic conditions interact to shape the incentives and constraints that drive AMU in the livestock sector. The main policy implication is that antimicrobial stewardship should be approached as an economy-wide One Health intervention, rather than as a standalone technical adjustment within livestock production.

Without decisive action, global antimicrobial use in livestock is expected to rise by around 30 percent by 2040 under a business-as-usual scenario.

Driven by rising demand for animal source foods and continued production intensification, particularly in emerging economies, global AMU in livestock is projected to increase substantially under current trajectories. However, this outcome is not inevitable. Strategic improvements in productivity and efficiency could reduce AMU by around 50 percent, demonstrating that substantial reductions are achievable with effective policies and practices.

Phasing out antimicrobial growth promoters in livestock production systems is an important step, but it may entail short-term productivity losses in some regions.

International organizations have called for restricting and progressively phasing out antimicrobial growth promoters (AGPs) in livestock production. At the same time, the analysis shows that AGPs are, on average, associated with measurable productivity gains across broiler chickens, pigs and cattle, reflected in faster growth and improved feed-use efficiency. These effects vary across regions and are often larger where baseline performance is lower and biosecurity and animal health services are weaker. This implies that phase-out policies should combine restrictions with practical measures that accelerate the availability and adoption of effective alternatives, strengthen animal health services and reduce disease pressure at the farm level.

The long-term economic burden of antimicrobial resistance far exceeds the costs of phasing out antimicrobial growth promoters, but accelerating action may still require at least USD 28 billion in transitional investment.

Phasing out AGPs imposes an upfront, visible shock, followed by partial recovery as producers adapt and scale alternatives. Antimicrobial resistance evolves in the opposite direction: The impact is silent initially but compounds over time, and there is no recovery. This imbalance creates a policy lock-in, with decision-makers facing immediate and concentrated adjustment pressures while the benefits of action accrue later, weakening incentives for timely intervention and encouraging delay despite much higher long-term costs. In this context, the investment needed to cover the transitional economic cost of action is estimated at USD 28.4 billion.

Livestock antimicrobial use should be reframed as a global public good. The anticipated increase in AMU in livestock is not merely technical but structural, driven by governance and market failures that misalign private benefits with collective social welfare. Addressing this challenge requires reframing livestock antimicrobial effectiveness as a global public good. This framework can better align farm- and country-level incentives with global health goals through stronger governance, market-based incentives, sustainable financing and capacity building that enables farm-level adoption.

Technical summary

A ONE HEALTH FRAMEWORK TO ASSESS THE ECONOMIC RETURN ON INVESTMENT IN LIVESTOCK ANTIMICROBIAL STEWARDSHIP

A One Health economic framework is presented to assess the return on investment in livestock antimicrobial stewardship by linking microeconomic factors, such as farm-level antimicrobial use (AMU), to governance capacity and macroeconomic outcomes. Antimicrobials support animal health and productivity, yet overuse and misuse accelerate the development of antimicrobial resistance (AMR) and impose costs on public health, trade and economic stability. Because producers capture immediate gains while societal costs are delayed and dispersed, AMU can exceed the social optimum, especially where enforcement and animal health services are weak.

Microeconomic drivers help explain persistent reliance on antimicrobials. These compounds often substitute for scarce or costly inputs such as capital, skilled labour and adequate space and infrastructure. Limited credit, weak veterinary coverage and high disease pressure in dense, intensified systems make preventive investment in housing, biosecurity, vaccination and monitoring harder to justify. For smallholders, antimicrobials can also function as a low-cost risk management tool that protects livestock assets and stabilizes income and food security when insurance and reliable advice are limited.

Governance mediates these choices through markets, governments and institutions. Prices and supply chains shape access and prescribing practices, while private standards, traceability and certification can reward reduced use through premiums and market entry. Correcting market failures requires public policy instruments such as prescription rules, controls on non-therapeutic use, measures to maintain residue and sanitary standards, and sustained investment in surveillance and veterinary services, complemented by financing and incentives that make alternatives affordable.

Macroeconomic forces shape AMU through growth strategies, fiscal constraints and trade competitiveness. In the short term, antimicrobial-enabled productivity supports output, jobs and export revenues, especially in intensive value chains with strong multiplier effects. Over time, however, rising resistance and tightening residue and sanitary standards increase vulnerability to compliance costs, market exclusion and supply disruptions that raise food prices and inflation pressures. AMR can erode the tax base and increase public spending, widening welfare losses in import-dependent and lower-income economies.

The main policy insight is that antimicrobial stewardship must be treated as an economy-wide One Health intervention and managed as a shared resource with cross-border spillovers, not as a narrow livestock-focused technical measure. Because AMU is driven by binding constraints and market incentives that do not internalize the wider costs of resistance, effective reduction requires coordinated packages that combine enforceable stewardship rules with investment in veterinary services, surveillance and diagnostics, and financing that makes prevention and alternatives affordable, while aligning value-chain and trade incentives so compliance costs do not fall disproportionately on smallholders.

THE FUTURE OF ANTIMICROBIAL USE IN LIVESTOCK

With AMR increasingly being recognized as a One Health risk affecting human, animal, plant and environmental health, trade and the long-term effectiveness of essential medicines, political interest in reducing AMU in livestock is gaining momentum. This direction was reinforced at the 2024 United Nations General Assembly High-level Meeting on AMR, where governments committed to meaningfully reduce AMU across agrifood systems by 2030, with particular emphasis on strengthening stewardship, surveillance and multisectoral coordination in settings where regulatory capacity and veterinary services remain limited.[1]

The livestock biomass conversion (LBC) method is introduced as a methodological advance to strengthen the measurement of antimicrobial use intensity (AMUI) for transparent benchmarking and progress tracking. Building on established international approaches, it refines the livestock biomass denominator using species-specific live weights and production cycle information, thereby better reflecting differences across production systems and time at risk. This added granularity improves comparability across species and regions and provides a robust baseline for projections and monitoring.

Under a business-as-usual (BAU) pathway, global AMU in livestock is projected to reach about 143 481 tonnes by 2040, an increase of 29.5 percent from 2019, reflecting continued growth in animal source food demand and ongoing intensification. Regional patterns remain highly concentrated, with Asia and the Pacific accounting for nearly 65 percent of global use by 2040 and South America contributing around 19 percent. Africa remains a smaller share in absolute terms but records one of the fastest growth rates as production scales up from a low base, while Northern America declines slightly and Europe remains broadly stable, reflecting stricter regulation and shifts away from routine prophylactic use.

Alternative trajectories indicate that changes in livestock biomass alone have limited effects on total antimicrobial volumes, whereas sustained reductions in use intensity provide the main leverage and can more than offset growth in production. A 30 percent reduction in AMUI delivers sizeable declines relative to BAU, while a 50 percent reduction, especially when combined with lower biomass growth, yields the deepest cuts, with total use falling by more than half relative to the baseline pathway by 2040. This underscores the strategic value of productivity and animal health improvements that reduce the need for routine antimicrobials while maintaining supply.

The main policy insight is that fulfilling global pledges is achievable, but will depend primarily on sustained reductions in AMUI through productivity and efficiency gains and preventive animal health management, rather than relying mainly on constraining livestock growth. This calls for coherent One Health policy packages that strengthen stewardship and surveillance, build veterinary and extension capacity, and scale practical alternatives such as vaccination, biosecurity and improved husbandry, supported by appropriate incentives and finance, so producers can reduce routine antimicrobial reliance while safeguarding food security, livelihoods and competitiveness in fast-growing regions.

GLOBAL IMPACT OF ANTIMICROBIAL GROWTH PROMOTERS ON LIVESTOCK PRODUCTIVITY

The use of antimicrobial growth promoters (AGPs) in livestock production has come under increasing scrutiny because of concerns about their contribution to AMR. In response, international organizations have called for restrictions on AGP use, and many countries are moving from voluntary guidance toward tighter regulation and

[1] **UNGA.** 2024. *Political declaration of the high-level meeting on antimicrobial resistance*. United Nations General Assembly. UNGA A/79/L.5. https://documents.un.org/doc/undoc/ltd/n24/278/35/pdf/n2427835.pdf

enforcement. Despite this momentum, considerable uncertainty persists regarding the economic consequences of AGP withdrawal. This uncertainty largely reflects the absence of globally representative productivity parameters that capture heterogeneity across species, production systems and regional contexts.

To address this gap, a globally representative meta-analysis synthesizes evidence on the productivity effects of AGPs. The evidence base comprises 95 studies and 128 treatment effects covering broilers, pigs and cattle, with comparable outcomes extracted for average daily gain (ADG) and feed use. Effects are pooled with confidence intervals and disaggregated by region, country income group, production stage, housing system, antimicrobial class and specific molecules. Results are also stratified by the World Health Organization (WHO) categories of importance for human medicine, allowing comparison between medically important antimicrobials and compounds not used in human medicine.

Antimicrobial growth promoters increase ADG across all species, with the largest gains in pigs. In broilers, ADG rises by 1.78 grams per day (g/day) on average. The increase is greater in animals housed in pens (2.14 g/day) than in those housed in cages (1.64 g/day); it peaks in sub-Saharan Africa (6.37 g/day) and the Near East and North Africa (3.62 g/day), and remains low in Europe and Central Asia (0.44 g/day). In pigs, ADG increases by 28.15 g/day overall, with larger increases seen in grower–finishers (37.54 g/day) than in weaned pigs (27.43 g/day). The highest responses are in Asia and the Pacific (33.69 g/day) and Europe and Central Asia (30.77 g/day). In cattle, ADG increases by about 30 g/day on average, reaching around 50 g/day with antimicrobials classified as important for human medicine, compared with roughly 10 g/day for non-human-use compounds.

Antimicrobial growth promoters also improve feed-use efficiency across species, meaning animals require less feed to achieve the same weight gain. In broilers, feed conversion ratios (FCRs) decline by about 0.05 grams of feed intake per gram of live weight gain (g/g) on average, with much larger improvements in sub-Saharan Africa (-0.24) and smaller effects in Asia and the Pacific, Europe and Central Asia, and Northern America. In pigs, FCRs fall by around 0.09 globally, with particularly strong effects in Europe and Central Asia and substantial gains in Latin America and the Caribbean as well as in Asia and the Pacific, while improvements are much smaller in high-income systems. In cattle, feed efficiency increases modestly on average (0.0043), with larger gains in high-income settings (0.0052) and more limited effects in middle-income regions (0.0014).

The key policy insight is that although phasing out AGPs remains a central One Health objective, the transition is unlikely to be costless in the short term. The results show that AGPs deliver measurable gains in growth and feed-use efficiency, particularly in settings with lower baseline performance and weaker biosecurity and animal health services. As a result, the adjustment costs of withdrawal are likely to be uneven across regions and income groups. Effective policy therefore requires pairing restrictions with targeted transition support, including investments in biosecurity, husbandry, vaccination and veterinary services; improved diagnostics and surveillance; and accelerated access to effective non-antibiotic alternatives.

ANTIMICROBIAL USE IN LIVESTOCK – THE ECONOMIC COST OF ACTION OR INACTION

This chapter evaluates the economic implications of two independent shocks affecting livestock production, namely the phase-out of AGPs and the productivity losses associated with the rising prevalence of AMR. It applies a global economic framework that links a global partial equilibrium model with a global multisector computable general equilibrium model alongside a detailed representation of the livestock sector. The framework traces how production shocks transmit through markets and into the wider economy, quantifying effects on output and economic welfare.

Under a BAU baseline, global livestock production is projected to rise from 536 million tonnes (Mt) to 657 Mt by 2040, representing an increase of about 23 percent. Growth is led by poultry and milk production, while beef and pork expand more slowly and the global share of pork edges down. Against this reference path, AGP restrictions are expected to have limited long-term effects on production. By contrast, rising AMR could reduce livestock output by about 15 Mt by 2040, a 2.2 percent deviation from baseline, equivalent to erasing roughly 16 percent of the baseline production increase projected between 2025 and 2040.

Cumulative impacts reinforce this contrast. In the most severe AGP phase-out case, cumulative production losses reach about 21.5 Mt by 2040, while under the highest-impact AMR case, they rise to around 150 Mt. The cumulative loss paths intersect around 2028 at roughly 20 Mt, after which AMR becomes the dominant driver of long-run production losses. Valued at constant global reference prices, cumulative losses amount to approximately USD 53 billion for the severe AGP phase-out case and about USD 318 billion under the high-AMR case. The monetary gap between the two trajectories peaks at about USD 28.4 billion in 2026, representing the minimum transitional investment needed to cover the short-term cost of action.

The broader welfare implications are assessed using the Livestock Policy Simulation Model – Global (LPSM-G). Over 2025–2040, cumulative global welfare losses are projected at about USD 1.25 trillion under the high-AMR case, far exceeding the roughly USD 80 billion cumulative loss under the severe AGP phase-out case. Over four-fifths of AMR-related welfare losses accrue to upper-middle-income countries (UMICs) and lower-middle-income countries (LMICs), with UMICs bearing around half of the global total. Low-income countries (LICs), although hosting smaller livestock sectors, face meaningful losses through spillovers to consumption, wages and value chains.

The key policy implication is a temporal asymmetry that can drive delay. Phasing out AGPs brings immediate and visible adjustment costs, but these effects diminish as producers adapt and alternatives scale. AMR follows the opposite path: impacts may appear limited at first, yet they accumulate year after year and generate much larger, persistent economic losses. This mismatch creates a policy lock-in, where short-term transition pressures weigh more heavily in decisions than the longer-term benefits of action, despite the much higher cost of inaction. Timely action may therefore depend on upfront investment to manage transition costs.

REFRAMING LIVESTOCK ANTIMICROBIAL USE AS A GLOBAL PUBLIC GOOD

Despite progress in strengthening veterinary oversight of antimicrobial prescription and use, expanding surveillance systems, and improving husbandry practices, reductions in AMU in livestock have been uneven and insufficient. The persistence of misuse and overuse reflects a structural problem rather than a lack of technical solutions. Livestock producers capture immediate and visible benefits from AMU, while the costs of resistance are delayed, diffuse, and borne across borders and sectors. This misalignment between private incentives and collective welfare represents a fundamental market and governance failure.

Current approaches to antimicrobial stewardship in livestock remain largely national and sector-specific. While they can deliver local improvements, their impact is limited by fragmented governance, voluntary commitments, and weak consideration of international spillovers, as resistant pathogens spread through trade, travel and environmental pathways. Because the societal costs of AMR are not reflected in production decisions, misuse and overuse persists, with challenges particularly acute in low- and middle-income countries, where limited veterinary infrastructure and access to alternatives constrain the scaling of good practices.

This chapter reframes antimicrobial effectiveness as a global public good (GPG) based on three defining characteristics. It is non-rival, since responsible use by one producer or country does not reduce its availability or effectiveness for others. It is effectively non-excludable at the global level, because once effectiveness is preserved, its benefits extend across borders, while resistance emerging in any single setting can undermine effectiveness everywhere. It also generates strong transboundary spillovers, with AMR spreading through interconnected food systems, trade, mobility and the environment.

Building on this framing, the chapter outlines an integrated stewardship framework with four reinforcing pillars. Global governance must move beyond coordination toward clearer targets and accountability under a One Health framework. Market-based incentives are needed to align private decisions with societal objectives, including caps, tradable standards and fiscal measures. Sustainable financing is essential to embedding AMR as a priority in national budgets and to mobilizing international co-financing. Farm-level adoption depends on access to veterinary services, preventive tools, training, and value chain incentives that reduce reliance on antimicrobials as a substitute for prevention.

The key policy implication is that antimicrobial stewardship in livestock cannot be achieved through technical guidance or national regulation alone. Preserving antimicrobial effectiveness requires treating it as a GPG and aligning farm- and country-level incentives with global health objectives through stronger international governance, economic instruments that internalize societal costs, predictable financing and sustained investment in capacity building. Without such a shift, AMU will continue to rise despite technical progress, undermining livestock productivity, food security and public health.

A NOTE ABOUT THE RESEARCH UNDERPINNING THIS REPORT

This report synthesizes findings from five peer-reviewed background studies[2–6] prepared by FAO and partners and published in scientific journals. These studies provide the analytical foundations for the report's projections of AMU in livestock, productivity parameterization, and the economic modelling of action versus inaction, as well as the policy framework for antimicrobial stewardship.

[2] **Acosta, A., Roland-Holst, D., Nicolli, F., Tirkaso, W., Rocha, J.S. & Song, J.** 2025. A One Health framework to assess the economic returns on investment in livestock antimicrobial stewardship. *One Health*, 21: 101188. https://doi.org/10.1016/j.onehlt.2025.101188

[3] **Acosta, A., Tirkaso, W., Nicolli, F., Van Boeckel, T.P., Cinardi, G. & Song, J.** 2025. The future of antibiotic use in livestock. *Nature Communications*, 16(1): 2469. https://doi.org/10.1038/s41467-025-56825-7

[4] **Acosta, A., Cardinal, K.M., Nicolli, F., Onofrio, F. & Song, J.** 2026. Global impact of antimicrobial growth promoters on livestock productivity: A meta-analysis for economic modeling. *Preventive Veterinary Medicine*, 250: 106754. https://doi.org/10.1016/j.prevetmed.2025.106754

[5] **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M. *et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

[6] **Acosta, A., Nicolli, F., Dalton, R., Valcarce, A., Kabali, E., Dorado Garcia, A., Bullon, C., Tirkaso, W. & Song, J.** 2026. Reframing livestock antimicrobial use as a global public good. *One Health*, 22: 101349. https://doi.org/10.1016/j.onehlt.2026.101349

1. A One Health framework to assess the economic return on investment in livestock antimicrobial stewardship

Antimicrobials have long played a critical role in livestock production by reducing disease incidence, sustaining productivity and supporting the growing global demand for animal protein (Roope *et al.*, 2019). However, their overuse and misuse accelerate the development of antimicrobial resistance (AMR), posing significant risks to public health, animal health and economic stability (Van Boeckel *et al.*, 2017). Global assessments suggest that AMR could lead to substantial livestock output losses, with particularly severe consequences in contexts where prevention measures and veterinary services are weak (World Bank, 2017). The human toll is also considerable. In 2019 alone, AMR was associated with an estimated 4.95 million deaths worldwide, including 1.27 million deaths directly attributable to bacterial AMR (Murray *et al.*, 2022). This situation reflects a classic tragedy of the commons, in which individual producers capture short-term productivity gains from antimicrobial use (AMU), while the resulting societal costs are diffuse, persistent, and global in scope (Hollis and Maybarduk, 2015).[1]

In response, the One Health perspective has gained traction as a holistic approach that recognizes the interconnected nature of human, animal and environmental health (Hernando-Amado *et al.*, 2019). Applying this lens to livestock AMU reveals that decisions at the farm level influence microeconomic factors, which shape governance and, ultimately, generate macroeconomic outcomes (Raboisson *et al.*, 2020). AMR, in turn, imposes indirect costs on health care systems, disrupts trade and creates regulatory pressures that can alter production incentives (Umair *et al.*, 2023). Although these interlinkages are critical to understanding the full economic consequences of AMU and AMR, most livestock analyses have remained narrowly focused, either on the productivity impacts within the sector or on isolated animal health costs. This sectoral orientation limits the ability of decision-makers to appreciate the full range of economic interdependencies and to evaluate the potential return on investment (ROI) from integrated stewardship strategies (Ryan, 2019; Babo Martins *et al.*, 2024). In this report, ROI is understood as the net present value of welfare gains from antimicrobial stewardship, accounting for farm-level productivity effects, public health costs, trade outcomes and macroeconomic resilience relative to continued AMU.

This chapter proposes a One Health economic framework to evaluate the ROI of livestock antimicrobial stewardship. The framework synthesizes literature from economics, public health, and veterinary science, and links microeconomic decision-making with governance structures and macroeconomic dynamics. It identifies three interdependent economic domains that shape AMU outcomes: (i) microeconomic factors, including on-farm behaviour influenced by cost structures, risk preferences and access to animal health services; (ii) governance structures, encompassing institutional capacity, regulatory enforcement, surveillance systems and public investment; and (iii) macroeconomic conditions, including market integration, trade competitiveness and national economic resilience. These domains interact dynamically and can amplify or offset each other depending on policy context and structural conditions (Acosta *et al.*, 2025a).

By integrating these dimensions into a unified analytical framework, we advance the theoretical foundations for ROI assessment under a One Health approach. As a first step in economic modelling, the framework identifies and structures the pathways linking farm-level AMU decisions to these three domains, providing a structured basis for analysing trade-offs between short-term productivity gains and long-term societal costs, and for identifying cross-sectoral synergies across livestock, public health and economic policy. Designed for application in both computable general equilibrium models, such as the Livestock Policy Simulation Model – Global (LPSM-G), as well as partial equilibrium models, such as the Agricultural Linkages – Commodity Simulation Model (Aglink-Cosimo), the framework offers a conceptual foundation for embedding antimicrobial stewardship

[1] This chapter builds on and adapts the analytical framework developed by Acosta *et al.*, previously published as **Acosta, A., Roland-Holst, D., Nicolli, F., Tirkaso, W., Rocha, J.S. & Song, J.** 2025. A One Health framework to assess the economic returns on investment in livestock antimicrobial stewardship. *One Health*, 21: 101188. https://doi.org/10.1016/j.onehlt.2025.101188

into national development, investment planning and decision-making based on system-wide economic modelling.

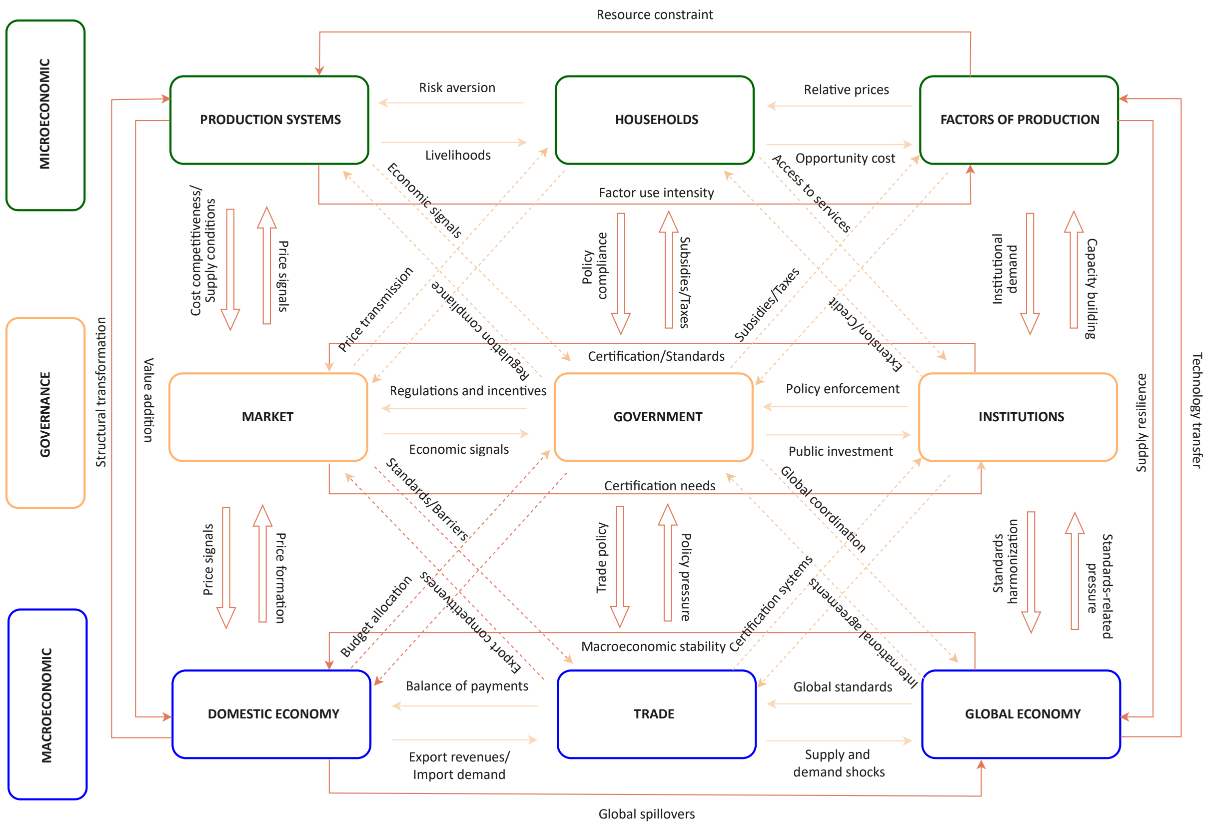
INTEGRATING THE MICROECONOMIC, GOVERNANCE, AND MACROECONOMIC DIMENSIONS OF LIVESTOCK ANTIMICROBIAL USE

AMU in livestock generates complex, interrelated effects that extend across production systems, governance structures, and macroeconomic performance. Understanding these connections is essential for designing interventions that sustain productivity while safeguarding long-term societal welfare. Figure 1 presents an integrated framework that shows how microeconomic factors, governance structures, and macroeconomic conditions interact to shape the incentives and constraints influencing AMU in the livestock sector.

At the core of this framework are microeconomic factors, including farm-level production systems, household decision-making and resource allocation. These shape how producers weigh the short-term benefits of AMU against the potential long-term risks of AMR and the costs of adopting alternative practices. Governance structures mediate farm-level decisions on AMU through market incentives, policy instruments and institutional arrangements. They establish regulatory, surveillance and service-delivery environments that can encourage responsible AMU or, conversely, reinforce unsustainable practices. Macroeconomic conditions capture the broader impacts of AMU on national output, employment, trade competitiveness and market integration. These outcomes depend on how well countries balance productivity, compliance with evolving international standards, and resilience to supply and market shocks.

FIGURE 1

ONE HEALTH ECONOMIC FRAMEWORK LINKING LIVESTOCK ANTIMICROBIAL USE TO THE WIDER ECONOMY FOR ASSESSING THE RETURN ON INVESTMENT



This figure illustrates the complex economy-wide interactions between microeconomic decisions, governance mechanisms, and macroeconomic outcomes that shape antimicrobial use and antimicrobial resistance in livestock systems. It highlights the flow of resources, risks and regulations across households, production systems, markets, governments and ecosystems.

Source: **Acosta, A., Roland-Holst, D., Nicolli, F., Tirkaso, W., Rocha, J.S. & Song, J.** 2025. A One Health framework to assess the economic returns on investment in livestock antimicrobial stewardship. *One Health*, 21: 101188. https://doi.org/10.1016/j.onehlt.2025.101188

MICROECONOMIC DRIVERS OF LIVESTOCK ANTIMICROBIAL USE

Microeconomic drivers, encompassing production factors, household decision-making, and production systems, shape AMU in ways that affect farm performance and contribute to the longer-term risk of AMR. Within a One Health perspective, these choices generate externalities that extend beyond the farm, influencing both animal health and public health, as well as wider economic outcomes. Recognizing these dynamics is central to assessing the potential ROI of antimicrobial stewardship, since the feasibility and effectiveness of alternatives to AMU depend on how producers allocate resources, manage risks and respond to market incentives.

AMU functions as an input that enhances the productivity of the classical factors of production, namely capital, labour and land, by sustaining animal health and stabilizing output under diverse production conditions. The extent to which producers rely on AMU depends on the availability and quality of these factors; this in turn shapes both the feasibility of adopting sustainable alternatives and the opportunity costs of substituting antimicrobials for other inputs.

Capital availability is a central determinant of AMU. Many non-pharmaceutical interventions, such as improved housing, climate control systems and advanced biosecurity, require significant upfront resources. When expected returns on such investments are uncertain, delayed, or perceived as lower than the immediate benefits of AMU, producers are less likely to commit to them. High interest rates, limited credit access, and underdeveloped lending systems, particularly in low- and middle-income countries, further constrain financing options (Lhermie, Gröhn and Raboisson, 2017). In such contexts, antimicrobials often substitute for capital-intensive upgrades. Large-scale producers with stronger capital bases can afford targeted veterinary care and infrastructure improvements, thereby reducing their reliance on AMU. By contrast, smaller-scale operations with limited financial resources frequently turn to antimicrobials as an inexpensive means to prevent disease and maintain yields (Akpan, Udoh and Nkanta, 2023).

Labour availability and quality also have a strong influence on AMU practices. Management practices such as improved housing, stricter hygiene controls, and continuous monitoring demand sustained labour inputs. Where labour is scarce or costly, producers may substitute antimicrobials as a less labour-intensive option. The presence of skilled workers is equally critical. Veterinarians and trained farm staff are essential for accurate diagnoses, proper dosing, and adherence to treatment protocols, all of which reduce misuse and help slow the development of resistance (Speksnijder *et al.*, 2015). In areas where veterinary services are limited or costly, farmers often self-medicate their livestock or rely on broad-spectrum antimicrobials, increasing the likelihood of inappropriate use. In high-risk environments without insurance coverage, risk-averse farmers may adopt prophylactic AMU as a form of risk management. Prescribing practices can also be distorted in contexts where veterinarians derive income from antimicrobial sales, since financial incentives may encourage higher usage (Raboisson *et al.*, 2020; Lhermie, Gröhn and Raboisson, 2017).

Land availability and the cost of housing infrastructure primarily influence AMU through their effects on animal density and disease pressure. High-density housing systems for cattle, pigs and poultry concentrate animals in limited spaces, which elevates exposure risks; these scenarios typically require stronger disease control measures, which often increases reliance on antimicrobials. By contrast, systems that allow for greater space or lower crowding reduce infection pressure and therefore the need for routine AMU. Where land is scarce or adequate infrastructure is prohibitively expensive, crowding intensifies and prophylactic use becomes more common as a preventive strategy. These dynamics are particularly relevant in rapidly intensifying production systems, where pressure to maximize output per area often leads to management trade-offs that favour reliance on antimicrobials. Conversely, where land and infrastructure resources permit lower stocking densities, investments in animal health can be more readily aligned with reduced AMU, as infection risks are naturally mitigated.

At the household level, AMU functions as a safety net input that helps protect livestock assets by reducing the risk of disease outbreaks that would otherwise undermine milk yields, weight gains, or egg production. Such stability is particularly important for smallholder families who depend on livestock not only for income but also for food, inputs (such as manure), and cultural practices (Acosta, Nicolli and Karfakis, 2021; Acosta, Nicolli and Tirkaso, 2024). Yet, overuse raises the risk of resistance (Shami *et al.*, 2024), potentially increasing production costs and inflating the prices of essential animal products.

Importantly, the relationship between antimicrobial use and resistance is non-linear and subject to threshold effects and time lags, which weakens the visibility of benefits from marginal reductions in use and complicates household-level decision-making. Because antimicrobials are relatively affordable and immediately effective, they are often the most accessible disease prevention tool for resource-constrained households, serving as a second-best but privately rational response to factors such as uninsured disease risk, limited access to credit and insurance, and weak access to veterinary services. In such settings, the expected short-run benefits of preventing livestock loss can outweigh poorly perceived or distant resistance risks, even when AMU is socially inefficient in the long run. However, this reliance can ultimately undermine livelihoods, including food security, and exacerbate vulnerability among certain groups (Adamie *et al.*, 2024).

The characteristics of individual farmers, such as their risk aversion, education level, and disease detection skills, can also strongly influence AMU practices by predisposing households to specific patterns of use (Farrell *et al.*, 2021). Beyond formal education, managerial capacity in areas such as record-keeping and disease monitoring affects a household's ability to adopt prudent AMU practices. Risk-averse households, particularly those close to subsistence, may adopt prophylactic AMU to avoid the economic shock of livestock loss even when such use is inefficient. In many low-income settings, limited access to vaccination programmes or veterinary services reinforces this behaviour and makes antimicrobials the default strategy (Fortané *et al.*, 2015). Information asymmetry further contributes to misuse: farmers often lack reliable guidance on dosages, timing, and withdrawal periods, leading to practices (such as partial treatments or routine prophylactic dosing) that accelerate resistance (Roope *et al.*, 2019).

Financial constraints add another layer of complexity. Households with limited access to savings or credit must weigh AMU against competing priorities such as food, education or health care. With preventive measures such as vaccination or improved housing often out of reach due to the higher upfront investments required and the length of time these measures take to deliver benefits, many households turn to antimicrobials for their ability to provide immediate protection at a relatively lower cost. These opportunity cost trade-offs explain why households may continue to prioritize AMU despite its long-term risks.

In sum, household AMU behaviour reflects a balance of affordability, access, risk management, and knowledge, all of which vary widely across contexts and shape the aggregate burden of AMR.

Production systems have a strong effect on AMU patterns. High-density operations create greater disease pressure, leading producers to rely more heavily on prophylactic or growth-promoting antimicrobials to sustain productivity. Since the mid-twentieth century, such practices have enabled the rapid intensification of livestock production, allowing industrial-scale operations to meet the rising demand for meat, dairy and eggs at relatively low unit costs (Kirchhelle, 2018). Yet, these same conditions amplify the risk of overuse, reinforcing a cycle in which antimicrobials are increasingly used as a form of insurance against disease losses (Van Boeckel *et al.*, 2015). Where easy access to antimicrobials combines with weak regulatory oversight, this reliance deepens, and AMU shifts from a productivity-enhancing input toward a source of structural vulnerability, as rising resistance progressively erodes the effectiveness of the very tool used to stabilize production.

The economic advantages of intensification can obscure the opportunity costs of overreliance on antimicrobials. Investments that could strengthen resilience (for example, vaccination, improved housing, or biosecurity) are often diverted toward preventive or metaphylactic antimicrobial regimens (Van Boeckel *et al.*, 2019). Market competition also incentivizes cost-cutting strategies, including the continued use of growth promoters despite resistance concerns. At the same time, global shifts in consumer preferences toward antibiotic-free or sustainably produced animal products are placing new pressures on producers, particularly those engaged in export markets, to adjust their AMU practices. Smaller-scale farms with limited margins often resort to cheaper antimicrobials, while larger farms with greater resources may adopt more selective usage (Ruckert *et al.*, 2020). Fluctuations in antimicrobial prices or supply can further destabilize decisions, creating difficult trade-offs in animal health management.

Over time, this reliance on pharmaceutical interventions enhances short-term efficiency but also raises the long-term risk of AMR in both animal and human populations (Laxminarayan *et al.*, 2016; O'Neill, 2016). The very factors that drive productivity gains, such as high stocking density, rapid growth rates, and reduced mortality, simultaneously increase infection risk and expand the demand for AMU. Production system choices are therefore shaped not only by immediate efficiency goals but also by regulation, market incentives and consumer preferences, all of which determine the balance between short-term gains and long-term risks.

GOVERNANCE DIMENSIONS OF ANTIMICROBIAL STEWARDSHIP

Governance structures play a central role in shaping the patterns of AMU in livestock, setting the "rules of the game" through market incentives, regulatory frameworks and institutional arrangements. The strength and quality of governance ultimately influence the ROI of antimicrobial stewardship, as they shape whether preventive and sustainable practices appear more attractive than routine antimicrobial reliance. Moreover, AMU decisions themselves generate feedback loops into governance by creating new market demands, regulatory pressures and institutional mandates. This section examines how markets, governments and institutions interact to influence AMU and shape the economic viability of stewardship strategies.

Market forces exert a profound influence on how antimicrobials are accessed, prescribed and used, shaping both on-farm decisions and broader supply-chain dynamics. In many livestock systems, vertically integrated operations and contract farming arrangements establish de facto standards for veterinary protocols, often institutionalizing the routine use of medicated feed to maintain consistent outputs (MacDonald, 2008; Maron, Smith, and Nachman, 2013). Larger, better-capitalized firms are typically able to invest in diagnostics, veterinary oversight, and data-driven usage protocols, whereas smaller producers with narrower profit margins frequently rely on prophylactic antimicrobials as a low-cost buffer against disease risk. These structural asymmetries create fragmented usage patterns within the same supply chain, challenging efforts to coordinate or standardize responsible AMU practices (Raboisson *et al.*, 2020).

The pricing of antimicrobials, as shaped by patent protections, generic drug markets and regulatory enforcement, further determines usage decisions. Where antimicrobials are inexpensive or widely available without oversight, farmers may favour prophylactic or metaphylactic use, which often appears as a cost-effective substitute for labour- or capital-intensive interventions (Anomaly, 2009). In some contexts, government subsidies or weak enforcement of prescription-only rules further lower prices, reinforcing habitual AMU and reducing incentives for preventive health measures. Low prices can also encourage overuse and the entry of substandard or counterfeit products, exacerbating the risk of treatment failures and resistance (Laxminarayan *et al.*, 2016; Mendelson *et al.*, 2016).

Access is also mediated by supply chain logistics. In areas with dense veterinary networks or informal drug markets, antimicrobials are more readily available and more frequently used. Conversely, when antimicrobial prices rise due to market forces or policy measures such as taxes or user fees, producers may shift toward alternatives such as biosecurity, vaccinations or improved husbandry, re-evaluating the cost–benefit calculus of routine AMU (Morgan, Moran and Van Boeckel, 2023). Supply disruptions from trade restrictions, production issues or regulatory changes can also create shortages, pushing producers toward lower-quality or unregulated alternatives and complicating disease management.

Beyond farm-level decisions, downstream actors are increasingly defining the norms surrounding AMU. Retailers, food processors, and brand owners are responding to consumer demand for “antibiotic-free” or sustainably produced animal source foods (Rochford *et al.*, 2018). These private standards often require traceability systems and third-party certifications that restrict routine AMU. Producers unable to comply risk exclusion from high-value markets, highlighting how private governance can simultaneously reward stewardship and penalize unsustainable practices. Such standards may also disadvantage smallholders who lack access to certification systems, traceability infrastructure, or finance, thereby reinforcing dual markets and widening inequalities within livestock value chains. Yet strong global demand for low-cost protein sustains incentives for intensive, high-volume production reliant on antimicrobials. Competitive pressures, particularly in export-oriented or low-margin markets, can therefore reinforce dependence on AMU even as regulatory and consumer expectations push toward reduction.

Thus, market dynamics are inherently dual in nature. On one side, they can accelerate responsible AMU adoption through premiums, certifications and reputational benefits; on the other, they perpetuate cost-minimization strategies that amplify AMR risks. Given the volatility of trade policies, consumer preferences and technological innovations, governance strategies must remain adaptive in order to realign incentives, internalize social costs, and enhance the long-term ROI of responsible AMU (Thornton, 2010; Reardon *et al.*, 2019).

Public-sector interventions play an indispensable role in steering AMU toward outcomes more closely aligned with societal and One Health objectives. Excessive or improper use of antimicrobials in livestock exemplifies a classic negative economic externality problem, in which the private benefits accruing to producers generate collective costs, including the spread of resistant pathogens and escalating health care costs (Raboisson *et al.*, 2020; Roope *et al.*, 2019). Because standard market forces do not internalize these widespread risks, government action is essential to correct market failures, safeguard public health and preserve the long-term efficacy of existing antimicrobial options.

Regulatory frameworks range from stringent requirements, such as mandated veterinary prescriptions and restricted over-the-counter sales, to more holistic strategies targeting per capita antimicrobial consumption in the livestock sector (Van Boeckel *et al.*, 2017; Birgand *et al.*, 2018). Such command-and-control policies can curtail some of the most harmful usage practices, but they often demand robust enforcement capacity and political resolve. Their effectiveness depends on well-resourced regulatory institutions capable of monitoring compliance, imposing penalties, and coordinating across sectors. Compliance costs, however, may weigh heavily on smaller-scale producers, necessitating parallel investments in extension services, veterinary infrastructure, and access to affordable alternatives such as vaccines or biosecurity measures (Padiyara, Inoue and Sprenger, 2018).

Economic instruments offer another policy lever to influence producers' cost–benefit calculations. Taxes on antimicrobials, for example, can discourage unwarranted use while generating revenue to support surveillance systems, research into novel treatments, and programmes that promote responsible AMU (Morgan, Moran and Van Boeckel, 2023). Subsidies and targeted grants can lower the barriers to adopting sustainable disease management practices such as vaccination, improved housing, or precision livestock farming technologies. These approaches require careful calibration to avoid placing disproportionate burdens on lower-income producers, but when well designed, they can accelerate the shift away from prophylactic and growth-promoting AMU (Padiyara, Inoue and Sprenger, 2018). A more ambitious proposal envisions cap-and-trade systems modelled on carbon markets, in which tradable permits directly limit total AMU and align sectoral practices with broader public health goals (Roope *et al.*, 2019). Though largely theoretical, such mechanisms reflect a growing consensus that market-based incentives can complement direct regulation in mitigating AMR.

Governments also regulate AMU through import controls and sanitary and phytosanitary standards, which align domestic practices with trade obligations. The growing public concern over antimicrobial residues and AMR has driven stricter regulations, while effective enforcement relies on robust customs procedures, testing, and interagency data sharing. In addition to rules and financial instruments, governments increasingly recognize the need for cross-ministerial and multilevel coordination, given that AMU intersects with public health, agriculture, trade, and environmental conservation. National action plans, often aligned with the Global Action Plan on AMR spearheaded by FAO, the World Health Organization (WHO), the World Organisation for Animal Health (WOAH) and the United Nations Environment Programme (UNEP), exemplify integrated governance. These strategies typically encompass improved surveillance, enhanced diagnostics, public awareness campaigns, and intersectoral training programmes, showing how government-led coordination can amplify the benefits of responsible AMU.

Ultimately, effective government interventions strike a delicate balance; they must safeguard public health and environmental sustainability without compromising the livelihoods of producers in low-income regions. By acknowledging that the misuse or overuse of antimicrobials has far-reaching consequences, including impacts on macroeconomic performance, trade competitiveness, and social well-being, policymakers can design targeted and evidence-based measures that optimize resource allocation while mitigating the long-term risks posed by AMR. Sustained international cooperation, including technical and financial support for low-income countries (LICs), is essential to ensuring the equitable and effective enforcement of AMU regulations globally.

Institutions, including veterinary authorities, financial systems and international organizations, form the structural backbone of AMU governance, ensuring that policy measures are both feasible and sustainable. National-level veterinary services are central to this institutional architecture. For instance, strong veterinary services provide accurate diagnoses, treatment guidance and reliable prescription monitoring (Birgand *et al.*, 2018). In contrast, weak veterinary infrastructures, whether due to funding shortages, uneven geographic coverage or inadequate training, create conditions for indiscriminate sales, self-medication, and substandard drug use, all of which heighten AMR risks (Padiyara, Inoue and Sprenger, 2018). Robust surveillance systems are essential for tracking AMU and meeting international reporting standards, while institutional gaps in monitoring can hinder market access and undermine antimicrobial stewardship.

Institutional efficacy also hinges on the quality of AMU and AMR surveillance systems. Timely, high-resolution, and spatially disaggregated data can alert policymakers to emerging hotspots of resistance, enabling a rapid response and more precise interventions (Babo Martins *et al.*, 2024). Inadequate or fragmented surveillance, however, not only jeopardizes public health but can undermine trade relations if international partners question the credibility of a country's monitoring and reporting regimes (Rochford *et al.*, 2018). Thus, investments in data infrastructure and coordination among governmental, academic, and private stakeholders become critical pillars of AMR mitigation strategies.

Financial institutions further shape AMU patterns by influencing producers' access to credit, insurance and other capital resources. In the absence of adequate financing, small-scale farmers may lack the means to transition toward higher-welfare animal housing, vaccination, and preventive management strategies, and may instead resort to routine antimicrobial usage (Moran, 2019). Institutions also serve as delivery channels for market-based incentives, including subsidies for vaccination or biosecurity improvements, as well as for insurance schemes that reduce the financial risks of adopting lower-AMU production systems based on preventive animal health and management practices. Appropriately designed credit programmes or risk-sharing mechanisms that incentivize biosecurity investments can lower the perceived costs of reduced AMU, making responsible practices more attractive.

International organizations such as FAO, WHO, WOAH and UNEP provide overarching guidelines, support capacity-building efforts and promote best practices across borders. These institutions further facilitate policy harmonization, create platforms for data sharing, and offer technical support to countries with limited resources. Yet their capacity to shape AMU outcomes depends on national commitments and the extent to which international guidelines are incorporated into domestic legislation and practice. Beyond technical guidance, institutional effectiveness depends on governments' ability to enforce regulations, conduct inspections, and apply penalties for non-compliance, functions that are often under-resourced in many low-income settings. Structural disparities in governance capacity, regulatory enforcement, and economic development often result in uneven implementation, perpetuating opportunities for high AMU and associated AMR risks.

Moreover, institutions are pivotal in shaping educational and awareness-raising efforts among producers and consumers. Targeted training programmes for veterinarians and extension agents, coupled with community-level outreach, can transform AMU practices by clarifying topics such as dosage, withdrawal periods, and the importance of monitoring. Over time, such efforts not only consolidate the scientific foundation of livestock health management but also enhance societal awareness of the externalities associated with AMR. This, in turn, can alter consumer behaviour, driving demand for products adhering to stricter AMU standards and reinforcing market incentives for prudent usage. In essence, well-functioning institutions enable a self-reinforcing dynamic: informed stakeholders adopt responsible AMU, which safeguards animal and public health, stabilizes markets and strengthens food security at both national and global scales. Enhancing institutional capacity, particularly in low-resource settings, is essential to implementing global AMU governance practices that are effective and fair to all.

MACROECONOMIC FORCES SHAPING ANTIMICROBIAL USE

Macroeconomic forces influence patterns of AMU in livestock, shaping both the incentives that encourage reliance on antimicrobials and the potential ROI. Factors such as national growth strategies, fiscal pressures, trade competitiveness, and global demand for animal protein interact with on-farm decisions, reinforcing or undermining efforts to reduce AMU. Assessing AMU through a macroeconomic lens therefore helps to identify the wider spillover effects of stewardship, highlighting how domestic policies, trade regimes, and global governance shape the balance between short-term productivity gains and long-term sustainable economic outcomes.

Livestock production is a major driver of agricultural gross domestic product in many LICs and lower-middle-income countries (LMICs), contributing substantially to national incomes and employment (Acosta, Nicolli and Tirkaso, 2024). Beyond farm-gate revenues, the sector also sustains a diverse set of upstream industries, including feed manufacturing and veterinary pharmaceuticals, as well as downstream activities, including processing, transport and retail. These linkages generate multiplier effects that extend throughout the wider economy (Herrero *et al.*, 2013). Compared to most crop-based systems, livestock value chains tend to generate greater value addition through processing, branding, and cold chain logistics, thereby amplifying spillover effects across the economy (FAO, 2018).

Within this system, AMU directly shapes the domestic ROI in livestock production, including private profitability, fiscal outcomes, and wider social welfare effects related to health, food security and economic stability. In the short term, widespread AMU can enhance productivity and mitigate production risks, supporting output, jobs and fiscal revenues. However, this dependence on antimicrobials also generates structural vulnerabilities. In contexts where antimicrobial prices rise, regulatory environments tighten, or supply chains for veterinary drugs and feed are disrupted, production costs can rise. This may reduce competitiveness and exacerbate volatility in food prices. Such dynamics directly affect consumer purchasing power and inflation, with broader implications for overall economic stability. In net food-importing countries, AMU-related trade restrictions can further affect food availability and prices, placing pressure on both households and government budgets.

Domestic AMU patterns also influence fiscal sustainability and consumer behaviour. Reduced livestock productivity from rising AMR may shrink the tax base, while public spending on health care or subsidies for alternative technologies adds to the fiscal burden. Governments increasingly deploy market-based instruments, such as taxes on non-therapeutic AMU or subsidies for AMR-reducing technologies, to realign producer incentives with public health objectives. At the same time, consumer concerns over AMR and antimicrobial residues in animal source foods are shifting demand toward "antibiotic-free" products (Xu *et al.*, 2023). This creates both pressure and opportunity for domestic producers; those investing in certification and transparent supply chains stand to enhance credibility and competitiveness, while others risk losing market share.

Livestock-producing economies operate in a deeply interconnected global trade system, where international competitiveness is frequently determined by cost efficiency and compliance with evolving standards. In the short term, AMU supports cost-effective production by reducing disease risks and sustaining high volumes, a clear advantage for exporters competing in price-sensitive markets (Rochford *et al.*, 2018). This cost orientation is reinforced by the absence of binding international rules on AMU, leaving enforcement largely at the national level. As a result, producers may prioritize short-term returns through intensive AMU strategies, even if such practices raise longer-term risks.

Over the longer term, however, shifting international standards and stricter residue limits, along with growing regulatory scrutiny, are increasingly shaping access to global markets. Non-compliance with residue thresholds can trigger import bans, heightened inspections, and reputational costs, undermining exporters' access to high-value markets (FAO and WHO, 2023). In contrast, countries that adopt stronger AMU regulations and certification systems can access premium markets at higher price points, although compliance raises production costs and may disadvantage small-scale or resource-constrained producers.

Consumer preferences in importing countries add another layer of complexity. Rising demand for responsibly produced, certified, or "antibiotic-free" products creates expanding opportunities for exporters investing in prudent AMU practices (Xu *et al.*, 2023; Schell *et al.*, 2023). At the same time, persistent global demand for low-cost animal protein sustains incentives for high-volume production reliant on AMU (Anomaly, 2009). These divergent signals mean that AMU choices shape not only immediate competitiveness but also longer-term access to markets.

From a ROI perspective, reliance on AMU delivers short-term efficiency gains and export revenues but exposes producers to mounting risks as standards tighten and consumer scrutiny grows. Countries and producers that invest early in compliance, certification and alternative health management strategies may face higher costs initially, yet they secure resilience, price premiums and stable market access over time. Conversely, those that delay adaptation risk exclusion from premium markets, increasing their vulnerability to trade disruptions and to long-term erosion of their export competitiveness.

The global drive to meet rising demand for animal source foods, particularly in developing regions, places sustained pressure on AMU to secure high-yield and disease-free livestock production. In the short term, AMU enables producers to maintain output and contain costs, which is critical for both food security and economic development. However, reliance on this strategy creates systemic vulnerabilities in the global food system. As leading exporters reduce the use of growth-promoting antimicrobials or tighten residue limits, these supply-side shifts can raise international prices, affecting affordability and altering welfare distribution among nations. Countries with historically high AMU dependence may find it difficult to remain competitive in global markets, risking disruptions to domestic livelihoods and food availability. Moreover, policy changes in one region, such as AMU bans or stricter maximum residue limits, can generate ripple effects throughout global supply chains, reshaping trade flows and price dynamics, with food-insecure, import-dependent countries facing the greatest risks (Rochford *et al.*, 2018; FAO and WHO, 2023).

Over the long term, the unchecked misuse of AMU and the consequent rise of AMR could pose far greater costs for the global economy. Once resistance becomes widespread, higher AMU no longer guarantees effective disease control, thereby undermining livestock productivity, compromising food supply stability, and eroding farmer resilience. The broader economic burden of AMR, including rising health care expenditures, productivity losses and reduced agricultural efficiency, places mounting strain on public finances and risks widening the disparities between high-, middle-, and low-income countries (Roope *et al.*, 2019; WHO, 2015).

These challenges are compounded by inequality. High-income countries (HICs) can often absorb compliance costs and invest in alternative technologies, maintaining access to premium markets. By contrast, LICs and LMICs may struggle to implement strict measures, thereby risking exclusion from high-value trade and facing sharper welfare losses from higher food prices (DANMAP, 2020). At the same time, the need to protect immediate herd health through metaphylaxis and prophylaxis must be weighed against the longer-term erosion of antimicrobial effectiveness. Because modern economies are tightly interconnected, regulatory changes in one country can trigger economic repercussions elsewhere, reinforcing the urgency of coordinated global action. Harmonized customs policies, aligned trade agreements and targeted international support are therefore essential to prevent market fragmentation and to ensure equitable access to safe and affordable animal source foods.

POLICY INSIGHTS

This chapter offers a comprehensive economic narrative on the factors that shape AMU in livestock production systems. The central policy insight is that antimicrobial stewardship cannot be treated as a standalone technical adjustment at the farm level. The returns to stewardship are determined by the interactions among actors across farms, value chains, markets and health systems, and therefore depend on coordinated, system-wide approaches rather than isolated measures (Acosta *et al.*, 2025a).

In many contexts, AMU reflects a rational response to structural constraints, including production risk, capital scarcity, and limited access to animal health services, often reinforced by governance and market failures. When these constraints persist, antimicrobials become a privately efficient but socially sub-optimal substitute for investments in animal health infrastructure, biosecurity and institutional capacity. This dynamic locks livestock systems into a low-resilience, high-AMR trajectory with spillovers across food value chains, trade, and health systems.

The analysis highlights the need for an integrated framework capable of addressing these interlinked constraints simultaneously. Policies that focus narrowly on restricting AMU, such as bans, taxes or prescription requirements, often generate short-term productivity losses, compliance costs and distributional pressures, particularly for smallholders and resource-constrained producers. A coordinated mix of interventions is more likely to align private incentives with collective welfare, generating complementarities across micro-level decision-making and macro-level economic dynamics. When policies act coherently across levels, they can activate feedback loops that amplify the returns to antimicrobial stewardship and reduce the risk of unintended consequences.

A One Health economic framework demonstrates that antimicrobial stewardship delivers sustained and system-wide positive returns only when microeconomic incentives, governance capacity, and macroeconomic objectives are addressed jointly. Investments in veterinary services, surveillance, extension, and preventive animal health reduce disease risk at source, while coherent regulation, market standards and institutional coordination convert these investments into credible incentives and compliance pathways. At the macroeconomic level, such integration protects productivity, stabilizes livestock value chains and preserves competitiveness under increasingly stringent international standards, contributing to a sustainable livestock transformation.

The policy implication is that maximizing the ROI in antimicrobial stewardship requires integrated One Health policy packages that reduce short-term adjustment costs while internalizing long-term societal damages. Framing AMU and AMR stewardship within economy-wide planning and investment frameworks, and aligning it with trade, development, and agrifood system transformation strategies, allows countries to manage the trade-off between short-run productivity and long-run resilience, transforming stewardship from a compliance obligation into a strategic investment in food security, economic stability and public health.

2. The future of antimicrobial use in livestock

Global momentum to reduce antimicrobial use (AMU) in livestock has intensified in recent years, driven by growing recognition of the sector's critical role in the emergence and spread of antimicrobial resistance (AMR). A key milestone was the adoption of the Muscat Manifesto in 2022, through which 47 countries committed to reducing AMU in agriculture by 30–50 percent by 2030 (FAO *et al.*, 2022). This declaration marked a turning point, positioning AMU reduction as a global priority aligned with sustainable development and One Health objectives.[2]

This political momentum was further reinforced at the Seventy-ninth United Nations General Assembly in September 2024, where a dedicated high-level meeting on AMR resulted in a political declaration explicitly calling for substantial reductions in AMU across agrifood systems by 2030 (UNGA, 2024). The declaration emphasized the urgency of coordinated global action, particularly in countries where regulatory frameworks, veterinary services and AMU monitoring remain limited.

Building on these commitments, the Fourth Global High-Level Ministerial Conference on AMR, held in Jeddah, Saudi Arabia, in November 2024, advanced the implementation agenda. Ministers from across regions endorsed the Jeddah Commitments, which outline practical steps to translate political pledges into action. These include improving AMU surveillance, expanding antimicrobial stewardship and strengthening multisectoral coordination under a One Health approach (Fourth Global High-Level Ministerial Conference on AMR, 2024).

Together, these international commitments reflect a growing consensus that continued reliance on high levels of antimicrobials in livestock production poses mounting risks, not only to animal health and agricultural productivity, but also to human health and the long-term efficacy of life-saving medicines. Achieving these targets, however, will be particularly challenging in regions where rapid population growth and rising incomes are driving increased production and consumption of animal source foods.

ADVANCING METHODOLOGIES FOR ESTIMATING ANTIMICROBIAL USE INTENSITY

Accurate and transparent estimates of current and future AMU in livestock are foundational for any evidence-based strategy for reducing reliance on antimicrobials. These estimates must capture not only the total quantity of antimicrobials but also how intensively they are used, given the significant differences across species, production systems and geographic regions. Policymakers need reliable data to design proportionate and feasible interventions. Without clear insights into where and how AMU is growing, any policy response risks being misdirected or insufficient to confront escalating challenges.

Global assessments of AMU in livestock have increasingly relied on metrics-based approaches that combine data on total antimicrobial use quantity (AMUQ) with estimates of livestock biomass (LBIO) to generate an intensity ratio, often referred to as antimicrobial use intensity (AMUI). However, much of this work has relied on the population correction unit (PCU) method, which calculates LBIO using average slaughter weights and simplified counts of the animal population (Van Boeckel *et al.*, 2019; Góchez *et al.*, 2019). While the PCU approach helped establish early benchmarks for comparing AMU across contexts, it has also attracted criticism for failing to capture variations in live weights, production cycles, and the actual time animals remain at risk of disease (and thus potentially require antimicrobial treatment).

Several studies have shown that the PCU denominator may overestimate livestock biomass, which in turn translates into lower-than-actual estimates of AMUI (measured, for instance, in milligrams of active ingredients per kilogram of LBIO). Such inaccuracies are problematic, as they can mask the true scale of antimicrobial reliance and limit the ability of stakeholders to identify which species or production systems would benefit most from targeted interventions.

[2] This chapter synthesizes findings from the peer-reviewed study **Acosta, A., Tirkaso, W., Nicolli, F., Van Boeckel, T.P., Cinardi, G. & Song, J.** 2025. The future of antibiotic use in livestock. *Nature Communications*, 16(1): 2469. https://doi.org/10.1038/s41467-025-56825-7

These methodological issues also affect broader economic assessments, given that LBIO often informs calculations related to livestock productivity and market value (Bulut and Ivanek, 2022; Radke, 2017; Li, Mayberry and Rushton, 2024).

In light of the limitations of PCU, Acosta *et al.* (2025b) developed a new approach – the livestock biomass conversion (LBC) method – to generate more accurate projections of future AMU. The LBC method refines the denominator by incorporating detailed species-specific live weights, thereby recognizing differences in commodity groups, production systems and production cycles. The method can also capture variation at the cohort level, allowing for finer distinctions in how animals grow and how long they remain on farms. This detail is particularly important for systems in transition, where shifts in feeding regimes, genetics, or management practices can alter the dynamics of how animals gain weight and their overall susceptibility to disease.

ESTABLISHING A 2019 BASELINE

Any forward-looking study benefits from a clearly defined baseline to anchor future projections. The year 2019 was selected as the baseline year for the projections in this chapter because it offers the most recent, comprehensive and harmonized global data on livestock production and AMU. To establish the baseline, two contrasting methodologies were applied to estimate global AMUQ and AMUI: the PCU method and the LBC method.

The PCU approach estimates LBIO by multiplying the number of animals by an assumed live weight at the time of treatment, typically based on average slaughter weights. In contrast, the LBC method provides a more detailed calculation of LBIO by incorporating species-specific live weights, production characteristics and cohort dynamics.

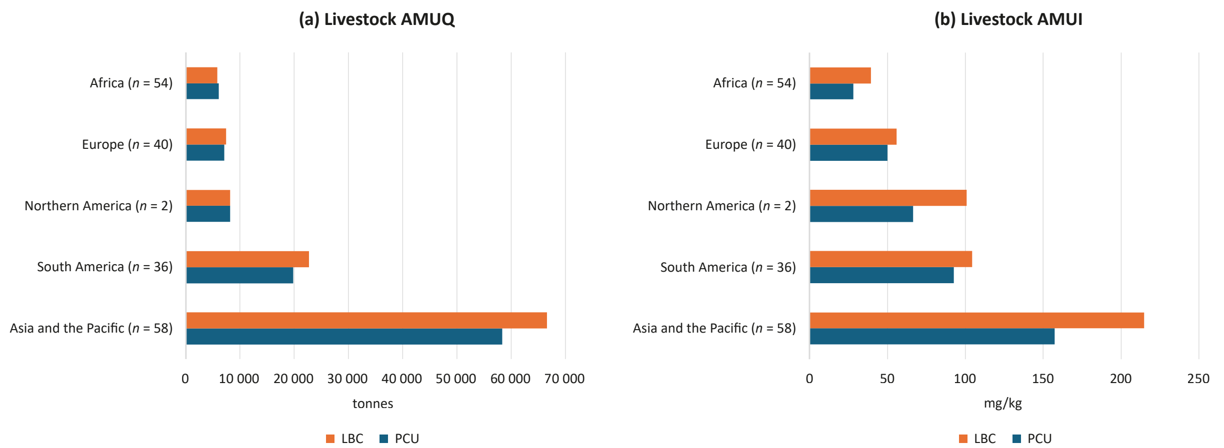
Applying these two methods to the 2019 data yields different results (see **Figure 2**). Under the LBC method, global AMUQ was estimated at approximately 110 777 tonnes, compared to 99 414 tonnes using the PCU method. The difference (of about 11 000 tonnes) highlights how methodological choices in estimating LBIO directly influence AMU assessments.

The divergence becomes even more pronounced when examining AMUI, calculated as the ratio of AMUQ to LBIO. Because the PCU method tends to overestimate biomass, it results in systematically lower AMUI figures. Under the LBC method, AMUI was found to be substantially higher compared to PCU-based estimates: namely, it was approximately 52 percent higher in Northern America, 40 percent higher in Africa, 36 percent higher in Asia and the Pacific, 13 percent higher in South America, and 12 percent higher in Europe.

These discrepancies highlight an important issue for policymakers, as reliance on PCU-derived statistics

FIGURE 2

LIVESTOCK ANTIMICROBIAL USE QUANTITY AND INTENSITY IN 2019 BY REGION USING THE LIVESTOCK BIOMASS CONVERSION AND POPULATION CORRECTION UNIT METHODS



This figure presents regional livestock antimicrobial use quantity (AMUQ) (in tonnes) and antimicrobial use intensity (AMUI) (in milligrams per kilogram, mg/kg) for 2019, estimated using two methodologies: livestock biomass conversion (LBC) and population correction unit (PCU). Panel (a) depicts AMUQ levels across regions, while panel (b) illustrates AMUI values. The orange bars represent LBC-based estimates; the blue bars represent PCU-based estimates. The sample size for each region (i.e. the number of countries included) is indicated by *n*.

Source: **Acosta, A., Tirkaso, W., Nicolli, F., Van Boeckel, T.P., Cinardi, G. & Song, J.** 2025. The future of antibiotic use in livestock. *Nature Communications*, 16(1): 2469. https://doi.org/10.1038/s41467-025-56825-7

may lead to underestimating the intensity of AMU in livestock production. A more accurate depiction, such as that provided by the LBC method, is vital for designing effective interventions, monitoring progress and supporting antimicrobial stewardship efforts.

GLOBAL ANTIMICROBIAL USE PROJECTIONS UNDER A BUSINESS-AS-USUAL PATHWAY

Moving beyond the 2019 baseline, a business-as-usual (BAU) scenario was developed to illustrate how global AMUQ might evolve if current trends in livestock growth and AMUI are maintained. The BAU scenario draws upon time-series econometric models that take into account historical consumption patterns, livestock production data, and macroeconomic factors that shape meat, dairy and egg demand.

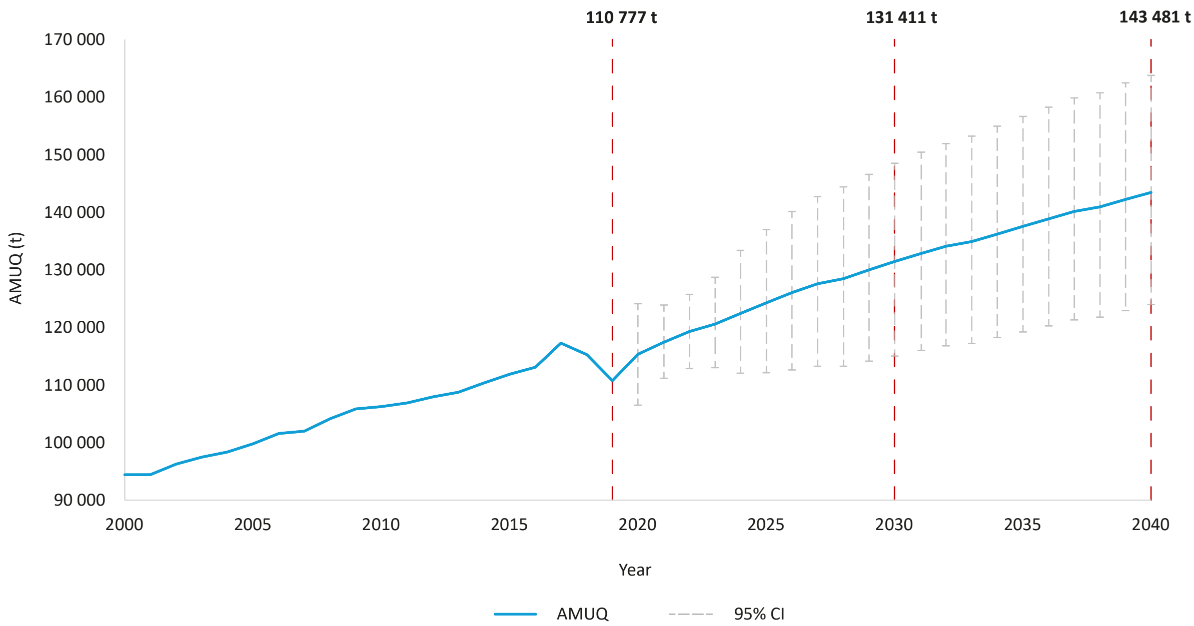
Under BAU, global AMUQ could reach roughly 131 411 tonnes by 2030 and 143 481 tonnes by 2040 (see **Figure 3**). These figures represent increases of 18.6 percent and 29.5 percent, respectively, from the LBC-based baseline of 2019. Though substantial, these increases reflect ongoing trends in intensification, population growth, and dietary change, especially in emerging markets where per capita consumption of animal source foods is rising. The analysis also captures an observed dip around 2018–2019, linked to the African swine fever outbreak that significantly reduced pig populations, particularly in Asia (Normile, 2019).

REGIONAL DYNAMICS

Both livestock production and AMU patterns vary widely across regions due to differences in climate, economic development, cultural preferences and regulatory frameworks (see **Figure 4**). By 2040, Asia and the Pacific are projected to remain the largest global users of livestock antimicrobials, accounting for nearly 65 percent of total use (approximately 92 687 tonnes). This prominence aligns with the region's fast-growing livestock sector and the higher demand for poultry, pork and, increasingly, dairy products. South America is expected to contribute around 19 percent of global AMUQ by 2040 (approximately 27 197 tonnes).

In contrast, Africa's share of global AMUQ is projected at approximately 5.7 percent by 2040 (approximately 8 173 tonnes), yet its AMU growth

FIGURE 3
GLOBAL LIVESTOCK ANTIMICROBIAL USE QUANTITY PROJECTIONS FOR 2030 AND 2040 UNDER A BUSINESS-AS-USUAL SCENARIO



This figure presents projected global antimicrobial use quantity (AMUQ) in tonnes (t) for livestock under a business-as-usual scenario from 2000 to 2040. The solid blue line represents AMUQ data dating back to 2000 as well as the projected AMUQ trend, while the dashed lines and error bars indicate the 95 percent confidence interval (CI) over the projection period. The dashed red lines and their accompanying figures represent, from left to right: baseline AMUQ in 2019; the projection for 2030; and the projection for 2040.

Source: **Acosta, A., Tirkaso, W., Nicolli, F., Van Boeckel, T.P., Cinardi, G. & Song, J.** 2025. The future of antibiotic use in livestock. *Nature Communications*, 16(1): 2469. https://doi.org/10.1038/s41467-025-56825-7

rate is among the highest in relative terms. Between 2019 and 2040, Africa is expected to see a 40.8 percent rise in AMUQ, driven by population surges and evolving food habits in many countries. Nonetheless, the region's lower absolute production base means that, in global terms, it still accounts for a smaller share of total AMUQ than Asia and the Pacific or South America.

Northern America, representing around 5.5 percent of global AMUQ by 2040 (approximately 7 922 tonnes), shows a slight decline in antimicrobial usage, reflecting stricter regulatory frameworks and a gradual shift toward more stringent on-farm management practices that reduce prophylactic antibiotic usage. Europe, which accounts for 5.2 percent (approximately 7 501 tonnes), is expected to remain relatively stable, reflecting similar regulatory pressures and the impacts of ongoing reforms.

These findings reinforce how policy contexts, market orientation, and investments in disease control measures interact to shape overall AMU trajectories. However, it is important to underscore that those regions with the highest AMUQ growth are also those anticipated to play a major role in the global supply of animal source foods, driven by increasing global food demand, by 2040.

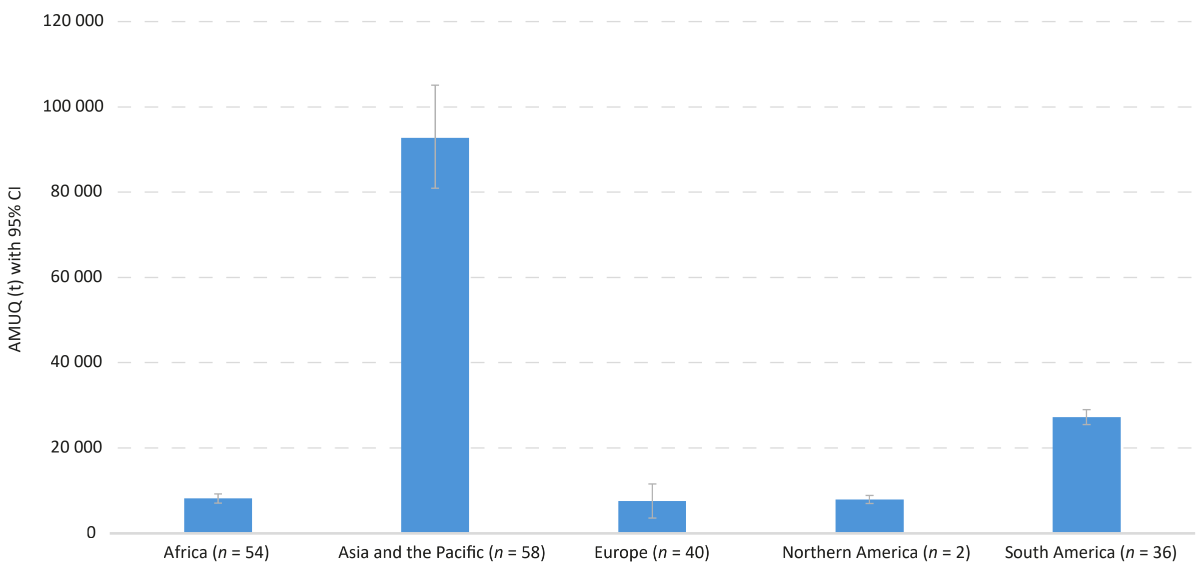
EXPLORING ALTERNATIVE PATHWAYS

We explore potential trajectories for livestock AMUQ by 2040 under eight different scenarios, as outlined in Table 1. These scenarios range from a BAU trajectory, where both LBIO and AMUI remain constant, to various combinations of upper and lower LBIO bounds with AMUI reductions of 30 percent or 50 percent.

Figure 5 reports percentage deviations from the BAU projection in 2040 across the eight scenarios. Scenario S1 (upper-bound LBIO with unchanged AMUI) yields an estimated +14 percent deviation, highlighting the risk of higher AMUQ when livestock numbers expand without reductions in AMUI. In contrast, Scenario S2 (lower-bound LBIO with unchanged AMUI) produces only a -14 percent deviation below BAU, suggesting that changes in livestock numbers alone have a limited effect on AMUQ. Scenarios that reduce AMUI by 30 percent (S3–S5) show that even moderate-intensity reductions can more than offset increases relative to BAU, particularly when combined with lower LBIO. The largest negative deviations occur under 50 percent reductions in AMUI (S6–S8). Scenario S8, combining lower LBIO with a 50 percent reduction in AMUI, delivers the greatest effect, with AMUQ at around 57 percent below the BAU projection for 2040.

FIGURE 4

PROJECTED REGIONAL LIVESTOCK ANTIMICROBIAL USE QUANTITY



This figure presents the projected antimicrobial use quantity (AMUQ) in livestock across five global regions by 2040, in tonnes (t). The projections include 95 percent confidence intervals (CIs), represented by the error bars, to indicate the level of uncertainty in each projection. The sample size for each region (i.e. the number of countries included) is indicated by *n*.

Source: **Acosta, A., Tirkaso, W., Nicolli, F., Van Boeckel, T.P., Cinardi, G. & Song, J.** 2025. The future of antibiotic use in livestock. *Nature Communications*, 16(1): 2469. https://doi.org/10.1038/s41467-025-56825-7

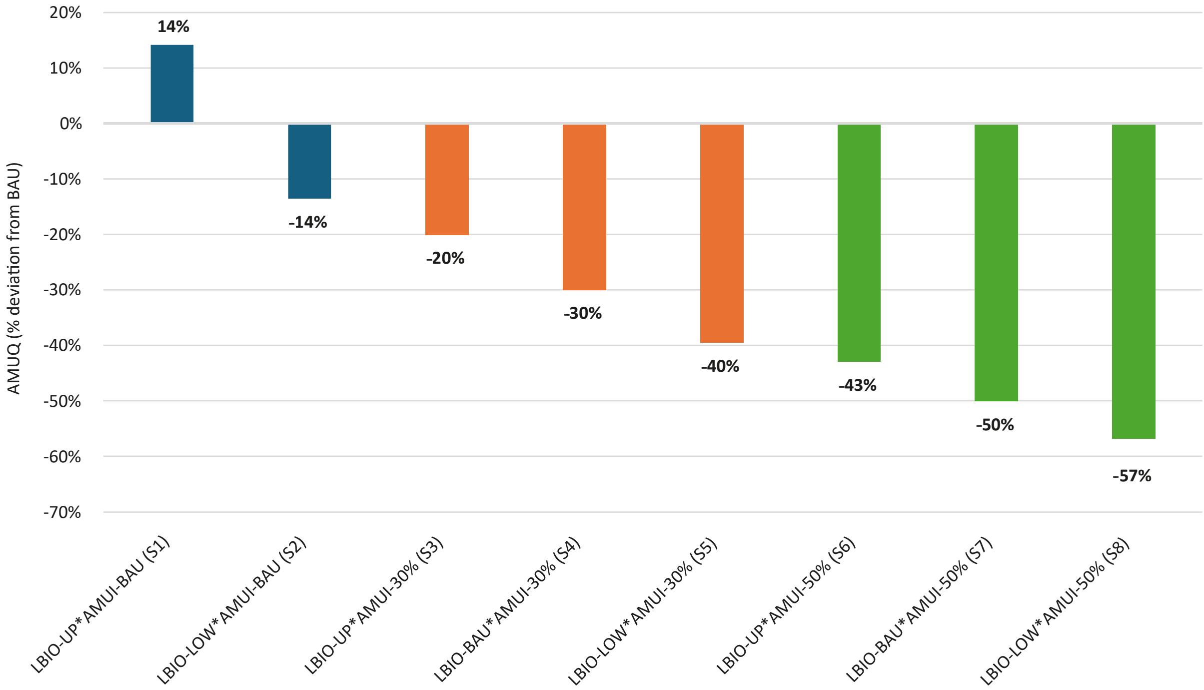
TABLE 1
LIVESTOCK ANTIMICROBIAL USE QUANTITY TRAJECTORIES UNDER DIFFERENT LIVESTOCK BIOMASS AND ANTIMICROBIAL USE INTENSITY SCENARIOS

Scenario	Definition	Description
S1	LBIO-UP*AMUI-BAU	LBIO at upper bound, AMUI remains at BAU.
S2	LBIO-LOW*AMUI-BAU	LBIO at lower bound, AMUI remains at BAU.
S3	LBIO-UP*AMUI-30%	LBIO at upper bound, AMUI decreases by 30 percent.
S4	LBIO-BAU*AMUI-30%	LBIO remains at BAU, AMUI decreases by 30 percent.
S5	LBIO-LOW*AMUI-30%	LBIO at lower bound, AMUI decreases by 30 percent.
S6	LBIO-UP*AMUI-50%	LBIO at upper bound, AMUI decreases by 50 percent.
S7	LBIO-BAU*AMUI-50%	LBIO remains at BAU, AMUI decreases by 50 percent.
S8	LBIO-LOW*AMUI-50%	LBIO at lower bound, AMUI decreases by 50 percent.

This table presents the eight scenarios included in the simulations, which differ based on assumptions for livestock biomass (LBIO) and antimicrobial use intensity (AMUI). LBIO is modelled at three levels: lower bound, upper bound, and business-as-usual (BAU). AMUI either remains at the BAU level or is reduced by 30 percent or 50 percent, depending on the scenario.

Source: **Acosta, A., Tirkaso, W., Nicolli, F., Van Boeckel, T.P., Cinardi, G. & Song, J.** 2025. The future of antibiotic use in livestock. *Nature Communications*, 16(1): 2469. https://doi.org/10.1038/s41467-025-56825-7

FIGURE 5
PROJECTED LIVESTOCK ANTIMICROBIAL USE QUANTITY BY 2040 UNDER DIFFERENT SCENARIOS



This figure illustrates the percentage deviation in livestock antimicrobial use quantity (AMUQ) from the business-as-usual (BAU) scenario by 2040 under eight scenarios describing different combinations of livestock biomass (LBIO) and antimicrobial use intensity (AMUI). These scenarios reflect varying assumptions about LBIO (upper bound, lower bound or BAU) and AMUI reductions (none, represented by the blue bars; 30 percent, orange bars; or 50 percent, green bars).

Source: **Acosta, A., Tirkaso, W., Nicolli, F., Van Boeckel, T.P., Cinardi, G. & Song, J.** 2025. The future of antibiotic use in livestock. *Nature Communications*, 16(1): 2469. https://doi.org/10.1038/s41467-025-56825-7

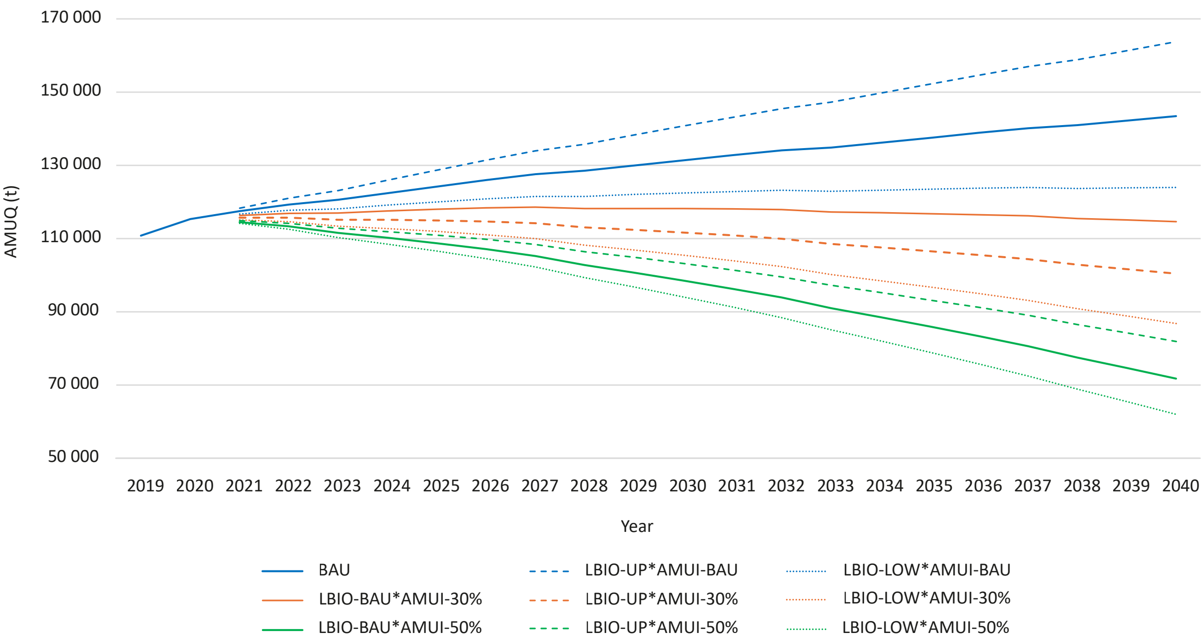
Figure 6 provides a detailed view of the projected livestock AMUQ trajectories by 2040 across the eight defined scenarios, plus a pure BAU scenario. Focusing first on scenarios where livestock biomass remains at the BAU level provides valuable insights into the role of AMUI in determining future AMUQ levels. In the pure BAU scenario, where both LBIO and AMUI continue to follow their current trends, AMUQ is projected to rise from approximately 110 777 tonnes as of 2019 to approximately 143 481 tonnes by 2040. This serves as the baseline scenario, highlighting the likely increase in AMUQ if no interventions are implemented to alter these trends.

In Scenario S4, where LBIO remains at BAU levels but AMUI is reduced by 30 percent, AMUQ is projected to decrease to approximately 100 437 tonnes by 2040. This significant reduction suggests that even moderate cuts in AMUI can substantially offset the AMUQ increase driven by steady LBIO levels. Scenario S7, where LBIO remains unchanged while AMUI is halved, projects an even more dramatic reduction, with AMUQ expected to drop to approximately 71 741 tonnes by 2040. Finally, S8, which combines the lowest LBIO with a 50 percent reduction in AMUI, achieves the most substantial decrease in AMU, with projections dropping to approximately 61 989 tonnes by 2040. This scenario underscores the synergistic effect of targeting both LBIO and AMUI, illustrating that comprehensive strategies addressing both factors are essential for minimizing AMUQ.

Notably, these scenarios also reveal that any single approach, whether limiting LBIO or slashing AMUI, rarely suffices to bring about major reductions in overall AMUQ on its own. Instead, a more integrated strategy that encourages moderate herd growth, better on-farm health practices and responsible drug use can produce cumulative benefits. By weighing the trade-offs among production costs, food security considerations, and antimicrobial stewardship, policymakers can select the scenario that best aligns with regional priorities and resource constraints. Ultimately, the scenarios serve as illustrative guides, showing that multiple routes exist to

FIGURE 6

LIVESTOCK ANTIMICROBIAL USE QUANTITY TRAJECTORIES BY 2040 UNDER DIFFERENT SCENARIOS



This figure shows the projected antimicrobial use quantity (AMUQ) in livestock from 2019 to 2040, in tonnes (t), under various scenarios, reflecting varying assumptions regarding livestock biomass (LBIO) and antimicrobial use intensity (AMUI). The solid lines represent, respectively, the business-as-usual (BAU) scenario; a scenario (S4) that assumes a 30 percent reduction in AMUI while keeping LBIO at the BAU level; and a scenario (S7) that assumes a 50 percent reduction in AMUI while maintaining LBIO at the BAU level. These scenarios illustrate the impact of AMUI reduction on AMUQ, independent of changes in LBIO. The dotted and dashed lines represent the remaining scenarios, in which LBIO reaches an upper or lower bound in combination with AMUI maintained at the BAU level or reduced by 30 percent or 50 percent.

Source: **Acosta, A., Tirkaso, W., Nicolli, F., Van Boeckel, T.P., Cinardi, G. & Song, J.** 2025. The future of antibiotic use in livestock. *Nature Communications*, 16(1): 2469. https://doi.org/10.1038/s41467-025-56825-7

curb AMU, each requiring varying degrees of innovation, investment and behavioural change at every level of the agrifood system.

POLICY INSIGHTS

The global commitments to reduce AMU in livestock reflect growing recognition that continued reliance on antimicrobials is not sustainable. Without decisive action, global AMU in livestock is expected to rise substantially over the coming decades, increasing by around 30 percent by 2040 under a BAU scenario. This chapter shows that such an outcome is not inevitable and identifies several distinct trajectories for the future of AMU. Strategic improvements in productivity and efficiency could reduce AMU by up to 50 percent, demonstrating that substantial reductions are achievable with effective policies and practices.

Accurate measurement of AMUI is essential for effective policy design. More refined approaches, such as those based on the LBC method, tend to capture higher AMUI levels, particularly in rapidly expanding production systems. These differences are not purely technical, as variations in measurement can influence risk characterization, the prioritization of investments and the calibration of policy responses. By complementing existing methodologies, the LBC approach can help strengthen the evidence base and support more proportionate and well-targeted policy interventions (Acosta *et al.*, 2025b).

The chapter's findings underscore the need for integrated strategies that jointly address AMUI and livestock biomass dynamics while improving overall system performance. Aligning antimicrobial stewardship with broader productivity and development objectives is especially important in low- and middle-income countries, where livestock growth underpins livelihoods and food security. At the same time, pronounced regional heterogeneity in projected trajectories suggests that global reduction goals will require differentiated pathways tailored to local production systems, development stages and institutional capacities.

3. Global impact of antimicrobial growth promoters on livestock productivity

The use of antimicrobial growth promoters (AGPs) in livestock production has been increasingly scrutinized due to concerns about their contribution to antimicrobial resistance (AMR). In response, international organizations have advocated restrictions on AGP use. FAO has recommended limiting AGPs in animal agriculture (FAO, 2015), while WOAH has committed to phasing out antibiotics for growth promotion (WOAH, 2016). More recently, in 2023 the Codex Alimentarius Commission established global food safety and quality standards addressing AGP use in livestock systems (FAO and WHO, 2023). These policy developments reflect a growing consensus on the need to balance livestock productivity with One Health objectives. Translating these commitments into feasible pathways, however, requires credible evidence on what AGPs contribute to production performance and how effects differ across livestock systems.[3]

Despite this momentum, significant uncertainty remains about the economic implications of AGP withdrawal. This uncertainty largely stems from the lack of globally representative productivity parameters that account for heterogeneity across production systems, animal species and regional contexts. In economic policy modelling, small changes in growth rates or feed conversion can translate into meaningful changes in output, prices and welfare, particularly in systems where feed costs dominate and margins are tight. Where modelling relies on fixed or context-specific assumptions, it risks overstating adjustment costs in some settings while understating them in others. For example, Laxminarayan, Van Boeckel and Teillant (2015) estimate that banning AGPs could reduce global meat production by 1.3–3.0 percent. These projections are driven by species-specific assumptions on relative reductions in average daily gain (ADG) under high- and low-impact scenarios, ranging (respectively) from 7 percent to 3 percent for cattle, 9 percent to 1 percent for pigs, and 4 percent to 0.7 percent for poultry. While informative, these projections are based on fixed parameters that do not account for heterogeneity in geography, management or antimicrobial class. This matters because baseline productivity, disease pressure, biosecurity and access to veterinary services and non-antibiotic alternatives vary sharply across regions and income groups, shaping both the magnitude of productivity effects and the scope for adaptation following AGP withdrawal.

This chapter contributes to the evidence base for the productivity effects of AGPs by conducting a systematic and globally representative meta-analysis across pigs, cattle and broilers (i.e. chickens raised specifically for meat production). Unlike previous syntheses that focus on single species or are primarily limited to high-income settings, this analysis draws on a diverse set of controlled trials spanning different geographic regions, income levels, and production systems, including lower-middle-income countries (LMICs) and low-biosecurity environments. By estimating treatment effects systematically across species and contexts, the study presented in this chapter aims to improve the consistency and applicability of productivity parameters used as input in economic models that assess the implications of AGP reduction. Rather than treating AGP withdrawal as a uniform shock, this chapter provides disaggregated estimates that support scenario analysis under heterogeneous production conditions and transition pathways. In addition, it examines whether the classification of antimicrobials based on their importance to human medicine, as defined by the World Health Organization (WHO, 2019), influences productivity outcomes. This dimension is particularly relevant from a One Health perspective, as some of the compounds associated with stronger productivity effects may also be those of greatest concern for human medicine; this could sharpen the policy trade-off between short-term performance gains and long-term AMR risks.

A META-ANALYSIS FOR ECONOMIC MODELLING

A total of 95 studies, comprising 128 treatment effects, were included in the analysis (Acosta *et al.*, 2026a). These studies covered three major production systems, namely broilers (43.8 percent; 56 observations), pigs (25.0 percent; 32 observations), and cattle (31.2 percent; 40 observations). In terms of geographical distribution,

[3] This chapter synthesizes findings from the peer-reviewed study **Acosta, A., Cardinal, K.M., Nicolli, F., Onofrio, F. & Song, J.** 2026. Global impact of antimicrobial growth promoters on livestock productivity: A meta-analysis for economic modeling. *Preventive Veterinary Medicine*, 250: 106754. https://doi.org/10.1016/j.prevetmed.2025.106754

the majority of studies originated from Asia and the Pacific and Latin America and the Caribbean, representing the largest shares at 31.6 percent each, followed by Northern America (16.8 percent). Notably, all cattle studies were conducted in Latin America and the Caribbean or Northern America. In terms of income classification, 56.8 percent of the studies were conducted in upper-middle-income countries (UMICs), 30.5 percent in high-income countries (HICs), and the remaining 12.7 percent in LMICs.

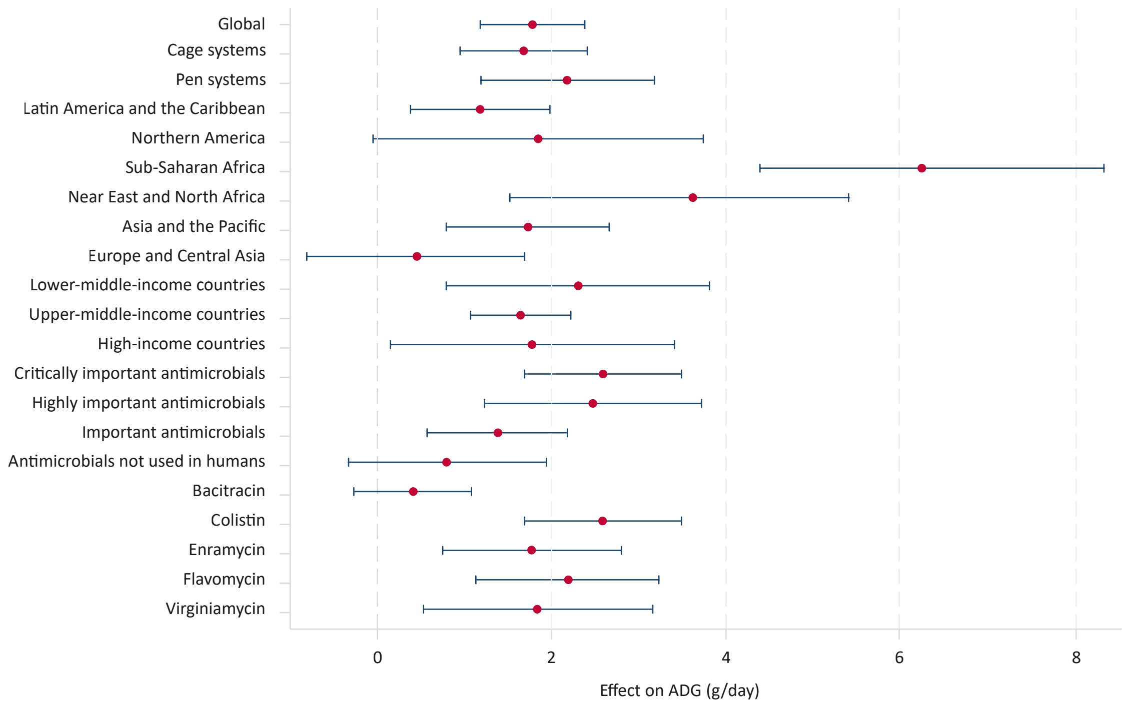
Antimicrobial growth promoters classified as highly important were the most frequently tested (37.1 percent), followed closely by those not used in human medicine (34.3 percent). AGPs considered important represented 17.2 percent of the tested compounds, while those classified as critically important were the least frequently tested (11.4 percent). In total, 22 AGPs were tested, with 14 studied in broiler trials, 13 in pig trials, and 6 in cattle trials. The most frequently tested AGPs across studies were virginiamycin (14.7 percent), avilamycin (14.7 percent), monensin (10.5 percent), colistin (9.4 percent) and bacitracin (8.4 percent).

IMPACT OF ANTIMICROBIAL GROWTH PROMOTERS ON AVERAGE DAILY GAIN

ADG is a measure of how much weight an animal gains per day. It is a key performance indicator in livestock production, directly influencing the time required to reach market weight, feed conversion costs, and overall farm profitability. From a policy perspective, ADG is a valuable proxy for economic output per animal and a critical input into models assessing the cost-effectiveness of restricting AGPs. Figures 7, 8 and 9 summarize the results of the meta-analysis, presenting the estimated effects of AGPs on ADG across production stages, geographic regions, country income groups, housing systems (i.e. pens vs cages) and antimicrobial classes and types. For each category, the marker represents the pooled mean effect on ADG, while the horizontal line denotes the corresponding confidence interval, illustrating both the magnitude of the productivity effect and the associated uncertainty. These estimates provide key quantitative parameters for assessing trade-offs between short-term productivity gains, regulatory

FIGURE 7

ESTIMATED EFFECTS OF ANTIMICROBIAL GROWTH PROMOTERS ON AVERAGE DAILY GAIN IN BROILERS



This figure presents the estimated effects of antimicrobial growth promoters (AGPs) on average daily gain (ADG) in broiler production, expressed in grams per day (g/day). Estimates are derived from a meta-analysis and are disaggregated by geographic region, country income group, antimicrobial type and classification, and housing type (pens vs. cages). The dots represent pooled mean estimates, while the horizontal bars show the corresponding 95 percent confidence intervals.

Source: **Acosta, A., Cardinal, K.M., Nicolli, F., Onofrio, F. & Song, J.** 2026. Global impact of antimicrobial growth promoters on livestock productivity: A meta-analysis for economic modeling. *Preventive Veterinary Medicine*, 250: 106754. https://doi.org/10.1016/j.prevetmed.2025.106754

interventions on AMU, and long-term public health objectives.

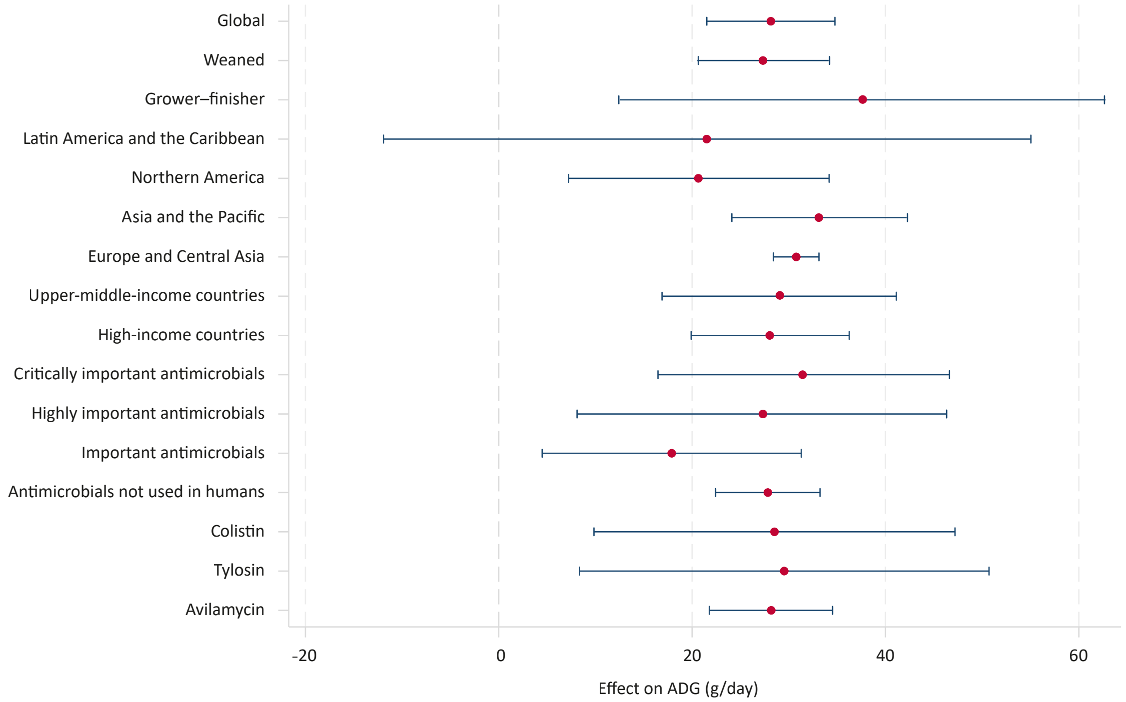
In broilers, AGPs increased ADG by an average of 1.78 grams per day (g/day) (see **Figure 7**). This effect was greater in pen systems (2.14 g/day) than in cage systems (1.64 g/day), consistent with evidence that the productivity benefits of AGPs tend to be larger in production systems with higher disease pressure and greater management variability. Gains were highest in sub-Saharan Africa (6.37 g/day), the Near East and North Africa (3.62 g/day) and Asia and the Pacific (1.73 g/day), while the average impact was negligible in Europe and Central Asia (0.44 g/day), where baseline biosecurity is already high. In terms of country income group, LMICs showed the largest improvement (2.30 g/day), but even UMICs (1.65 g/day) and HICs (1.78 g/day) showed notable benefits. Antimicrobial growth promoters classified as critically important antimicrobials (CIAs) delivered the highest gains (2.59 g/day), although non-CIA molecules such as flavomycin (2.18 g/day) also performed strongly.

Pigs exhibited a strong growth response to AGPs (see **Figure 8**), with an average gain of 28.15 g/day. Effects were stronger in grower-finisher stages (37.54 g/day) than in weaned pigs (27.43 g/day), consistent with differences in growth potential, feeding regimes and health constraints across stages. Geographically, the largest effects were seen in Asia and the Pacific (33.69 g/day) and Europe and Central Asia (30.77 g/day), while lower responses were reported in Latin America and the Caribbean (21.56 g/day) and Northern America (20.70 g/day). Pigs in UMICs responded best (29.01 g/day), followed closely by those in HIC settings (28.07 g/day). Among antimicrobial classes, CIAs produced the greatest growth response (31.54 g/day), outperforming both highly important (27.22 g/day) and important antimicrobials (17.89 g/day). The molecules tylosin (29.53 g/day), avilamycin (28.16 g/day) and colistin (28.52 g/day) were the most effective.

Cattle showed a more modest relative growth response to AGPs (see **Figure 9**), despite an average absolute gain of 30 g/day. While smaller than

FIGURE 8

ESTIMATED EFFECTS OF ANTIMICROBIAL GROWTH PROMOTERS ON AVERAGE DAILY GAIN IN PIGS

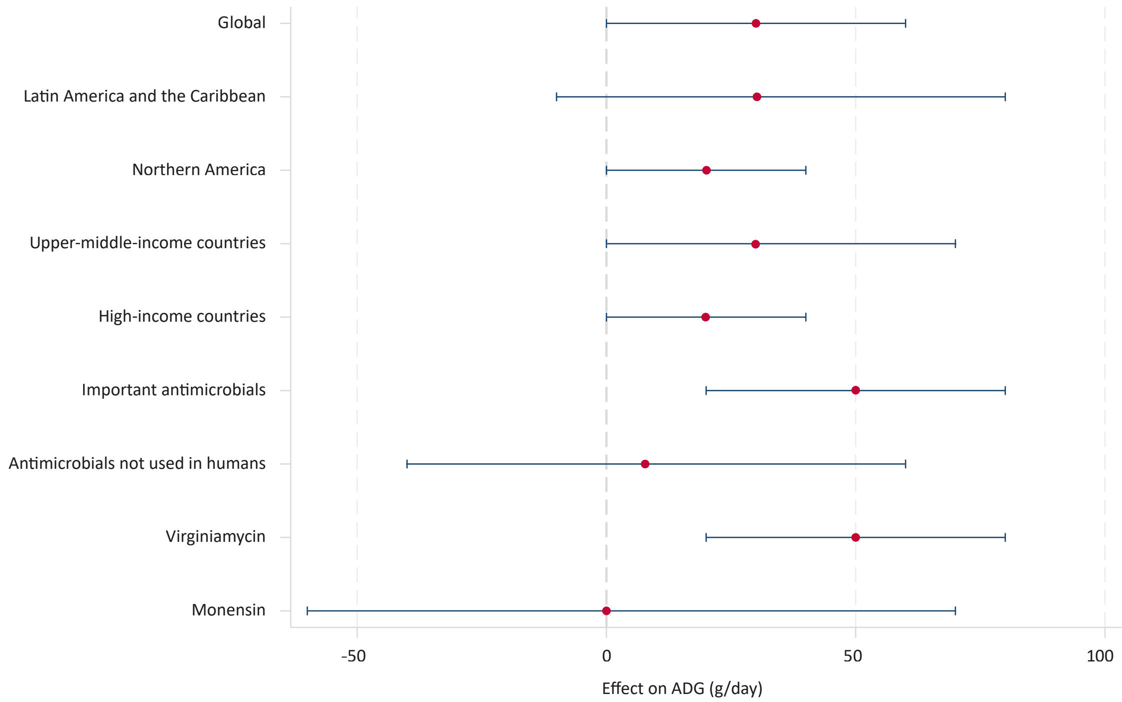


This figure shows the estimated effects of antimicrobial growth promoters on average daily gain (ADG) in pig production, expressed in grams per day (g/day). Results are based on a meta-analysis and reported across production stages (i.e. weaned vs. grower–finisher), geographic regions, country income groups, and antimicrobial type and classification. The dots represent pooled mean estimates, while the horizontal bars show the corresponding 95 percent confidence intervals.

Source: **Acosta, A., Cardinal, K.M., Nicolli, F., Onofrio, F. & Song, J.** 2026. Global impact of antimicrobial growth promoters on livestock productivity: A meta-analysis for economic modeling. *Preventive Veterinary Medicine*, 250: 106754. https://doi.org/10.1016/j.prevetmed.2025.106754

FIGURE 9

ESTIMATED EFFECTS OF ANTIMICROBIAL GROWTH PROMOTERS ON AVERAGE DAILY GAIN IN CATTLE



This figure illustrates the estimated effects of antimicrobial growth promoters (AGPs) on average daily gain (ADG) in cattle production, expressed in grams per day (g/day). The estimates were obtained from a meta-analysis and are presented across geographic regions, country income groups, and antimicrobial type and classification. The dots represent pooled mean estimates, while the horizontal bars show the corresponding 95 percent confidence intervals.

Source: **Acosta, A., Cardinal, K.M., Nicolli, F., Onofrio, F. & Song, J.** 2026. Global impact of antimicrobial growth promoters on livestock productivity: A meta-analysis for economic modeling. *Preventive Veterinary Medicine*, 250: 106754. https://doi.org/10.1016/j.prevetmed.2025.106754

in monogastric species, these gains can still produce substantial economic effects in long-cycle finishing systems. The largest effect was observed in UMICs (30 g/day), with gains slightly lower in HICs (20 g/day) and in Northern America (20 g/day). In terms of molecule classifications, important antimicrobials produced the highest ADG effect (50 g/day), while non-human-use antimicrobials showed a smaller but still measurable effect (10 g/day). Virginiamycin, an antimicrobial commonly used in cattle, was associated with the largest individual molecule effect (50 g/day). Monensin, in contrast, showed no impact on ADG in the pooled estimates, possibly due to data limitations or microbial resistance development.

IMPACT OF ANTIMICROBIAL GROWTH PROMOTERS ON FEED CONVERSION RATIO AND FEED EFFICIENCY

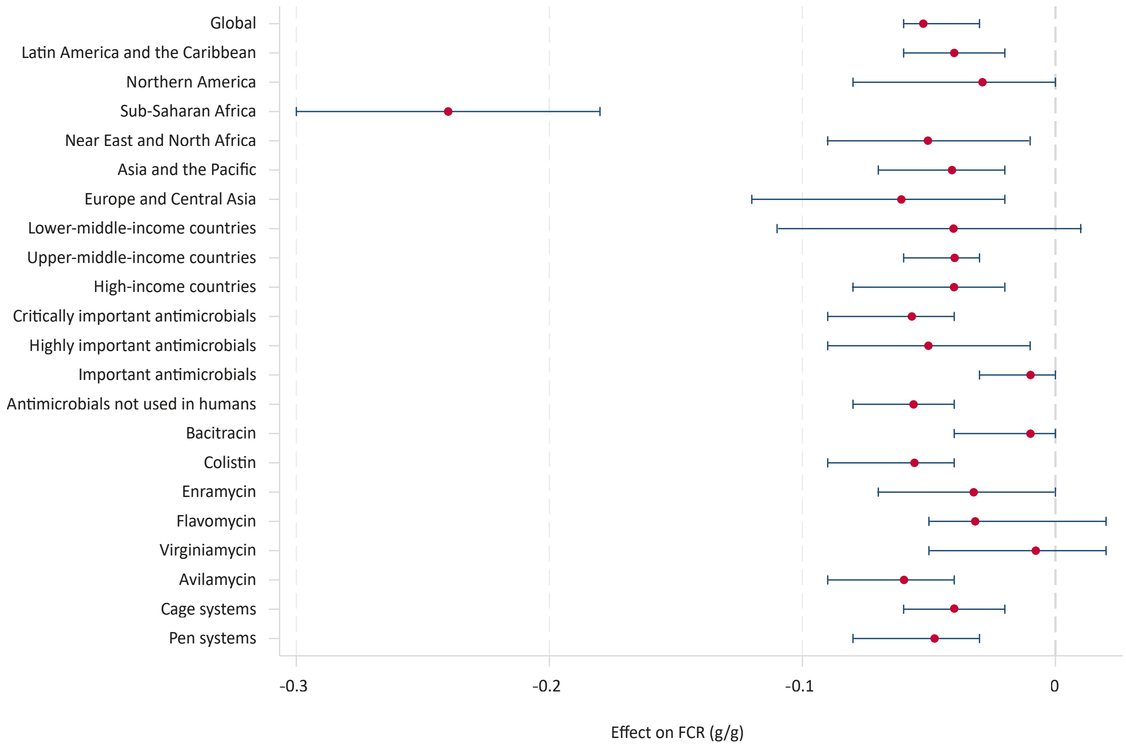
Feed conversion ratio (FCR) and feed efficiency (FE) are essential metrics used to evaluate how effectively livestock convert feed into body weight. A lower FCR means less feed is required per unit of gain, while a higher FE indicates better conversion of feed into weight. In this chapter, FCR (for broilers and pigs) is expressed as grams of feed intake per gram of live weight gain (g/g), and FE (for cattle) is expressed as grams of live weight gain per gram of feed intake (g/g). These indicators are not only key drivers of profitability, especially where feed costs account for over half of production costs, but are also critical for assessing the environmental and resource-use implications of livestock systems. Figures 10, 11 and 12 present the effects of AGPs on FCR for broilers and pigs, and on FE for cattle.

Use of AGPs reduced FCR in broilers by an average of 0.05 g/g, meaning birds required less feed to achieve the same weight gain (see **Figure 10**). These improvements were consistent across housing systems, with a reduction of 0.04 for birds housed in cages and a reduction of 0.05 for birds housed in pens. However, substantial regional differences were observed. In terms of regional differences, AGPs yielded the strongest reduction in FCR in sub-Saharan Africa (-0.24), pointing to their significant role in improving feed use in lower-biosecurity and disease-prone systems. In Asia and the Pacific and in Europe and Central Asia, average reductions were 0.04 and 0.06, respectively, while in Northern America, the effect was smaller (0.03). In income terms, FCR reductions were uniform across country income groups, averaging 0.04 in high-income, upper-middle-income, and lower-middle-income settings. When categorized by antimicrobial importance, CIAs and antimicrobials not used in humans produced the largest effect (-0.06), followed closely by highly important antimicrobials (-0.05). Among specific molecules, colistin (-0.06) and avilamycin (-0.06) performed best, though bacitracin, enramycin and flavomycin also delivered modest improvements (-0.01 to -0.03).

In pigs, AGPs improved feed conversion by reducing FCR by an average of 0.09 g/g (see **Figure 11**). This gain was larger than in broilers and likely reflects the particularly high post-weaning stress experienced in pig production systems, where AGPs are often used to support gut health and nutrient absorption. Regionally, the most substantial improvement occurred in Europe and Central Asia (-0.24), followed by Latin America and the Caribbean (-0.12) and Asia and the Pacific (-0.07). These differences may reflect variations in baseline disease pressure, feed composition, and production practices. The impact of AGPs also varied by income level. UMICs saw a reduction of -0.10 g/g, whereas HICs experienced a smaller reduction (-0.02). In terms of antimicrobial class, CIAs produced a strong benefit (-0.11), with antimicrobials

FIGURE 10

ESTIMATED EFFECTS OF ANTIMICROBIAL GROWTH PROMOTERS ON FEED CONVERSION RATIO IN BROILERS

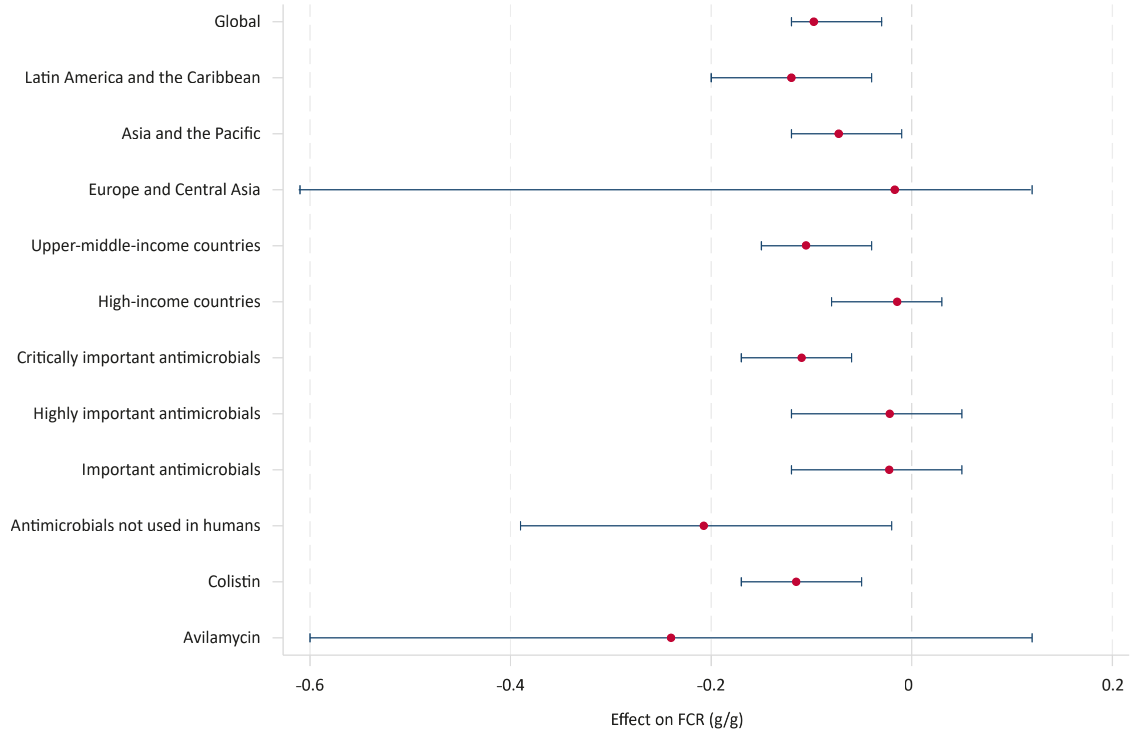


This figure presents the estimated effects of antimicrobial growth promoters on feed conversion ratio (FCR) in broiler production, expressed as grams of feed intake per gram of live weight gain (g/g). The results are based on a meta-analysis and are disaggregated by housing type (pens vs. cages), geographic region, country income group, and antimicrobial type and classification. The dots represent pooled mean estimates, while the horizontal bars show the corresponding 95 percent confidence intervals.

Source: **Acosta, A., Cardinal, K.M., Nicolli, F., Onofrio, F. & Song, J.** 2026. Global impact of antimicrobial growth promoters on livestock productivity: A meta-analysis for economic modeling. *Preventive Veterinary Medicine*, 250: 106754. https://doi.org/10.1016/j.prevetmed.2025.106754

FIGURE 11

ESTIMATED EFFECTS OF ANTIMICROBIAL GROWTH PROMOTERS ON FEED CONVERSION RATIO IN PIGS



This figure shows the estimated effects of antimicrobial growth promoters on feed conversion ratio (FCR) in pig production, expressed as grams of feed intake per gram of live weight gain (g/g). Estimates are derived from a meta-analysis and are reported across geographic regions, country income groups, and antimicrobial type and classification. The dots represent pooled mean estimates, while the horizontal bars show the corresponding 95 percent confidence intervals.

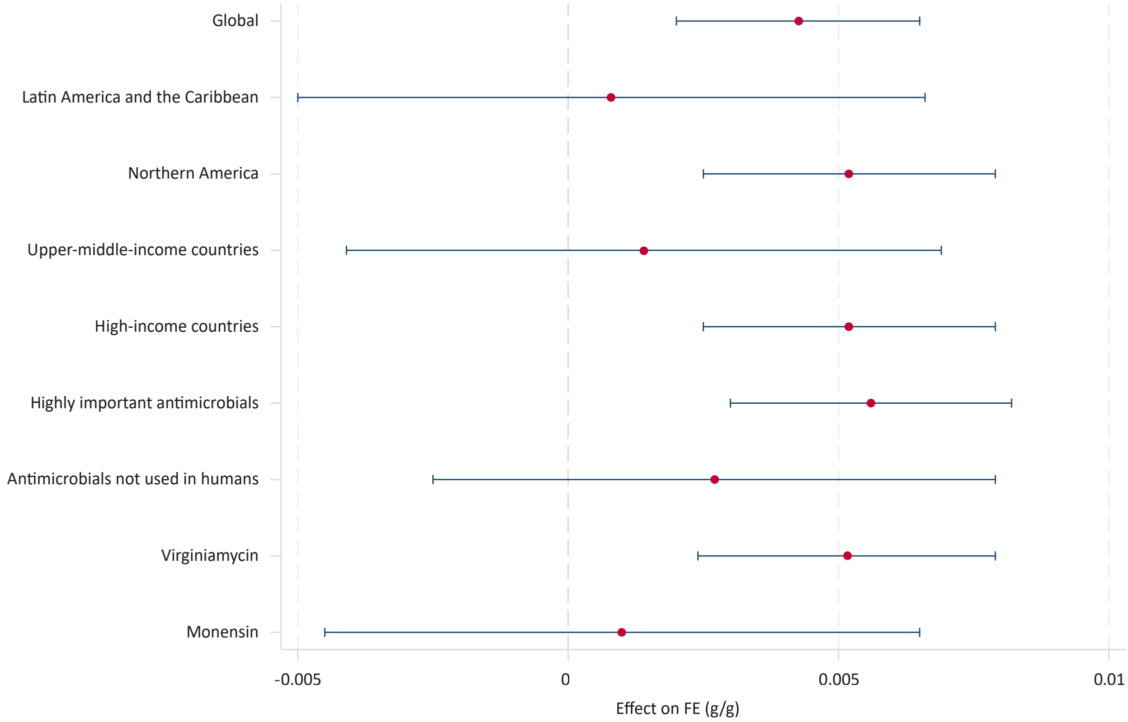
Source: **Acosta, A., Cardinal, K.M., Nicolli, F., Onofrio, F. & Song, J.** 2026. Global impact of antimicrobial growth promoters on livestock productivity: A meta-analysis for economic modeling. *Preventive Veterinary Medicine*, 250: 106754. https://doi.org/10.1016/j.prevetmed.2025.106754

not used in humans also showing a large reduction (-0.21). This supports the broader finding that medically important antimicrobials are often very effective growth promoters, which raises policy dilemmas for efforts to reduce AMR risks. Among individual compounds, colistin (-0.11) and avilamycin (-0.24) stood out for their strong feed conversion improvements.

For cattle, FE rather than FCR is typically used, reflecting the species' longer production cycles and different digestive physiology. The meta-analysis shows that AGPs improved FE by an average of 0.0043 globally, equivalent to an additional 4.3 grams of live weight gain per kilogram of feed intake (see **Figure 12**). Although this figure may seem small in absolute terms, it translates into meaningful feed savings and cost reductions over longer finishing periods.

Among regions, the highest gains were observed in Northern America (0.0052), with strong improvements in HICs generally (0.0052) and more moderate gains in upper-middle-income settings (0.0014). Latin America and the Caribbean showed a minimal gain of 0.0008. Among antimicrobial classifications, highly important antimicrobials (0.0056) and those not used in humans (0.0027) delivered the strongest improvements in FE. Virginiamycin, a commonly used AGP in feedlot cattle, produced a 0.0052 increase in FE, while monensin yielded a smaller effect on feed efficiency (0.0010), consistent with previous studies suggesting diminishing returns from long-term use.

FIGURE 12
ESTIMATED EFFECTS OF ANTIMICROBIAL GROWTH PROMOTERS ON FEED EFFICIENCY IN CATTLE



This figure illustrates the estimated effects of antimicrobial growth promoters on feed efficiency (FE), expressed as grams of live weight gain per gram of feed intake (g/g). The estimates are based on a meta-analysis and are presented across geographic regions, country income groups, and antimicrobial type and classification. The dots represent pooled mean estimates, while the horizontal bars show the corresponding 95 percent confidence intervals.

Source: **Acosta, A., Cardinal, K.M., Nicolli, F., Onofrio, F. & Song, J.** 2026. Global impact of antimicrobial growth promoters on livestock productivity: A meta-analysis for economic modeling. *Preventive Veterinary Medicine*, 250: 106754. https://doi.org/10.1016/j.prevetmed.2025.106754

INTERPRETING THE PRODUCTIVITY EFFECTS OF ANTIMICROBIAL GROWTH PROMOTERS IN A ONE HEALTH CONTEXT

The results of this meta-analysis highlight that the productivity effects of AGPs are highly heterogeneous across species, production systems and contexts. While AGPs are consistently associated with improvements in growth performance and feed efficiency, the magnitude of these effects varies substantially depending on baseline conditions. This heterogeneity is not incidental, but reflects structural differences in disease pressure, management practices, and access to alternative health interventions across livestock systems, including genetic, microbial and feeding-related factors that shape animals' responses to growth-promoting inputs (Acosta *et al.*, 2026a).

Across species, the strongest productivity responses to AGPs are observed in systems characterized by lower baseline performance and higher health constraints. In broilers and pigs, larger gains in ADG and FCR are concentrated in regions and income groups where biosecurity levels are lower and exposure to enteric and respiratory pathogens is higher. This pattern is consistent with evidence showing that AGP efficacy is strongly mediated by baseline disease pressure, feed quality, and environmental stressors, which vary widely across production systems and climatic conditions (Detmann *et al.*, 2014; Lazzarini *et al.*, 2016).

In such contexts, AGPs function less as marginal productivity enhancers and more as substitutes for missing investments in preventive animal health, hygiene, and veterinary services. Physiologically, subtherapeutic AGPs are known to improve gut health, reduce low-grade inflammation and enhance nutrient absorption, particularly under conditions of microbial challenge or nutritional stress (Dibner and Richards, 2005; Niewold, 2007). In broilers, these mechanisms have been linked to improvements in gut morphology and immune modulation, which translate into higher growth responses where baseline conditions are suboptimal (Yazdi *et al.*, 2014; Moses, Onimisi and Jegede, 2017). At the same time, the presence of trials reporting limited or null effects highlights the importance of host-specific factors, including microbiota composition and health status, in modulating AGP efficacy.

Conversely, in high-income settings with more advanced management and disease control practices, the incremental productivity benefits of AGPs are smaller, consistent with diminishing returns as systems approach biological and managerial frontiers. In these systems, higher baseline biosecurity, standardized genetics, and access to alternative interventions reduce both the marginal contribution of AGPs and the scope for further productivity gains, helping to explain the more limited effects observed in high-income contexts (Teillant and Laxminarayan, 2015). These patterns help reconcile the wide range of estimates reported in the literature and explain why global modelling exercises based on fixed productivity penalties may misrepresent adjustment costs. Applying uniform assumptions to AGP withdrawal risks overstating economic impacts in well-managed systems while understating them in settings where disease pressure remains high and alternatives are not yet fully deployed. The disaggregated estimates provided in this chapter therefore offer a more nuanced basis for scenario analysis, allowing economic models to better capture context-specific transition pathways.

The findings also shed light on a central One Health dilemma: Antimicrobials classified as critically important for human medicine are often associated with the largest productivity gains, particularly in pig production. This reflects their pharmacological effectiveness but also raises significant concerns regarding the acceleration of AMR with continued use. From an economic perspective, this creates a non-trivial trade-off between short-term productivity gains and long-term societal costs. Productivity benefits derived from CIAs may be real and measurable, but they must be weighed against the erosion of antimicrobial effectiveness and the associated risks to public health.

Importantly, the results do not imply that productivity losses following AGP withdrawal are inevitable or permanent. Rather, they underscore that the scale and duration of adjustment costs depend critically on the availability and adoption of alternative practices, including improved biosecurity, vaccination, nutrition and herd management. Where such alternatives are scaled effectively, productivity gaps can be narrowed over time, reducing reliance on AGPs without compromising output. In this sense, AGP withdrawal should be interpreted not as a single shock, but as part of a broader transition process toward livestock systems that rely less on antimicrobials and more on preventive health and system-level resilience.

POLICY INSIGHTS

This chapter provides critical empirical evidence to support economic assessments of policies aimed at reducing or phasing out AGPs in livestock production. By delivering species-specific and regionally differentiated estimates of the effects of AGPs on productivity indicators, it strengthens the empirical basis for parameterizing economic models and assessing the magnitude and distribution of adjustment costs associated with AGP reduction.

The results indicate that the economic consequences of AGP withdrawal are unlikely to be uniform across species, regions, production systems or antimicrobial classes. Adjustment costs depend critically on baseline productivity, disease pressure and the availability of alternative management and animal health interventions. Production systems with lower baseline performance and weaker veterinary infrastructure, particularly in lower-middle-income and lower-resource production settings, are more likely to face pronounced short-term output effects. In contrast, systems in high-income settings, where preventive practices and non-antibiotic alternatives are already more widespread, may experience more limited disruption. In addition, some of the compounds associated with the strongest productivity responses are also those classified as critically important for human medicine. These differences underscore the importance of transition strategies that are tailored to local production conditions, rather than relying on uniform policy assumptions.

Incorporating these heterogeneous effects explicitly into economic modelling allows the short-term productivity impacts of AGP reduction to be evaluated alongside longer-term public health considerations. By providing disaggregated productivity parameters, this chapter supports scenario-based analyses that explore alternative transition pathways away from AGPs, helping to inform balanced policy choices without presuming uniform outcomes or predefined solutions.

4. Antimicrobial use in livestock – the economic cost of action or inaction

Antimicrobial use in livestock has long been an essential component of strategies to promote animal health, enhance productivity and support the development of intensive production systems. Among these strategies, the use of antimicrobial growth promoters (AGPs) has historically contributed to improved feed efficiency and faster growth (Tang *et al.*, 2017; Landers *et al.*, 2012). However, growing global concern about the contribution of antimicrobial use (AMU) to the emergence of antimicrobial resistance (AMR) has intensified scrutiny of non-therapeutic practices and renewed calls for tighter restrictions. From an economic perspective, the core tension in this regard is a timing asymmetry: The costs of reducing AMU are often immediate and visible at the farm and market levels, whereas the costs of rising resistance accumulate gradually and are harder to attribute until they become disruptive.[4]

This issue presents a complex economic and regulatory challenge, particularly in countries where AGPs remain widely used. In these settings, decision-makers are faced with evaluating whether the short-term economic impacts of action, such as removing AGPs from production systems, are justified in light of the broader and cumulative consequences of inaction, which include the rising burden of AMR on livestock productivity, public health and economic stability. From a One Health perspective, the trade-off also involves preserving antimicrobial effectiveness as a shared resource. Individual incentives to maintain performance can diverge from societal welfare when resistance costs are diffuse and cross-sectoral.

This chapter explores the nature of this trade-off by analysing the economic risks associated with both action and inaction. It draws on global livestock production projections, harmonized productivity parameters and quantitative modelling to estimate how reductions in AGP use or increases in AMR may affect livestock production, sectoral losses and broader macroeconomic outcomes. Productivity shocks associated with AGP withdrawal draw on harmonized, species-specific parameters from Chapter 3, avoiding the use of uniform productivity parameters that ignore differences across species, production systems and regional contexts. To capture both the direct effects on global livestock output and the broader economy-wide implications for welfare, the analysis combines a partial equilibrium (PE) model with a computable general equilibrium (CGE) model. This integrated approach allows us to trace how livestock-sector shocks translate into changes in prices, incomes and welfare across the broader economy. In doing so, it distinguishes between (i) transitional adjustment costs linked to AGP phase-out, which may attenuate as producers adopt substitutes and management improvements, and (ii) persistent losses linked to rising AMR, which compound over time in the absence of effective mitigation.

SCENARIO SIMULATIONS – PHASING OUT ANTIMICROBIAL GROWTH PROMOTERS VERSUS INCREASING ANTIMICROBIAL RESISTANCE

The analysis presented in this chapter relies on a set of nine scenario simulations (see Table 2) designed to estimate how global production of livestock commodities (meat, milk and eggs) might evolve through 2040 under two primary shocks: the withdrawal of AGPs and the rise in AMR. The baseline scenario is aligned with the recent *Agricultural Outlook* published by FAO and the Organisation for Economic Co-operation and Development (OECD), which assumes continuity in current production, consumption and policy trends (OECD and FAO, 2024). It therefore reflects existing patterns of AGP use and background levels of AMR embedded in historical data and serves as a reference trajectory against which antimicrobial-related shocks are evaluated.

To assess the direct impacts of AGP withdrawal and rising AMR on global livestock markets, the analysis draws on the Aglink-Cosimo partial equilibrium modelling framework (OECD and FAO, 2024). The model simulates the supply, demand, prices and trade for major agricultural commodities, including

[4] This chapter synthesizes findings from the peer-reviewed study **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M.** ***et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

TABLE 2
SIMULATION SCENARIOS

Scenario	Description
AGP-L*LE-B	Effect of AGP withdrawal on livestock production is low; legislative conditions remain at baseline.
AGP-M*LE-B	Effect of AGP withdrawal on livestock production is moderate; legislative conditions remain at baseline.
AGP-H*LE-B	Effect of AGP withdrawal on livestock production is high; legislative conditions remain at baseline.
AGP-L*LE-M	Effect of AGP withdrawal on livestock production is low; effectiveness of existing legislation is moderate.
AGP-M*LE-M	Effect of AGP withdrawal on livestock production is moderate; effectiveness of existing legislation is moderate.
AGP-H*LE-M	Effect of AGP withdrawal on livestock production is high; effectiveness of existing legislation is moderate.
AMR-L	AMR has a relatively low impact on production, leading to an estimated 5% increase in mortality rate.
AMR-M	AMR has a relatively moderate impact on production, leading to an estimated 10% increase in mortality rate.
AMR-H	AMR has a relatively high impact on production, leading to an estimated 15% increase in mortality rate.

This table presents the nine scenarios included in the simulations used to analyse the evolution of global livestock commodities through 2040. The scenarios differ based on three key dimensions: (i) the impact of antimicrobial growth promoter (AGP) withdrawal, modelled as a reduction in productivity with three levels of severity – low (L), moderate (M), and high (H); (ii) the degree of regulatory enforcement, with a baseline enforcement (LE-B) scenario that assumes strong implementation and compliance with AGP-related legislation, and a moderate enforcement (LE-M) scenario reflecting weaker oversight and partial compliance; and (iii) the intensity of antimicrobial resistance (AMR), captured through estimated increases in mortality of 5 percent (low), 10 percent (moderate), and 15 percent (high).

Source: **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M. *et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

beef, poultry, pork, eggs and milk, across more than 40 countries and regional aggregates. Within this framework, antimicrobial-related shocks are introduced as exogenous disturbances to livestock productivity and mortality, allowing their effects to propagate through markets via changes in production, prices and trade flows (Acosta *et al.*, 2026b).

To capture the wider economy-wide implications of these livestock-sector shocks, the analysis complements Aglink-Cosimo with the Livestock Policy Simulation Model – Global (LPSM-G), a CGE model calibrated on the Global Trade Analysis Project (GTAP) database. While Aglink-Cosimo traces the direct market impacts within livestock and related agricultural sectors, LPSM-G translates these shocks into broader effects on prices, incomes and welfare across the economy, accounting for interactions with non-agricultural sectors and factor markets.

Productivity effects associated with AGP withdrawal are implemented in the simulations as negative supply-side shocks, parameterized using the species-specific estimates derived in Chapter 3. These shocks capture reductions in growth performance and feed-use efficiency following AGP removal and provide a consistent empirical basis for linking the meta-analytic evidence to the modelling framework.

The withdrawal of AGPs is modelled under three levels of severity – low, moderate and high – reflecting the range of productivity responses observed in the empirical literature. Each severity level is combined with two different assumptions on regulatory enforcement, distinguishing between scenarios where existing legislation is fully implemented and scenarios where enforcement is moderately effective. This structure reflects the idea that policy outcomes depend not only on formal restrictions, but on the extent to which these restrictions translate into actual changes in production practices at the farm level.

To capture how quickly livestock systems recover from productivity shocks, the model incorporates a speed-of-adjustment mechanism. Economically, this mechanism represents the sector's capacity to mitigate initial losses through the adoption of alternative practices, such as improved biosecurity, vaccination, nutrition and herd management. Rather than assuming a fixed recovery path, the rate of adjustment is estimated empirically using an autoregressive distributed lag model, tailored to each species and region. This allows recovery dynamics to vary across production systems, reflecting differences in institutional capacity, access to inputs and baseline animal health conditions.

AMR is modelled as a persistent shock to livestock production, reflected in increased livestock mortality rates. Three of the scenarios capture different levels of AMR intensity, with estimated increases in mortality of 5 percent, 10 percent, and 15 percent, depending on species and country conditions. Unlike with the AGP withdrawal scenarios, no speed-of-adjustment mechanism is applied, as AMR is treated as a cumulative biological process that progressively constrains productivity over time, with no built-in recovery mechanism over the projection horizon.

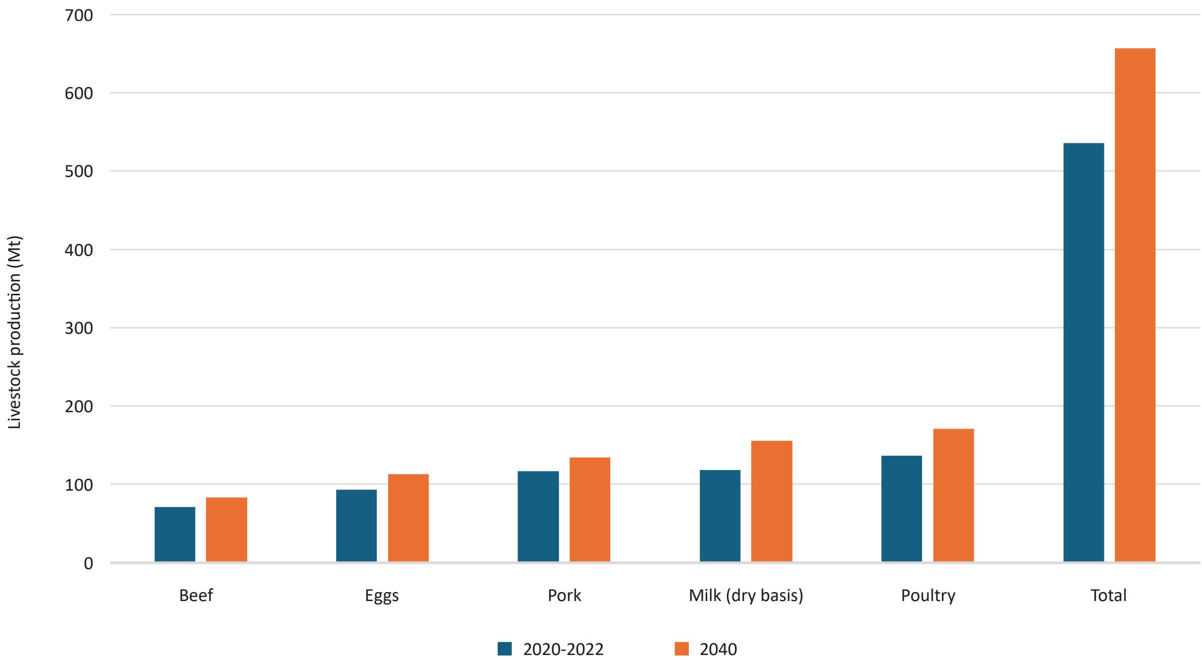
Finally, all physical and market-level shocks simulated in Aglink-Cosimo are passed to the LPSM-G framework to assess economy-wide spillover effects. This step enables the analysis to move beyond sector-specific outcomes and evaluate impacts on GDP, economic welfare and household consumption across income groups. By linking PE and CGE results, the modelling framework captures both the direct effects on livestock markets and the broader macroeconomic and distributional implications of antimicrobial-related shocks (Acosta *et al.*, 2026b).

GLOBAL LIVESTOCK PRODUCTION: BASELINE PROJECTIONS TO 2040

The business-as-usual (BAU) base projection (see **Figure 13**) is derived from an extended version of the Aglink-Cosimo model, aligned with the OECD–FAO *Agricultural Outlook* (OECD and FAO, 2024). It assumes the continuation of existing livestock production practices, consumption patterns and policy environments, thereby implicitly reflecting current levels of AGP use and AMR prevalence embedded in the historical data that underpin the model. In other words, AGPs remain in use where legally permitted and AMR evolves at background rates, without new regulatory interventions or technological changes affecting AMU. This projection therefore represents a status quo trajectory against which the effects of AGP withdrawal and progressive AMR scenarios are evaluated. Deviations from this baseline are interpreted as impacts of antimicrobial-related shocks on livestock production and the wider economy.

Under the baseline projection scenario, global livestock production across the commodities represented in **Figure 13** increases from 536 million tonnes (Mt) in 2020–2022 to 657 Mt by 2040, corresponding to a 23 percent rise and an additional 121 Mt of output. Poultry production expands from 137 Mt to 171 Mt, reinforcing its position as the largest contributor to global livestock output. Beef production increases from 71 Mt to 83 Mt, while pork production increases from 117 Mt to 134 Mt, resulting in a slight decline in its share of global output. Egg production increases from 93 Mt to 113 Mt, and milk (dry basis) production expands from 118 Mt to 156 Mt.

FIGURE 13
GLOBAL LIVESTOCK PRODUCTION: BASELINE PROJECTIONS TO 2040



This figure displays projected changes in global livestock production by commodity between the 2020–2022 average and 2040 under the business-as-usual (BAU) scenario, expressed in million tonnes (Mt). The projections cover major livestock commodities, including beef, poultry, pork, eggs and milk (dry basis). The figure represents the baseline trajectory against which the impacts of antimicrobial growth promoter withdrawal and increasing antimicrobial resistance are evaluated.

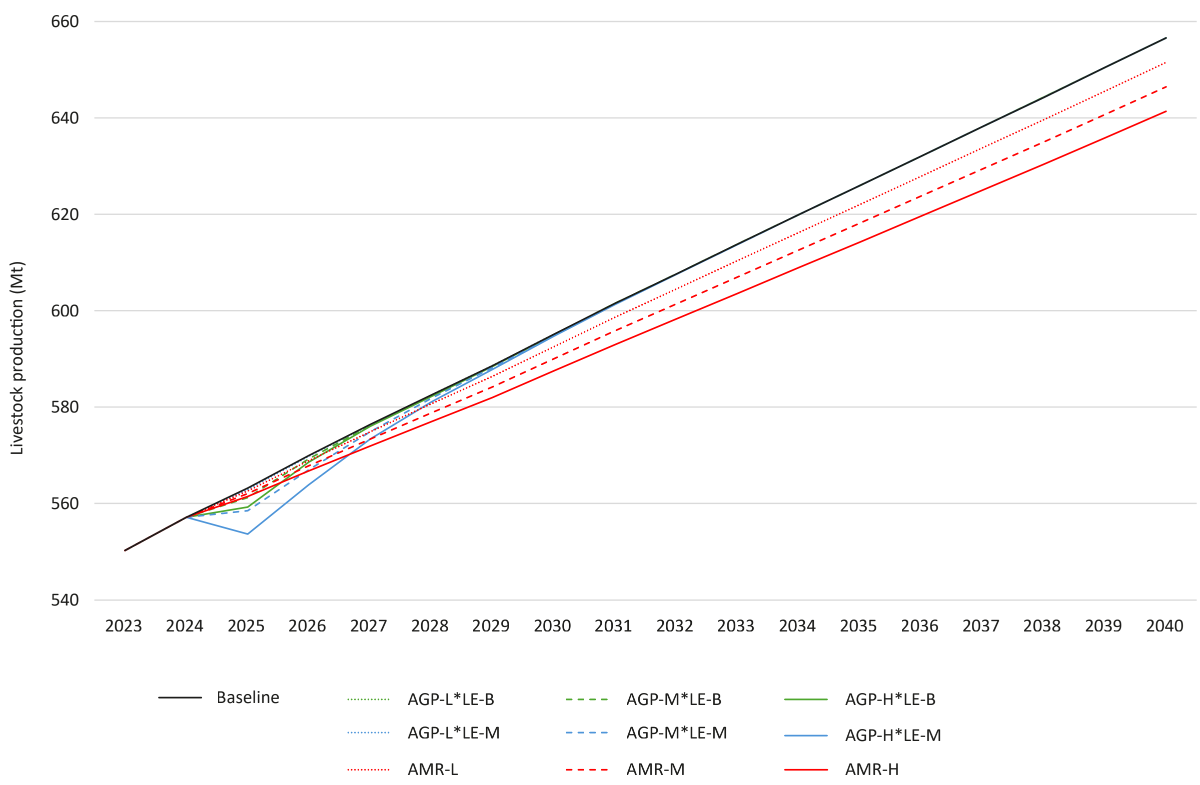
Source: **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M. *et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041, based on an extended version of the Aglink-Cosimo model and the 2025 OECD-FAO *Agricultural Outlook*.

TOTAL IMPACT ON GLOBAL LIVESTOCK PRODUCTION

Results from the AGP withdrawal scenarios indicate minimal deviations from the OECD–FAO baseline projection for 2040 (see **Figure 14**). Even under the most adverse setting (AGP-H*LE-M), global meat, milk and egg production remain virtually unchanged relative to the baseline. In contrast, the AMR progression scenarios reveal a gradual but persistent decline in global livestock output. Under AMR-L, total production in 2040 falls by approximately 5 Mt (-0.7 percent) compared with the baseline, reaching 10 Mt (-1.5 percent) under AMR-M and 15 Mt (-2.2 percent) under AMR-H. These findings suggest that AMR acts as a silent shock, exerting a slow-moving yet compounding drag on production that erodes long-term growth. Although proportionally small, these cumulative reductions offset around 16 percent of the expansion projected between 2025 and 2040.

FIGURE 14

TOTAL IMPACT OF ANTIMICROBIAL GROWTH PROMOTER AND ANTIMICROBIAL RESISTANCE SCENARIOS ON GLOBAL LIVESTOCK PRODUCTION, 2023–2040



This figure presents projected global livestock production from 2023 to 2040 under different scenarios involving antimicrobial growth promoter (AGP) restrictions and the impacts of antimicrobial resistance (AMR), expressed in million tonnes (Mt). The baseline (black) reflects the Aglink-Cosimo model's global projection. The AGP scenarios show slight initial declines in production followed by recovery, with the latter dependent on impact severity and legislative effectiveness. In contrast, the AMR scenarios result in progressively lower livestock outputs, driven by increased livestock mortality.

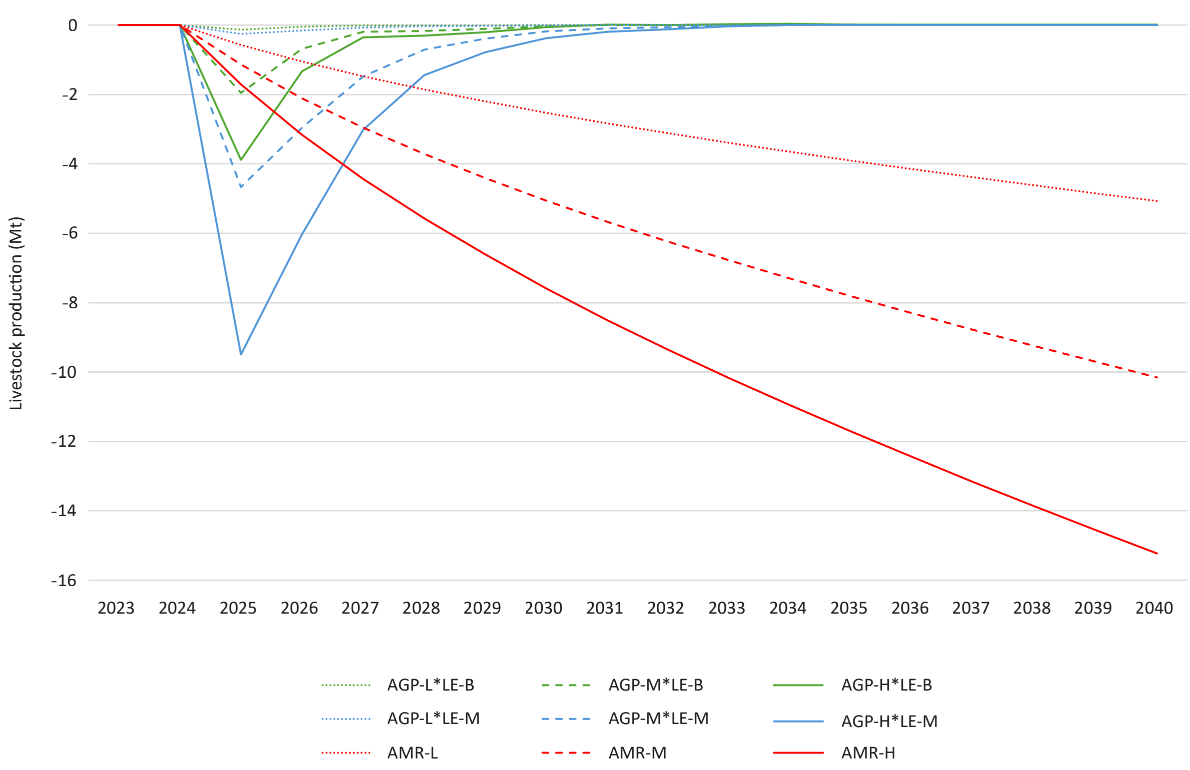
Source: **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M. *et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

ANNUAL IMPACT ON GLOBAL LIVESTOCK PRODUCTION

The projected effects of AGP withdrawal and AMR progression reflect the modelling assumptions applied to each case (see Figure 15). In the AGP scenarios, production initially declines before returning to baseline levels as the sector adjusts. This adjustment is modelled through a speed-of-adjustment mechanism, which indicates the adaptation process. Under the AGP-H*LE-B scenario, where the enforcement of laws banning the use of AGPs is assumed to be strong and adoption of alternatives is rapid, global livestock output falls by 3.9 Mt in 2025 but returns to baseline within two years. In the AGP-H*LE-M scenario, which assumes weaker enforcement, the decline reaches 9.5 Mt in 2025, with recovery beginning within four years.

In contrast, the AMR scenarios exhibit a different adjustment path. As AMR leads to increased disease burden and mortality, it progressively reduces animal health and production. Unlike AGP withdrawal, which triggers a one-time shock followed by recovery, for AMR we assume that there is no corrective mechanism, and that its negative effects consequently accumulate over time. In the AMR-H scenario, global livestock production decreases continuously throughout the projection period, reaching a 15 Mt shortfall by 2040, with no recovery. This contrast shows that while the economic effects of AGP withdrawal are likely to be transitory, AMR leads to a sustained decline in production over time.

FIGURE 15
ANNUAL IMPACT ON GLOBAL LIVESTOCK PRODUCTION



This figure illustrates the annual deviation in global livestock production under various antimicrobial growth promoter (AGP) and antimicrobial resistance (AMR) scenarios from 2023 to 2040, expressed in million tonnes (Mt). The AGP restriction scenarios (green and blue lines) show sharp short-term declines, especially under high withdrawal impact and moderate legislation effectiveness (AGP-H*LE-M), followed by gradual recovery. In contrast, the AMR scenarios (red lines) result in sustained and worsening production losses, with the high-mortality scenario (AMR-H) causing the steepest long-term decline.

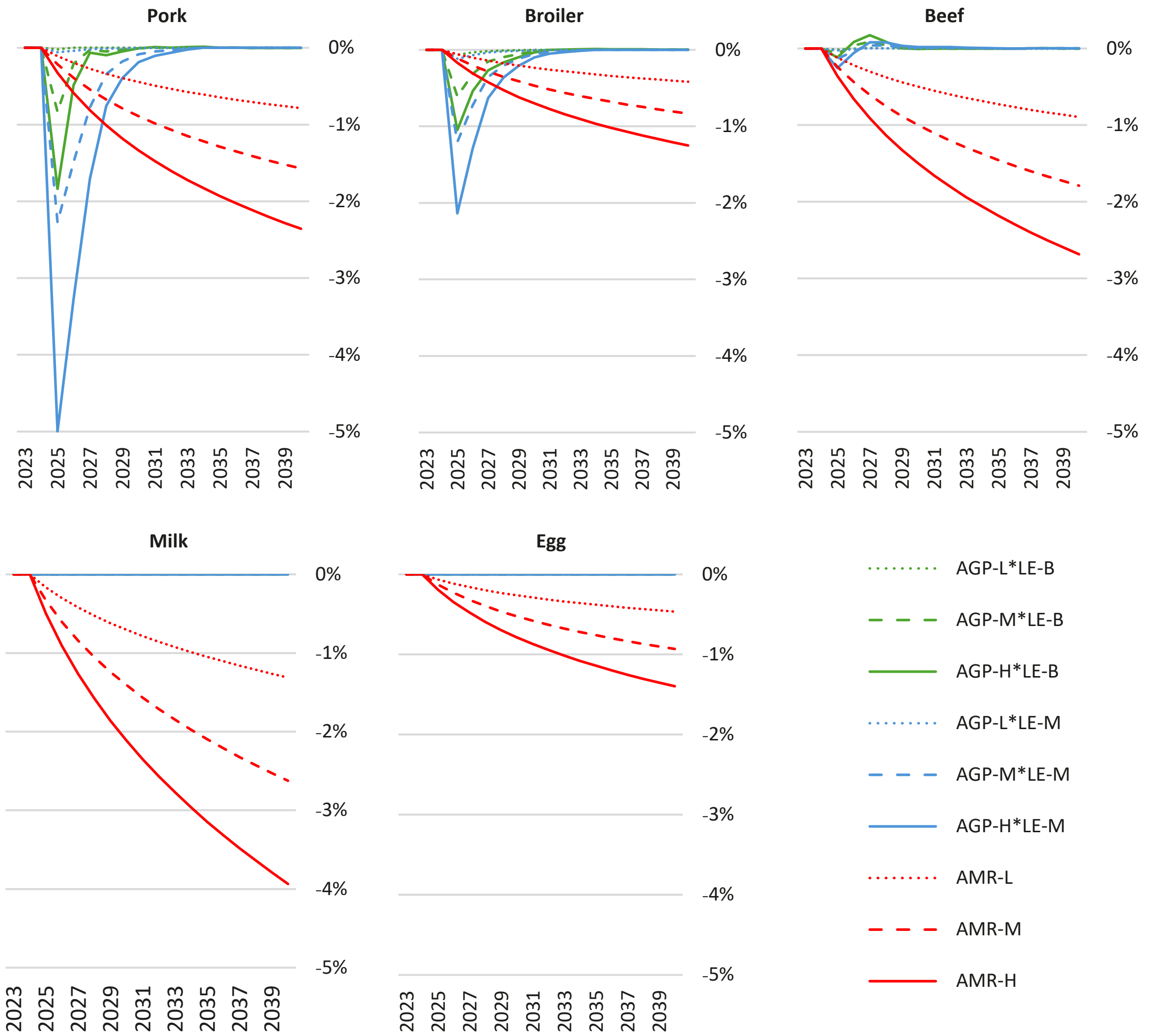
Source: **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M. *et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

COMMODITY-SPECIFIC EFFECTS OF ANTIMICROBIAL GROWTH PROMOTERS AND ANTIMICROBIAL RESISTANCE ON GLOBAL LIVESTOCK PRODUCTION

To examine the distributional effects of antimicrobial-related shocks, the projected impacts of AGP withdrawal and increasing AMR are disaggregated across major livestock commodities. Figure 16 shows the percentage deviations from baseline for global pork, broiler, beef, milk and egg production under selected scenarios, illustrating how the magnitude and timing of the shocks differ by commodity.

Pork and poultry systems experience the largest percentage declines following AGP withdrawal, reflecting their greater reliance on growth promoters in intensive production settings. In the AGP-H*LE-M scenario, which represents high initial AGP dependency and moderate enforcement, global pork output falls by 5.0 percent in 2025, while poultry production declines by 2.1 percent. By contrast, beef, milk and egg production change by less than 1 percent across the AGP scenarios, consistent with their lower or negligible reliance on AGPs.

FIGURE 16
COMMODITY-SPECIFIC DEVIATIONS IN GLOBAL LIVESTOCK PRODUCTION



This figure illustrates the annual percentage deviations from baseline in global pork, broiler, beef, milk and egg production under antimicrobial growth promoter (AGP) and antimicrobial resistance (AMR) scenarios from 2023 to 2040, highlighting variation in the timing and magnitude of effects across commodity groups.

Source: **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M.** ***et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

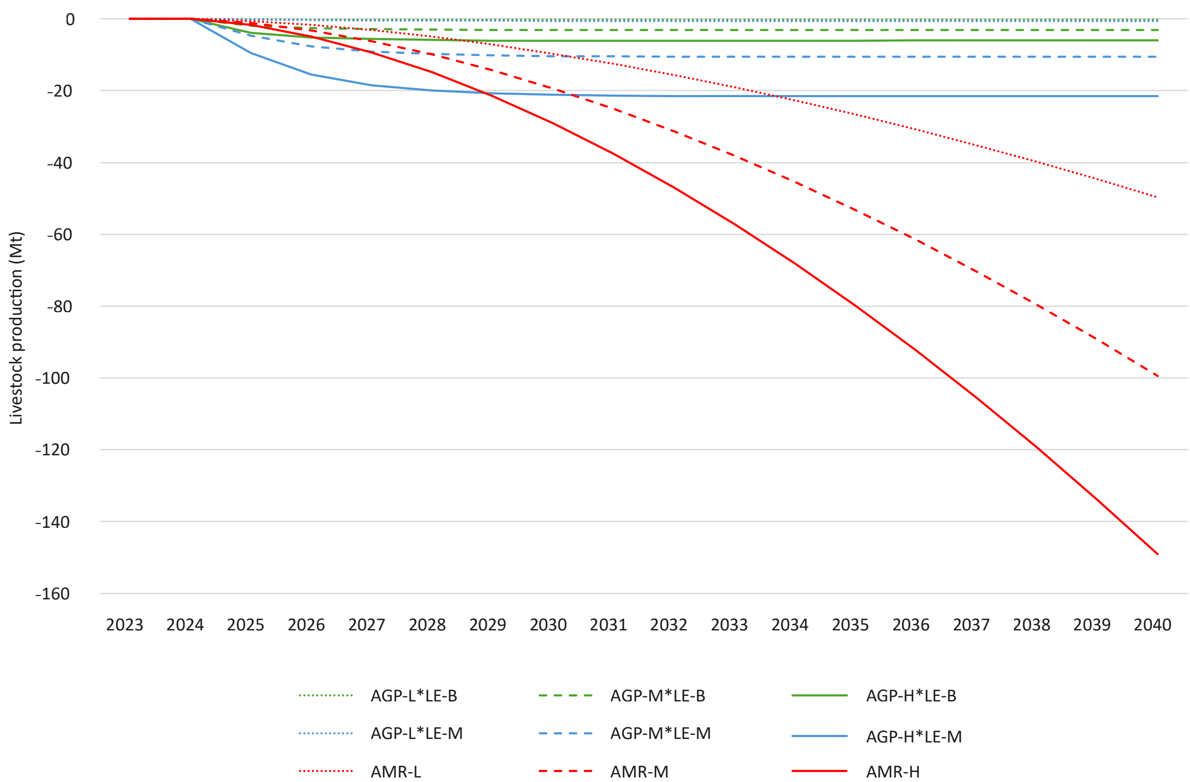
The effects of AMR are more widespread and sustained across commodities. Unlike AGP withdrawal, which causes a one-time decline followed by recovery, AMR progression results in a continuing reduction in output. Under the AMR-H scenario, production declines by 2.7 percent for beef, 2.4 percent for pork, 1.2 percent for poultry, 3.9 percent for milk, and 1.4 percent for egg by 2040, with no recovery observed within the projection period. This continuing decline reflects the long-run biological constraints imposed by AMR rather than a regulatory or market-driven adjustment.

CUMULATIVE IMPACT ON GLOBAL LIVESTOCK PRODUCTION

We assess the cumulative effects of AGP reduction and rising AMR on global livestock output (see **Figure 17**). AGP-related losses are front-loaded. They deepen in the initial years after withdrawal and then stabilize as producers adapt. However, AMR exhibits a fundamentally different pattern. Although early losses are smaller, cumulative deficits grow continuously over the projection period. The AGP-H*LE-M and AMR-H trajectories intersect around 2028, when cumulative losses in both scenarios reach roughly 20 Mt; beyond this point, AMR-H becomes the dominant source of long-run output reductions. This intersection reflects the scenario design, which models AGP withdrawal as a temporary production shock and AMR as a cumulative loss.

The magnitude of these impacts varies across scenarios. Under AGP-H*LE-B, stronger enforcement limits cumulative losses to less than 6 Mt by 2040, whereas under AGP-H*LE-M, losses stabilize at approximately 22 Mt from the late 2020s onward.

FIGURE 17
CUMULATIVE IMPACT ON GLOBAL LIVESTOCK PRODUCTION



This figure shows the cumulative impact of different antimicrobial growth promoter (AGP) and antimicrobial resistance (AMR) scenarios on global livestock production from 2023 to 2040, expressed in million tonnes (Mt). The AGP restriction scenarios result in relatively modest cumulative losses (below 25 Mt), with losses stabilizing after initial shocks. In contrast, the AMR scenarios, particularly AMR-H, lead to severe and compounding production losses, reaching around 150 Mt by 2040.

Source: **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M. *et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

AMR scenarios display progressively larger cumulative deficits with higher assumed mortality. Under AMR-L, the deficit increases from about 0.6 Mt in 2025 to nearly 49.7 Mt by 2040; under AMR-M, it reaches roughly 99.4 Mt; and under AMR-H, it increases from 1.71 Mt in 2025 to around 149.1 Mt by 2040. Unlike with AGP withdrawal, none of the AMR trajectories show signs of stabilization within the projection horizon, indicating a persistent and compounding long-term effect.

ECONOMIC VALUATION OF CUMULATIVE LIVESTOCK PRODUCTION LOSSES

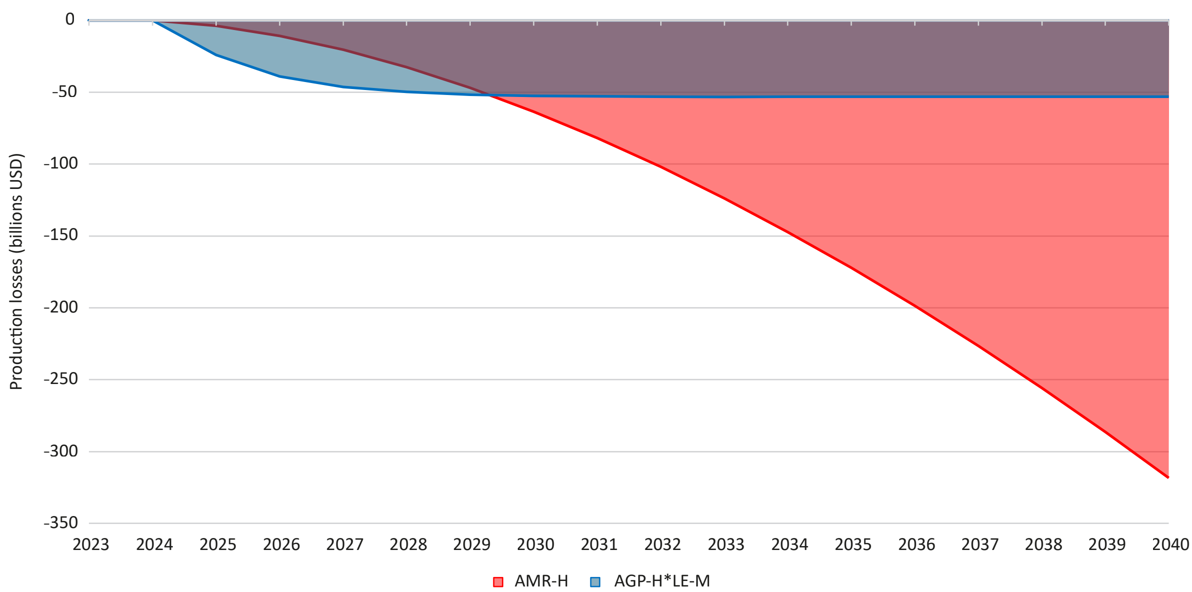
Figure 18 presents the economic valuation of the cumulative livestock production losses under the two high-impact scenarios, AGP-H*LE-M and AMR-H. Projected livestock output losses are valued using constant global reference prices from the 2021–2023 period, based on the Aglink-Cosimo baseline. Holding prices constant allows the analysis to isolate the effects of volume changes associated with antimicrobial-related shocks, abstracting from price movements.

The blue area represents the cumulative losses associated with AGP withdrawal, while the red area captures losses driven by AMR progression. Using this constant-price valuation, cumulative losses amount to approximately USD 53.2 billion in the AGP-H*LE-M scenario and USD 318.2 billion in the AMR-H scenario. The difference between the two trajectories is largest around 2026, when the cost of AGP withdrawal exceeds AMR-related losses by roughly USD 28.4 billion. From 2030 onward, AMR-related costs surpass those of AGP withdrawal, with a difference of about USD 264.9 billion by 2040. This comparison illustrates the shift from short-term adjustments associated with AGP withdrawal to longer-term AMR-related economic pressures.

GLOBAL ECONOMIC WELFARE SPILLOVER EFFECTS

We assess the macroeconomic implications of AGP withdrawal and rising AMR using the LPSM-G model. Because livestock and livestock-related activities account for a relatively small share of global value added, aggregate GDP effects remain modest in

FIGURE 18
ECONOMIC VALUE OF PRODUCTION LOSSES



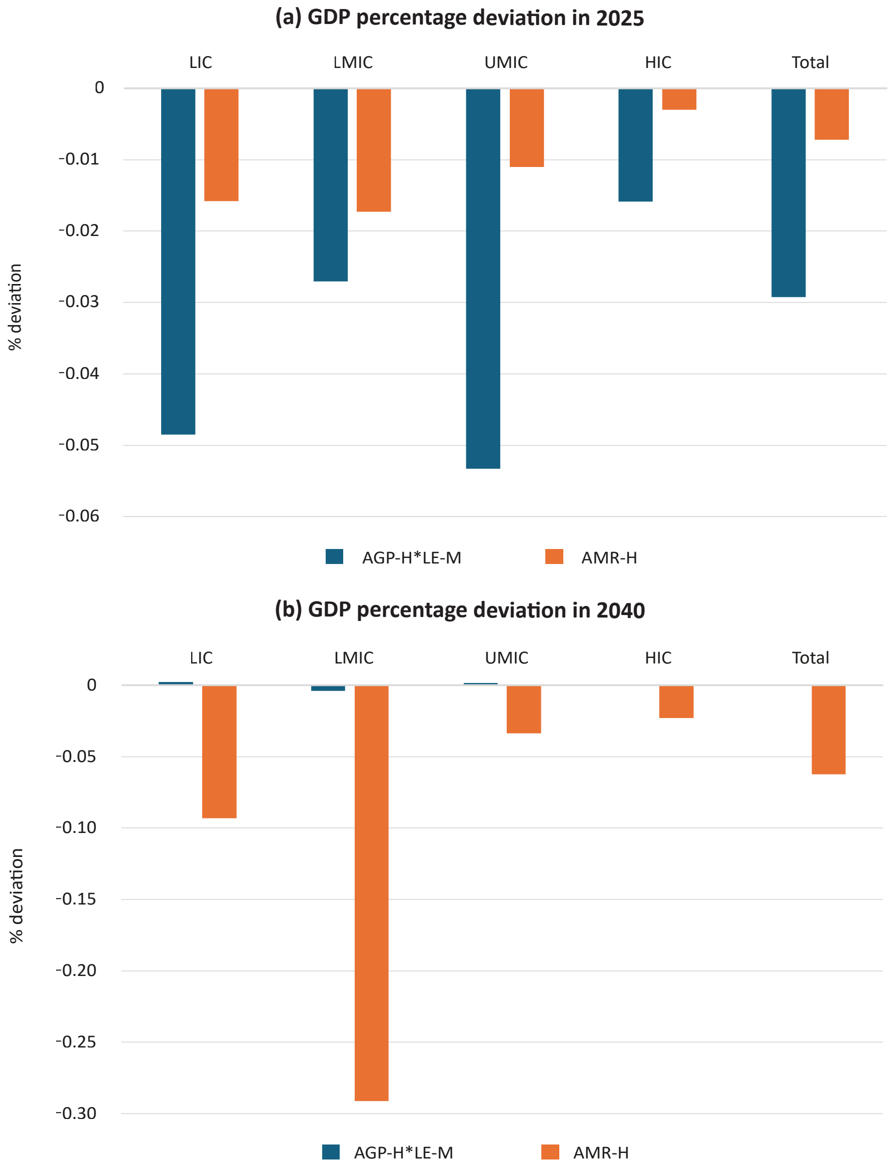
This figure depicts the cumulative economic losses from reduced livestock production under two scenarios: high antimicrobial growth promoter (AGP) restriction with moderate legislation effectiveness (AGP-H*LE-M) and high antimicrobial resistance (AMR) impact (AMR-H). While AGP-related losses peak around USD 50 billion and then plateau, AMR-induced losses escalate sharply, reaching nearly USD 320 billion by 2040.

Source: **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M.** ***et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041 absolute terms. Their policy relevance lies instead in their persistence over time and uneven distribution across income groups.

On average over the 2025–2040 period, GDP losses under AMR-H are roughly ten times larger than under AGP-H*LE-M (about -0.04 percent vs. -0.004 percent, respectively), with the strongest impacts observed in low-income countries (LICs) and lower-middle-income countries (LMICs) (see **Figure 19**). These averages, however, mask important temporal differences. In the short term, AGP withdrawal generates a larger GDP deviation as production systems adjust. Over time, this effect fades as adaptation occurs. By contrast, AMR-related losses intensify steadily,

FIGURE 19

GDP PERCENTAGE DEVIATIONS IN 2025 AND 2040 UNDER HIGH-IMPACT ANTIMICROBIAL GROWTH PROMOTER RESTRICTION AND ANTIMICROBIAL RESISTANCE SCENARIOS



This figure presents percentage deviations in global GDP from baseline under the highest-impact antimicrobial growth promoter withdrawal scenario (AGP-H*LE-M) and antimicrobial resistance (AMR) progression scenario (AMR-H), shown for 2025 in panel (a) and 2040 in panel (b). The effects are presented across the full range of country income groups: low-income countries (LICs), lower-middle-income countries (LMICs), upper-middle-income countries (UMICs), and high-income countries (HICs). While AGP withdrawal generates a larger short-term GDP deviation as production systems adjust, these effects fade over time. In contrast, AMR-related GDP losses intensify and become dominant by 2040, particularly in LICs and LMICs.

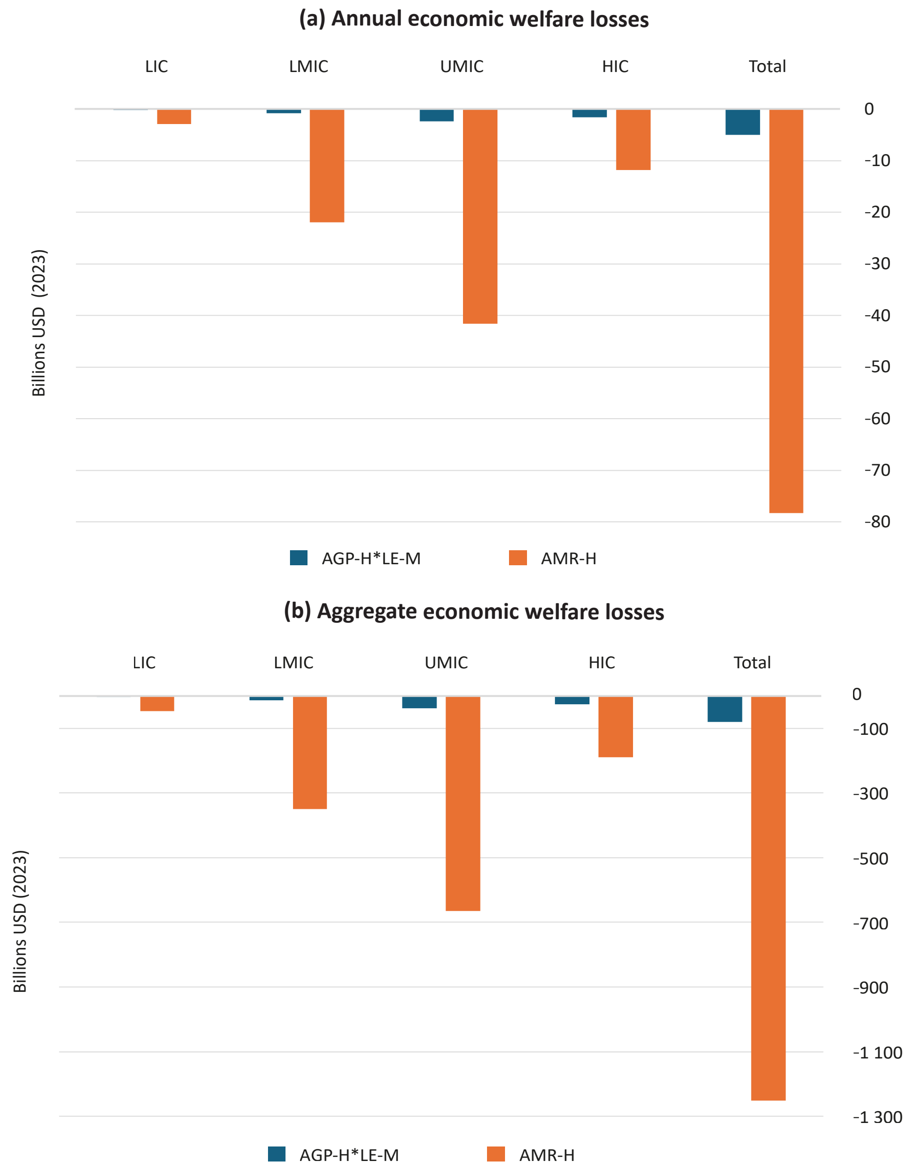
Source: **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M. *et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

becoming the dominant source of GDP decline by 2040 (resulting in losses of about 0.06 percent globally), driven largely by losses in LMICs (around 0.29 percent) and LICs (about 0.09 percent).

Annual and cumulative welfare losses provide a broader view of the economy-wide impacts (see **Figure 20**). In 2040, annual global welfare losses reach about USD 78.2 billion under AMR-H, compared with roughly USD 5.0 billion under AGP-H*LE-M. Over the 2025 to 2040 period, cumulative losses amount to around USD 1.25 trillion under AMR-H, far exceeding the cumulative loss of about USD 80.3 billion under AGP-H*LE-M. More than four-fifths of AMR-related welfare losses accrue to upper-middle-income countries

FIGURE 20

ECONOMIC WELFARE LOSSES BY INCOME GROUP UNDER HIGH-IMPACT ANTIMICROBIAL GROWTH PROMOTER AND ANTIMICROBIAL RESISTANCE SCENARIOS, 2025–2040



This figure presents modelled global welfare losses by country income group under the highest-impact antimicrobial growth promoter (AGP) withdrawal and antimicrobial resistance (AMR) scenarios. Panel (a) shows annual welfare losses in 2040, while panel (b) displays cumulative losses over the period 2025–2040. Losses are expressed in constant 2023 billions USD and disaggregated by World Bank country income classifications: low-income countries (LICs), lower-middle-income countries (LMICs), upper-middle-income countries (UMICs), and high-income countries (HICs). Welfare losses under AMR are substantially larger and more persistent than those associated with AGP withdrawal, with the majority of cumulative losses accruing to UMICs and LMICs, highlighting the strong distributional dimension of AMR-related economic impacts.

Source: **Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M. *et al.*** 2026. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

(UMICs) and LMICs, with UMICs bearing roughly half of the global total. LICs, although having smaller livestock sectors, still experience sizeable losses through spillovers on consumption, wages and value chain linkages. Taken together, these results show that AMR-related production deterioration compounds through markets and factor allocation, whereas the adjustment following AGP withdrawal remains temporary and limited in scale.

INTERPRETING ECONOMIC TRADE-OFFS BETWEEN ACTION AND INACTION

The results point to a clear economic asymmetry between the effects associated with phasing out AGPs and those linked to the progression of AMR. In the AGP withdrawal scenarios, productivity losses emerge as an immediate response to policy action but remain largely transitory. Even under relatively adverse assumptions on enforcement, global livestock production returns to close to baseline levels within a few years, reflecting producers' capacity to adjust through alternative practices such as improved biosecurity, vaccination, nutrition and herd management. As a result, deviations from the baseline are limited in the long run, with cumulative production losses under the most severe AGP scenario reaching about 21.5 Mt by 2040.

By contrast, AMR is modelled as a cumulative biological process that progressively constrains livestock productivity through higher mortality and disease burden. Unlike AGP withdrawal, AMR does not trigger an endogenous recovery mechanism in the model. Its effects therefore compound over time, even if initial annual losses appear modest. Under the high-AMR scenario, global livestock output in 2040 is around 15 Mt lower than the baseline, corresponding to a 2.2 percent deviation and offsetting roughly 16 percent of the projected production growth between 2025 and 2040. This dynamic illustrates how AMR can act as a "silent shock". Early impacts are relatively small and diffuse, while long-run losses become increasingly dominant.

The contrast between the two shocks is particularly evident when cumulative effects are considered. While AGP-related losses are front-loaded and stabilize as adjustment occurs, AMR-related losses continue to rise throughout the projection horizon. The cumulative production loss trajectories intersect around 2028, when both the AGP-H*LE-M and AMR-H scenarios reach roughly 20 Mt of foregone output. Beyond this point, AMR becomes the dominant source of long-run production losses, reaching about 149 Mt cumulatively by 2040. Valued at constant global prices, these trajectories correspond to cumulative losses of approximately USD 53 billion for AGP withdrawal and over USD 318 billion for AMR, a gap that widens markedly after 2030.

Heterogeneity across commodities and income groups further shapes these outcomes. Following AGP withdrawal, pork and poultry systems, which rely more heavily on intensive production practices, experience larger short-term declines but also exhibit relatively rapid recovery. In contrast, AMR-related losses are more persistent and broadly distributed across beef, milk, pork, poultry and eggs. From a distributional perspective, long-run welfare impacts are concentrated in UMICs and LMICs, which together account for more than four-fifths of global AMR-related welfare losses. Although livestock represents only about 1.1 percent of global value added, AMR-related shocks propagate through prices, incomes and consumption, generating cumulative global welfare losses of around USD 1.25 trillion over 2025–2040 under the high-AMR scenario, compared with roughly USD 80 billion under the most severe AGP withdrawal scenario.

Taken together, these findings highlight that the economic relevance of antimicrobial stewardship lies less in avoiding short-term adjustment costs and more in preventing the accumulation of long-term, system-wide losses (Acosta *et al.*, 2026b). From a One Health perspective, the analysis reinforces that the core policy challenge is intertemporal. Short-run production impacts associated with AGP phase-out are visible and politically salient, whereas the costs of rising AMR emerge gradually and are harder to attribute until they become substantial. Recognizing this imbalance is essential for aligning private production incentives with long-term societal welfare and for motivating timely and coordinated policy responses.

POLICY INSIGHTS

This chapter highlights a fundamental economic asymmetry relevant for policy design. Measures aimed at reducing AMU, such as phasing out AGPs, tend to generate short-term and largely transitory production and income losses, while the costs of inaction in the face of rising AMR materialize gradually and persist over time. In practice, this means that adjustment costs are visible and immediate, whereas the benefits of prevention accrue slowly and often beyond typical policy horizons.

As AMR progresses, productivity losses compound through livestock markets and spill over into the wider economy, eroding output, income and welfare in the absence of an endogenous adjustment mechanism. Because these long-term costs are initially diffuse and difficult to attribute, they are frequently underweighted in decision-making, contributing to delayed intervention and underinvestment in preventive action.

From a policy perspective, the central trade-off is therefore not between economic performance and antimicrobial stewardship, but between absorbing manageable short-term adjustment costs today and facing substantially larger and more persistent economic losses in the future. Recognizing this temporal imbalance is essential for sequencing policy action, designing supportive transition measures, and motivating international coordination to address a challenge whose economic and welfare implications extend well beyond national borders. In this sense, the investment needed to absorb the transitional economic cost of action is estimated at USD 28.4 billion.

5. Reframing livestock antimicrobial use as a global public good

Despite intensified efforts, the analysis presented in Chapter 2 of this report indicates that antimicrobial use (AMU) in livestock is likely to continue increasing under current trajectories. This trend is driven not just by technical constraints, but by governance and incentive structures that allow one of humanity's most valuable health resources to be eroded by short-term private gains (Hollis and Maybarduk, 2015; Roope *et al.*, 2019).[5]

Antimicrobial misuse and overuse in livestock accelerate antimicrobial resistance (AMR) in ways that can outpace mitigation efforts, with consequences that extend well beyond farms (Acosta *et al.*, 2025b). What is at stake is not the physical availability of antimicrobials, but their effectiveness, understood as the ability of these drugs to prevent or treat infections over time. Antimicrobial effectiveness is inherently shared across borders. When one country reduces unnecessary AMU, others benefit. When resistance emerges in one setting, treatment options can deteriorate elsewhere. As a result, the benefits of stewardship are global and long-term, while the economic gains from overuse remain immediate and local (Hollis and Maybarduk, 2015). This misalignment between private incentives and social costs leads to AMU that exceeds socially optimal levels.

Political recognition of this challenge has increased, from the 2022 Muscat Ministerial Manifesto to the 2024 United Nations General Assembly Declaration and the 2024 Jeddah Commitments (FAO *et al.*, 2022; UNGA, 2024; Fourth Global High-Level Ministerial Conference on AMR, 2024). Yet policy responses remain fragmented and largely voluntary. Technical measures such as improved veterinary oversight, enhanced surveillance, and better husbandry practices are essential, but may have limited impact when implemented in isolation (FAO, 2021; FAO and WHO, 2023). Without stronger governance arrangements and better-aligned incentives, national stewardship plans are less likely to deliver sustained reductions in AMU at scale.

From an economic perspective, the inability to confine antimicrobial effectiveness within national boundaries implies that even well-designed domestic policies may fall short. Reductions in AMU generate benefits beyond national borders, while resistance arising in one location can undermine treatment efficacy elsewhere through trade, travel, and environmental pathways. This cross-border interdependence points to a collective action problem that may be difficult to address through national efforts alone and underscores the role of coordinated international action under a One Health approach (Acosta *et al.*, 2026c).

Against this background, framing antimicrobial effectiveness as a global public good (GPG) offers a useful lens for understanding why existing stewardship efforts remain limited in their ability to deliver sustained reductions in AMU, and for structuring more coherent responses. Rather than assuming a lack of concern among producers or governments, this perspective highlights the structural gap between local decision-making and global consequences. Building on this framing, this chapter examines how governance arrangements and economic instruments might help better align incentives across farms, value chains, national authorities and international coordination, with the aim of slowing the erosion of antimicrobial effectiveness and safeguarding livestock productivity, food security, and public health.

CHALLENGES WITH EXISTING APPROACHES

Current antimicrobial stewardship efforts in livestock are predominantly framed at the national or sectoral level. While such initiatives can generate measurable improvements, their effectiveness is often constrained when addressing challenges that are global in scope and shaped by collective action problems (Hollis and Maybarduk, 2015; Roope *et al.*, 2019).

One central weakness is fragmented governance. National action plans are often voluntary, unevenly enforced within and across countries, and rarely designed with mechanisms to account for the cross-border spillovers of national decisions (Rochford *et al.*, 2018; FAO and WHO, 2023). As a result, a country may adopt strict regulations on AMU in livestock production yet still face rising resistance

[5] This chapter synthesizes findings from the peer-reviewed study **Acosta, A., Nicolli, F., Dalton, R., Valcarce, A., Kabali, E., Dorado Garcia, A., Bullon, C., Tirkaso, W. & Song, J.** 2026. Reframing livestock antimicrobial use as a global public good. *One Health*, 22: 101349. https://doi.org/10.1016/j.onehlt.2026.101349

levels if neighbouring countries or trading partners maintain high-use practices. Resistant bacteria and resistance genes can spread through trade in live animals, food products, and feed, as well as via environmental pathways such as water systems (Van Boeckel *et al.*, 2017).

These governance challenges are further compounded in contexts where antimicrobials are accessed through informal or unauthorized supply chains. In such settings, stewardship policies that rely on regulated distribution channels and formal compliance mechanisms face inherent limitations, as enforcement capacity is weakened and use decisions occur outside official oversight. Recent work highlights that widespread over-the-counter access to antibiotics in many low-income countries (LICs) and lower-middle-income countries (LMICs) reflects broader health system constraints rather than isolated regulatory failure, underscoring the need for stewardship approaches that are compatible with existing supply realities while progressively strengthening formal control mechanisms (Mendelson *et al.*, 2025).

Economic incentives further weaken stewardship efforts. Livestock producers often derive immediate private benefits from AMU, including reduced disease risk, higher productivity and more predictable output. By contrast, the costs associated with AMR, such as declining treatment efficacy, increased morbidity and higher veterinary and medical expenditures, are diffuse, delayed, and largely absent from market prices (Hollis and Maybarduk, 2015). In the absence of corrective policies, these incentives encourage levels of AMU that exceed what would be socially optimal.

Structural constraints also limit the effectiveness of technical interventions, particularly in LICs and LMICs. Limited infrastructure, inadequate veterinary services and restricted access to diagnostics or vaccines often prevent improved practices from reaching scale (Farrell *et al.*, 2021; Visschers *et al.*, 2014). Even market-based instruments such as certification schemes or residue monitoring can reinforce inequities if compliance costs fall disproportionately on smallholders or exporters without accompanying support (Xu *et al.*, 2023; Schell *et al.*, 2023).

Taken together, these limitations indicate that current stewardship approaches, while necessary, risk being insufficient when pursued primarily through voluntary or domestic measures alone. Addressing AMR in livestock will benefit from complementing national action plans with governance arrangements that support cross-border coordination, better align incentives with shared outcomes, and facilitate implementation according to capacity and impact.

RECONCEPTUALIZING ANTIMICROBIAL USE THROUGH A GLOBAL PUBLIC GOOD LENS

The persistent misuse and overuse of antimicrobials in livestock reflects the logic of a shared resource whose benefits are immediate and private, while the costs are delayed and widely dispersed. Viewing antimicrobial effectiveness through a GPG lens helps explain why stewardship efforts that rely primarily on national action and voluntary compliance struggle to deliver sustained reductions in use (Kaul, Grunberg and Stern, 1999; Buchholz and Sandler, 2021).

Antimicrobial effectiveness has two defining economic properties. It is non-rival in the sense that prudent use by one actor does not reduce its availability to others. It is also effectively non-excludable at the global level, since preserved effectiveness cannot be confined within national borders, and resistance emerging in one setting can undermine treatment options elsewhere. Trade, travel, and environmental pathways facilitate transboundary spillovers (i.e. the spread of resistant organisms and genes across regions, nations and continents), thereby linking local use decisions to global outcomes (Van Boeckel *et al.*, 2017). In the absence of coordinated governance, these characteristics create strong incentives for overuse (Hollis and Maybarduk, 2015; Roope *et al.*, 2019).

At the producer level, AMU generates tangible private benefits, including reduced mortality, improved feed conversion and more predictable output. By contrast, the broader social costs associated with AMR accrue slowly, often outside the sector or country where use occurs. Because these costs are not reflected in production decisions, AMU tends to exceed socially optimal levels (Cornes and Sandler, 1984).

Economic instruments offer one avenue to address this imbalance. Tradable permit systems can establish enforceable caps on AMU while allowing flexibility through exchange among users (Roope *et al.*, 2019). Taxes on veterinary antimicrobials can discourage non-essential use and generate resources for investment in preventive measures and alternatives (Morgan, Moran and Van Boeckel, 2023). To be effective, such instruments must be paired with measures that reduce the cost and risk of adopting vaccines, diagnostics, biosecurity and improved husbandry practices (Van Boeckel *et al.*, 2017).

The global impact of AMU also depends on how individual actions aggregate. In the context of AMR, all countries contribute to the global resistance pool, but those with large livestock sectors or high AMU intensity exert disproportionate influence (Sandler, 2004). Strong veterinary services and stewardship systems can mitigate these effects, while institutional weaknesses can amplify risks, even in smaller producing countries, if resistant pathogens spread through trade or live animal movements.

Trade plays a dual role in this context. On one hand, it facilitates the transmission of resistant organisms across borders. On the other, it can create incentives for improved stewardship when access to high-value markets depends on compliance with the standards set by WOAH and the Codex Alimentarius. For LICs and LMICs, meeting higher requirements often requires targeted investment support to avoid exacerbating existing inequities (FAO and WHO, 2023; DANMAP, 2020).

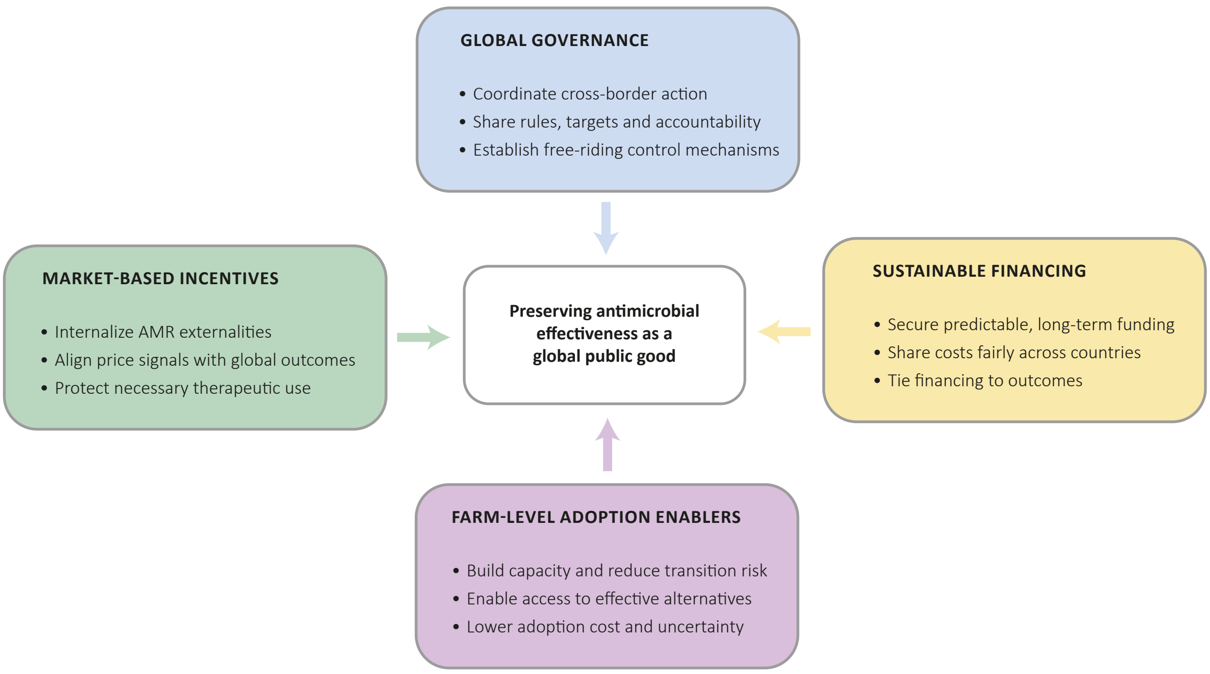
Taken together, non-rivalry, non-excludability and transboundary spillovers create a classic commons problem. Addressing it requires institutions capable of translating shared global objectives into credible incentives at the national and sectoral levels, embedding stewardship within trade and market structures, and supporting monitoring systems that enable mutual accountability. Without such arrangements, antimicrobial effectiveness faces a continued risk of erosion, with consequences that are both irreversible and widely shared.

TOWARDS A GLOBAL FRAMEWORK FOR ANTIMICROBIAL STEWARDSHIP

Recognizing antimicrobial effectiveness as a GPG provides a basis for rethinking the policy and institutional arrangements relevant to addressing AMR (Acosta *et al.*, 2026c). This section synthesizes the preceding analysis into an integrated framework for antimicrobial stewardship that places antimicrobial effectiveness at the centre and highlights how outcomes depend on the interaction of international governance, economic incentives, sustainable financing and farm-level adoption. (See **Figure 21** for a visual summary of this framework.) Rather than prescribing specific instruments, the framework illustrates how these elements must align to support sustained reductions in AMU while preserving access for animal health needs.

The progress that has been made through the Quadripartite collaboration (FAO, WHO, WOAH and UNEP) has strengthened technical guidance and coordination through mechanisms such as the AMR Multi-Stakeholder Partnership Platform and the Global Leaders Group on AMR. However, these arrangements

FIGURE 21
TOWARDS A GLOBAL POLICY FRAMEWORK TO PRESERVE ANTIMICROBIAL EFFECTIVENESS AS A GLOBAL PUBLIC GOOD



This figure illustrates the framework for preserving antimicrobial effectiveness through integrated governance and policy instruments. It highlights the main drivers of preservation and the corresponding challenges associated with each.

Source: **Acosta, A., Nicolli, F., Dalton, R., Valcarce, A., Kabali, E., Dorado Garcia, A., Bullon, C., Tirkaso, W. & Song, J.** 2026. Reframing livestock antimicrobial use as a global public good. *One Health*, 22: 101349. https://doi.org/10.1016/j.onehlt.2026.101349 remain largely advisory and have limited capacity to ensure consistent implementation or accountability across countries (Rochford *et al.*, 2018; FAO and WHO, 2023). Strengthening the Quadripartite Joint Secretariat through clearer mandates, predictable operational resources, and enhanced capacity to support national implementation could improve coherence across sectors. Recent recognition of the role of the Quadripartite Joint Secretariat under the One Health framework in the 2024 United Nations General Assembly Political Declaration provides an opportunity to further institutionalize this function.

Independent scientific input is also essential for credible decision-making. The Independent Panel on Evidence for Action Against AMR (IPEA), endorsed in the 2024 Declaration and outlined in the Quadripartite AMR Roadmap, is intended to provide integrated assessments and policy-relevant guidance across sectors. For this body to be effective, it will require institutional independence, adequate resourcing and a clearly defined role in informing target setting, monitoring progress, and promoting learning across countries. Over time, more formal international arrangements could help clarify shared responsibilities and support sustained collective action.

Governance reforms alone are unlikely to correct the market failures that drive antimicrobial overuse. Producers often face immediate private benefits from AMU through reduced disease risk and more predictable output, while the broader costs associated with resistance remain diffuse and delayed (Hollis and Maybarduk, 2015; Roope *et al.*, 2019). Economic instruments can help internalize these costs. Approaches such as tradable allowance systems or targeted taxation may discourage unnecessary use while preserving access for therapeutic purposes, provided they are designed with sufficient flexibility to respond to animal health needs (Roope *et al.*, 2019; Morgan, Moran and Van Boeckel, 2023). These instruments are most effective when combined with measures that reduce the cost and risk of adopting preventive practices, including vaccination, diagnostics, and improved biosecurity and husbandry (Van Boeckel *et al.*, 2017).

Financing is a critical link between policy ambition and implementation. Many countries, particularly those in the low- and middle-income groups, lack dedicated budget lines for AMR and continue to rely heavily on short-term external funding (FAO and WHO, 2023). Integrating antimicrobial stewardship into national budgetary processes and public investment planning can improve sustainability and strengthen national ownership. At the international level, blended finance, concessional lending and results-based mechanisms may help mobilize resources for investments that reduce dependence on antimicrobials, including animal health infrastructure and preventive technologies.

Beyond overall resource mobilization, financing arrangements should reflect equitable burden-sharing given the cross-border benefits of stewardship. Countries that deliver substantial global benefits through reductions in AMU may warrant co-financing, particularly where domestic fiscal space is limited. Linking financial support to measurable outcomes, such as verified reductions in use or strengthened surveillance capacity, can reinforce accountability. In this context, global monitoring platforms – including the Global Antimicrobial Resistance and Use Surveillance System (GLASS), the global database on Animal Antimicrobial Use (ANIMUSE), the International FAO Antimicrobial Resistance Monitoring (InFARM) system, and the Quadripartite Global Integrated System for Surveillance of AMR and AMU (GISSA) – provide a common evidence base for tracking progress and supporting mutual confidence.

Ultimately, the effectiveness of stewardship efforts depends on decisions made at the farm level. While price signals matter, they are insufficient if producers lack access to veterinary services, diagnostics, credit or reliable information. Capacity-building initiatives such as Farmer Field Schools, veterinary outreach and peer learning can support behavioural change by reducing uncertainty and strengthening confidence in preventive practices (Farrell *et al.*, 2021; Visschers *et al.*, 2014). A useful example in this direction is FAO's RENOFARM initiative, which supports farm-level adoption through a combination of services, good practices, alternatives and incentives designed to reduce the need for antimicrobials (FAO, 2024).

Actors along the value chain also play an important role. Processors and retailers can reinforce stewardship by integrating AMU criteria into procurement standards, offering price premiums, or establishing longer-term contractual arrangements. Public policy can complement these efforts through co-financing, risk-sharing mechanisms and targeted support for investments in housing, biosecurity and animal health. In the absence of such enabling conditions, resource-constrained producers are likely to remain locked into production systems that depend heavily on AMU.

POLICY INSIGHTS

Preserving antimicrobial effectiveness is ultimately a test of whether the international community can act collectively to safeguard a resource whose value depends on responsible use and effective governance to limit the gradual and often invisible spread of resistance. In livestock systems, this challenge is shaped not only by technical constraints but by structural misalignments between local decision-making and global consequences. As this chapter has shown, antimicrobial effectiveness exhibits key features of a GPG, making it vulnerable to overuse when stewardship relies primarily on voluntary or nationally bounded approaches.

Many of the elements required to address this challenge are already in place. Technical guidance, surveillance systems, market-based tools and preventive practices are well established, and recent political commitments reflect growing recognition of the risks associated with rising antimicrobial use. Yet these elements remain insufficiently integrated within governance arrangements capable of aligning incentives, mobilizing sustained financing and supporting implementation across countries and production systems. The central constraint is therefore institutional rather than technological.

Reframing antimicrobial effectiveness as a GPG provides a coherent economic rationale for strengthening international cooperation and for linking national stewardship efforts more explicitly to shared global outcomes. Rather than prescribing specific policy instruments, this perspective highlights the importance of coordinated governance, incentive-compatible economic tools, predictable financing and farm-level capacity as mutually reinforcing components of effective stewardship under a One Health approach.

From a policy perspective, the key lesson is that preserving antimicrobial effectiveness requires moving beyond fragmented action toward more coherent and mutually supportive policy mixes. Progress will depend on countries' ability to translate shared recognition of the problem into sustained cooperation while tailoring implementation pathways to national contexts and capacities. Strengthening coordination, improving alignment between short-term incentives and long-term outcomes, and supporting adoption at the farm level are therefore central to safeguarding antimicrobial effectiveness as a foundation for livestock productivity, food security and public health.

References

Acosta, A., Nicolli, F. & Karfakis, P. 2021. Coping with climate shocks: The complex role of livestock portfolios. *World Development*, 146: 105546. https://doi.org/10.1016/j.worlddev.2021.105546

Acosta, A., Nicolli, F. & Tirkaso, W. 2024. Cattle ownership and households' welfare: Evidence from Southern Africa. *Global Food Security*, 42: 100772. https://doi.org/10.1016/j.gfs.2024.100772

Acosta, A., Roland-Holst, D., Nicolli, F., Tirkaso, W., Rocha, J.S. & Song, J. 2025a. A One Health framework to assess the economic returns on investment in livestock antimicrobial stewardship. *One Health*, 21: 101188. https://doi.org/10.1016/j.one-hlt.2025.101188

Acosta, A., Tirkaso, W., Nicolli, F., Van Boeckel, T.P., Cinardi, G. & Song, J. 2025b. The future of antibiotic use in livestock. *Nature Communications*, 16(1): 2469. https://doi.org/10.1038/s41467-025-56825-7

Acosta, A., Cardinal, K.M., Nicolli, F., Onofrio, F. & Song, J. 2026a. Global impact of antimicrobial growth promoters on livestock productivity: A meta-analysis for economic modeling. *Preventive Veterinary Medicine*, 250: 106754. https://doi.org/10.1016/j.prevetmed.2025.106754

Acosta, A., Tirkaso, W., Artavia, M., Nicolli, F., Chatzopoulos, T., Araujo, S., Cicowiez, M. ***et al.*** 2026b. Antimicrobial Use in Livestock: The Economic Cost of Action or Inaction. *Journal of Agricultural Economics*, 77(2). https://doi.org/10.1111/1477-9552.70041

Acosta, A., Nicolli, F., Dalton, R., Valcarce, A., Kabali, E., Dorado Garcia, A., Bullon, C., Tirkaso, W. & Song, J. 2026c. Reframing livestock antimicrobial use as a global public good. *One Health*, 22: 101349. https://doi.org/10.1016/j.onehlt.2026.101349

Adamie, B.A., Akwar, H.T., Arroyo, M., Bayko, H., Hafner, M., Harrison, S., Jeannin, M., ***et al.*** 2024. *Forecasting the Fallout from AMR: Economic Impacts of Antimicrobial Resistance in Food-Producing Animals – A report from the EcoAMR series.* Paris & Washington, D.C., World Organisation for Animal Health and World Bank. https://doi.org/10.20506/ecoAMR.3541

Akpan, S.B., Udoh, E.J. & Nkanta, V.S. 2023. Agricultural Credit Policy and Livestock Development in Nigeria. *Problems of World Agriculture*, 23(3): 45–60. https://doi.org/10.22630/PRS.2023.23.3.11

Anomaly, J. 2009. Harm to others: The social cost of antibiotics in agriculture. *Journal of Agricultural and Environmental Ethics*, 22(5): 423–435. https://doi.org/10.1007/s10806-009-9160-y

Babo Martins, S., Sucena Afonso, J., Fastl, C., Huntington, B. & Rushton, J. 2024. The burden of antimicrobial resistance in livestock: A framework to estimate its impact within the Global Burden of Animal Diseases programme. *One Health*, 19: 100917. https://doi.org/10.1016/j.onehlt.2024.100917

Birgand, G., Castro-Sánchez, E., Hansen, S., Gastmeier, P., Lucet, J.C., Ferlie, E., Holmes, A. & Ahmad, R. 2018. Comparison of governance approaches for the control of antimicrobial resistance: Analysis of three European countries. *Antimicrobial Resistance and Infection Control*, 7: 28. https://doi.org/10.1186/s13756-018-0321-5

Buchholz, W. & Sandler, T. 2021. Global Public Goods: A Survey. *Journal of Economic Literature*, 59(2): 488–545. https://doi.org/10.1257/jel.20191546

Bulut, E. & Ivanek, R. 2022. Comparison of different biomass methodologies to adjust sales data on veterinary antimicrobials in the USA. *Journal of Antimicrobial Chemotherapy*, 77(3): 827–842. https://doi.org/10.1093/jac/dkab441

Cornes, R. & Sandler, T. 1984. Easy Riders, Joint Production, and Public Goods. *The Economic Journal*, 94(375): 580–598. https://doi.org/10.2307/2232704

DANMAP (The Danish Integrated Antimicrobial Resistance Monitoring and Research Programme). 2020. *DANMAP 2019 – Use of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from food animals, food and humans in Denmark*. Copenhagen, Statens Serum Institut & National Food Institute, Technical University of Denmark. https://www.danmap.org/reports/2019

Detmann, E., Paulino, M.F., de Campos Valadares Filho, S. & Huhtanen, P. 2014. Nutritional aspects applied to grazing cattle in the tropics: a review based on Brazilian results. *Semina: Ciências Agrárias*, 35(4): 2829–2854. https://bvs-vet.org.br/vetindex/periodicos/semina-ciencias-agrarias/35-(2014)-4/nutritional-aspects-applied-to-grazing-cattle-in-the-tropics-a-review-/

Dibner, J.J. & Richards, J.D. 2005. Antibiotic growth promoters in agriculture: history and mode of action. *Poultry Science*, 84(4): 634–643. https://doi.org/10.1093/ps/84.4.634

FAO (Food and Agriculture Organization of the United Nations) & WHO (World Health Organization). 2023. *Report of the Forty-sixth Session of the Codex Alimentarius Commission, 27 November–2 December 2023*. Rome, FAO and WHO. https://www.fao.org/fao-who-codexalimentarius/sh-proxy/hu/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FMeetings%252FCX-701-46%252F%25E2%2598%2585Final%252520Report%252FREP23_CACe.pdf

FAO, WHO, WOAH (World Organisation for Animal Health) & UNEP (United Nations Environment Programme). 2022. *Muscat Ministerial Manifesto. Third Global High-level Ministerial Conference on Antimicrobial Resistance, 24–25 November 2022.* Muscat. https://amrconference.omansf.com/MuscatManifesto

FAO. 2015. Resolution 4/2015 – Antimicrobial Resistance. *Report of the Conference of FAO, Thirty-ninth Session*, pp. 45–46. Rome, FAO. Also available at https://resolutionsportal.fao.org/akn/un/statement/deliberation/fao/2015-06-13/4-2015/

FAO. 2018. *World Livestock: Transforming the livestock sector through the Sustainable Development Goals – In brief*. Rome, FAO. https://openknowledge.fao.org/handle/20.500.14283/ca1177en

FAO. 2021. *The FAO Action Plan on Antimicrobial Resistance 2021–2025*. Rome. https://doi.org/10.4060/cb5545en

FAO. 2024. *Reduce the Need for Antimicrobials on Farms for Sustainable Agrifood Systems Transformation (RENOFARM) – Innovation, technologies and hand-in-hand partnerships to address antimicrobial resistance for healthier agrifood systems*. Rome. https://doi.org/10.4060/cd1715en

Farrell, S., McKernan, C., Benson, T., Elliott, C. & Dean, M. 2021. Understanding farmers' and veterinarians' behavior in relation to antimicrobial use and resistance in dairy cattle: A systematic review. *Journal of Dairy Science*, 104(4): 4584–4603. https://doi.org/10.3168/jds.2020-19614

Fortané, N., Bonnet-Beaugrand, F., Hémonic, A., Samedi, C., Savy, A. & Belloc, C. 2015. Learning Processes and Trajectories for the Reduction of Antibiotic Use in Pig Farming: A Qualitative Approach. *Antibiotics*, 4(4): 435–454. https://doi.org/10.3390/antibiotics4040435

Fourth Global High-Level Ministerial Conference on Antimicrobial Resistance. 2024. *Jeddah Commitments*. Fourth Global High-Level Ministerial Conference on Antimicrobial Resistance, 15–16 November 2024. Jeddah, the Kingdom of Saudi Arabia. https://amrconference2024.com/documents/16_11_THE_JEDDAH_COMMITMENTS.pdf

Góchez, D., Raicek, M., Ferreira, J.P., Jeannin, M., Moulin, G. & Erlacher-Vindel, E. 2019. OIE Annual Report on Antimicrobial Agents Intended for Use in Animals: Methods Used. *Frontiers in Veterinary Science*, 6: 317. https://doi.org/10.3389/fvets.2019.00317

Hernando-Amado, S., Coque, T.M., Baquero, F. & Martínez, J.L. 2019. Defining and combating antibiotic resistance from One Health and Global Health perspectives. *Nature Microbiology*, 4: 1432–1442. https://doi.org/10.1038/s41564-019-0503-9

Herrero, M., Grace, D., Njuki, J., Johnson, N., Enahoro, D., Silvestri, S. & Rufino, M.C. 2013. The roles of livestock in developing countries. *Animal*, 7(Supplement 1): 3–18. https://doi.org/10.1017/S1751731112001954

Hollis, A. & Maybarduk, P. 2015. Antibiotic Resistance is a Tragedy of the Commons That Necessitates Global Cooperation. *Journal of Law, Medicine & Ethics*, 43(Supplement 3): 33–37. https://doi.org/10.1111/jlme.12272

Kaul, I., Grunberg, I. & Stern, M., eds. 1999. *Global Public Goods: International Cooperation in the 21st Century*. Oxford, UK, Oxford University Press. https://doi.org/10.1093/0195130529.001.0001

Kirchhelle, C. 2018. Pharming animals: A global history of antibiotics in food production (1935–2017). *Palgrave Communications*, 4: 96. https://doi.org/10.1057/s41599-018-0152-2

Landers, T.F., Cohen, B., Wittum, T.E. & Larson, E.L. 2012. A Review of Antibiotic Use in Food Animals: Perspective, Policy, and Potential. *Public Health Reports*, 127(1): 4–22. https://doi.org/10.1177/003335491212700103

Laxminarayan, R., Matsoso, P., Pant, S., Brower, C., Røttingen, J.-A., Klugman, K. & Davies, S. 2016. Access to effective antimicrobials: a worldwide challenge. *The Lancet*, 387(10014): 168–175. https://doi.org/10.1016/S0140-6736(15)00474-2

Laxminarayan, R., Van Boeckel, T. & Teillant, A. 2015. *The Economic Costs of Withdrawing Antimicrobial Growth Promoters from the Livestock Sector.* OECD Food, Agriculture and Fisheries Papers, No. 78. Paris, OECD Publishing. https://doi.org/10.1787/5js64kst5wvl-en

Lazzarini, Í., Detmann, E., de Campos Valadares Filho, S., Fonseca Paulino, M., Batista, E.D., de Almeida Rufino, L.M., Santiago dos Reis, W.L. & de Oliveira Franco, M. 2016. Nutritional Performance of Cattle Grazing during Rainy Season with Nitrogen and Starch Supplementation. *Asian-Australasian Journal of Animal Sciences*, 29(8): 1120–1128. https://doi.org/10.5713/ajas.15.0514

Lhermie, G., Gröhn, Y.T. & Raboisson, D. 2017. Addressing Antimicrobial Resistance: An Overview of Priority Actions to Prevent Suboptimal Antimicrobial Use in Food-Animal Production. *Frontiers in Microbiology*, 7: 2114. https://doi.org/10.3389/fmicb.2016.02114

Li, Y., Mayberry, D. & Rushton, J. 2024. Estimating livestock biomass across diverse populations and data ecosystems. *Revue scientifique et technique*, 43: 23–29. https://doi.org/10.20506/rst.43.3514

MacDonald, J.M. 2008. *The Economic Organization of U.S. Broiler Production.* USDA Economic Information Bulletin, No. 38. Washington, D.C., United States Department of Agriculture, Economic Research Service. https://www.ers.usda.gov/publications/pub-details?pubid=44256

Maron, D.F., Smith, T.J.S. & Nachman, K.E. 2013. Restrictions on antimicrobial use in food animal production: an international regulatory and economic survey. *Globalization and Health*, 9: 48. https://doi.org/10.1186/1744-8603-9-48

Mendelson, M., Afari-Asiedu, S., Schellack, N., Wertheim, H., Mpundu, M. & Gautham, M. 2025. Facing up to reality: over-the-counter access to antibiotics in low-income and middle-income countries needs a paradigm shift in thinking. *The Lancet Global Health*, 13(12): e2175–e2179. https://doi.org/10.1016/S2214-109X(25)00394-8

Mendelson, M., Røttingen, J.A., Gopinathan, U., Hamer, D.H., Wertheim, H., Basnyat, B., Butler, C., Tomson, G. & Balasegaram, M. 2016. Maximising access to achieve appropriate human antimicrobial use in low-income and middle-income countries. *The Lancet*, 387(10014): 188–198. https://doi.org/10.1016/s0140-6736(15)00547-4

Moran, D. 2019. A framework for improved one health governance and policy making for antimicrobial use. *BMJ Global Health*, 4(5): e001807. https://doi.org/10.1136/bmjgh-2019-001807

Morgan, A.L.K., Moran, D. & Van Boeckel, T.P. 2023. Taxation of veterinary antibiotics to reduce antimicrobial resistance. *One Health*, 17: 100650. https://doi.org/10.1016/j.onehlt.2023.100650

Moses, O., Onimisi, P.A. & **Jegede, J.O.** 2017. Effect of Different Inclusion Levels of CRINA® Poultry Plus as Replacement for Antibiotic Growth Promoters on the Performance of Broiler Chickens Reared under Field Conditions in Nigeria. *Nigerian Journal of Animal Science*, 19(2): 62–71. https://www.ajol.info/index.php/tjas/article/view/163909

Murray, C.J.L., Ikuta, K.S., Sharara, F., Swetschinski, L., Robles Aguilar, G., Gray, A., Han, C. *et al.* 2022. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *The Lancet*, 399(10325): 629–655. https://doi.org/10.1016/S0140-6736(21)02724-0

Niewold, T.A. 2007. The Nonantibiotic Anti-Inflammatory Effect of Antimicrobial Growth Promoters, the Real Mode of Action? A Hypothesis. *Poultry Science*, 86(4): 605–609. https://doi.org/10.1093/ps/86.4.605

Normile, D. 2019. African swine fever marches across much of Asia. *Science*, 364(6441): 617–618. https://doi.org/10.1126/science.364.6441.617

O'Neill, J. 2016. *Tackling drug-resistant infections globally: final report and recommendations*. London, The Review on Antimicrobial Resistance. https://amr-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf

OECD (Organisation for Economic Co-operation and Development) & FAO. 2024. *OECD–FAO Agricultural Outlook 2024–2033*. Paris & Rome, OECD & FAO. https://doi.org/10.1787/4c5d2cfb-en

Padiyara, P., Inoue, H. & Sprenger, M. 2018. Global Governance Mechanisms to Address Antimicrobial Resistance. *Infectious Diseases: Research and Treatment*, 11: 1–4. https://doi.org/10.1177/1178633718767887

Raboisson, D., Ferchiou, A., Sans, P., Lhermie, G. & Dervillé, M. 2020. The economics of antimicrobial resistance in veterinary medicine: Optimizing societal benefits through mesoeconomic approaches from public and private perspectives. *One Health*, 10: 100145. https://doi.org/10.1016/j.onehlt.2020.100145

Radke, B.R. 2017. Towards an improved estimate of antimicrobial use in animals: Adjusting the "population correction unit" calculation. *Canadian Journal of Veterinary Research*, 81(3): 235–240. https://pubmed.ncbi.nlm.nih.gov/28725116/

Reardon, T., Echeverría, R., Berdegué, J., Minten, B., Liverpool-Tasie, S., Tschirley, D. & Zilberman, D. 2019. Rapid transformation of food systems in developing regions: Highlighting the role of agricultural research & innovations. *Agricultural Systems*, 172: 47–59. https://doi.org/10.1016/j.agsy.2018.01.022

Rochford, C., Sridhar, D., Woods, N., Saleh, Z., Hartenstein, L., Ahlawat, H., Whiting, E., *et al.* 2018. Global governance of antimicrobial resistance. *The Lancet*, 391(10134): 1976–1978. https://doi.org/10.1016/S0140-6736(18)31117-6

Roope, L.S.J., Smith, R.D., Pouwels, K.B., Buchanan, J., Abel, L., Eibich, P., Butler, C.C. *et al.* 2019. The challenge of antimicrobial resistance: What economics can contribute. *Science*, 364(6435): eaau4679. https://doi.org/10.1126/science.aau4679

Ruckert, A., Fafard, P., Hindmarch, S., Morris, A., Packer, C., Patrick, D., Weese, S., *et al.* 2020. Governing antimicrobial resistance: A narrative review of global governance mechanisms. *Journal of Public Health Policy*, 41: 515–528. https://doi.org/10.1057/s41271-020-00248-9

Ryan, M. 2019. *Evaluating the economic benefits and costs of antimicrobial use in food-producing animals*. OECD Food, Agriculture and Fisheries Papers No. 132. Paris, OECD Publishing. https://doi.org/10.1787/f859f644-en

Sandler, T. 2004. *Global Collective Action*. Cambridge, UK, Cambridge University Press. https://doi.org/10.1017/CBO9780511617119

Schell, R.C., Bulut, E., Padda, H., Greiner Safi, A., Moroni, P. & Ivanek, R. 2023. Responsible antibiotic use labelling and consumers' willingness to buy and pay for fluid milk. *Journal of Dairy Science*, 106(1): 132–150. https://doi.org/10.3168/jds.2022-21791

Shami, A., Abdallah, M., Alruways, M.W., Mostafa, Y.S., Alamri, S.A., Ahmed, A.E., Al Ali, A. & Ali, M.E. 2024. Comparative Prevalence of Virulence Genes and Antibiotic Resistance in *Campylobacter jejuni* Isolated from Broilers, Laying Hens and Farmers. *Pakistan Veterinary Journal*, 44(1): 200–204. https://www.pvj.com.pk/pdf-files/23-553.pdf

Speksnijder, D.C., Jaarsma, D.A.C., Verheij, T.J.M. & Wagenaar, J.A. 2015. Attitudes and perceptions of Dutch veterinarians on their role in the reduction of antimicrobial use in farm animals. *Preventive Veterinary Medicine*, 121(3–4): 365–373. https://doi.org/10.1016/j.prevetmed.2015.08.014

Tang, K.L., Caffrey, N.P., Nóbrega, D.B., Cork, S.C., Ronksley, P.E., Barkema, H.W., Polachek, A.J., *et al.* 2017. Restricting the use of antibiotics in food-producing animals and its associations with antibiotic resistance in food-producing animals and human beings: a systematic review and meta-analysis. *The Lancet Planetary Health*, 1(8): e316–e327. https://doi.org/10.1016/s2542-5196(17)30141-9

Teillant, A. & Laxminarayan, R. 2015. Economics of Antibiotic Use in U.S. Swine and Poultry Production. *Choices*, 30(1): 1–11. https://doi.org/10.22004/ag.econ.197166

Thornton, P.K. 2010. Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1554): 2853–2867. https://doi.org/10.1098/rstb.2010.0134

Umair, M., Hassan, B., Farzana, R., Ali, Q., Sands, K., Mathias, J., Afegbua, S. *et al.* 2023. International manufacturing and trade in colistin, its implications in colistin resistance and One Health global policies: a microbiological, economic, and anthropological study. *The Lancet Microbe*, 4(4): e264–e276. https://doi.org/10.1016/S2666-5247(22)00387-1

UNGA (United Nations General Assembly). 2024. *Political declaration of the high-level meeting on antimicrobial resistance*. United Nations General Assembly. UNGA A/79/L.5. https://documents.un.org/doc/undoc/ltd/n24/278/35/pdf/n2427835.pdf

Van Boeckel, T.P., Brower, C., Gilbert, M., Grenfell, B.T., Levin, S.A., Robinson, T.P., Teillant, A. & Laxminarayan, R. 2015. Global trends in antimicrobial use in food animals. *Proceedings of the National Academy of Sciences*, 112(18): 5649–5654. https://doi.org/10.1073/pnas.1503141112

Van Boeckel, T.P., Glennon, E.E., Chen, D., Gilbert, M., Robinson, T.P., Grenfell, B.T., Levin, S.A., Bonhoeffer, S. & Laxminarayan, R. 2017. Reducing antimicrobial use in food animals. *Science*, 357(6358): 1350–1352. https://doi.org/10.1126/science.aao1495

Van Boeckel, T.P., Pires, J., Silvester, R., Zhao, C., Song, J., Criscuolo, N.G., Gilbert, M., Bonhoeffer, S. & Laxminarayan, R. 2019. Global trends in antimicrobial resistance in animals in low- and middle-income countries. *Science*, 365(6459): eaaw1944. https://doi.org/10.1126/science.aaw1944

Visschers, V.H.M., Iten, D.M., Riklin, A., Hartmann, S., Sidler, X. & Siegrist, M. 2014. Swiss pig farmers' perception and usage of antibiotics during the fattening period. *Livestock Science*, 162: 223–232. https://doi.org/10.1016/j.livsci.2014.02.002

WHO. 2015. *Global action plan on antimicrobial resistance*. Geneva, Switzerland, WHO. https://iris.who.int/handle/10665/193736

WHO. 2019. *Critically important antimicrobials for human medicine*, 6th revision. Geneva, Switzerland, WHO. https://iris.who.int/handle/10665/312266

WOAH (World Organisation for Animal Health). 2016. *Resolution No. 36 – Combating Antimicrobial Resistance through a One Health Approach: Actions and OIE Strategy*. 84th General Session of the World Assembly of Delegates of the OIE, 22–27 May 2016. 84 GS/FR. Paris, WOAH. https://www.woah.org/fileadmin/Home/eng/Our_scientific_expertise/docs/pdf/AMR/A_RESO_AMR_2016.pdf

World Bank. 2017. *Drug-resistant infections: a threat to our economic future*. Washington, D.C., World Bank. http://documents.worldbank.org/curated/en/323311493396993758 Licence: CC-BY-3.0 IGO.

Xu, X., Wang, X., Song, C., Yan, B., Zhang, R., Li, L. & Zhou, X. 2023. The effect of a One Health message intervention on willingness to pay for antibiotic-free animal foods: A randomized controlled trial among Chinese college students. *One Health*, 17: 100612. https://doi.org/10.1016/j.onehlt.2023.100612

Yazdi, F.F., Ghalamkari, G., Toghyani, M., Modaresi, M. & **Landy, N.** 2014. Efficiency of *Tribulus terrestris* L. as an antibiotic growth promoter substitute on performance and immune responses in broiler chicks. *Asian Pacific Journal of Tropical Disease*, 4(Suppl. 2): S1014–S1018. https://doi.org/10.1016/S2222-1808(14)60774-X

Antimicrobial use in livestock is projected to increase by 30 percent by 2040. This report shows why changing that trajectory is an economic, health and food security priority. It examines livestock antimicrobial use through an integrated One Health economic framework that connects microeconomic decisions at the farm and value-chain level with governance capacity, market incentives and macroeconomic outcomes for production, trade, welfare and food security.

The report identifies a central policy dilemma: In the long term, the economic cost of inaction is higher than the cost of action, as antimicrobial resistance accumulates gradually and acts as a silent shock across livestock systems and the wider economy. In the short term, however, action can generate visible adjustment costs. Closing this gap requires transitional investment, estimated at USD 28 billion, to support a shift towards prevention, improved productivity, better husbandry and stronger animal health systems.

The report concludes that preserving antimicrobial effectiveness should be treated as a global public good. Responsible antimicrobial use requires coordinated governance, sustainable financing, appropriate market incentives and capacity building to make change feasible for farmers, value chains and governments. By investing in this transition now, countries can reduce future antimicrobial resistance risks while protecting animal health, public health, food security and economic resilience.

ISBN 978-92-5-140684-7

9 789251 406847

CD9571EN/1/05.26