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Economics of antimicrobial resistance in livestock: charting the path towards antimicrobial resistance neutrality

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Summary

Antimicrobial resistance (AMR) poses a fundamental threat to global health security. The overuse and misuse of antimicrobials for livestock production systems has been highlighted as playing an important role in the emergence and spread of AMR, prompting world leaders to agree on making efforts to reduce antimicrobial use by 2030. By analysing current economic realities and successful transition pathways, this article examines the economic dimensions of achieving 'AMR neutrality' in livestock, a state in which sustainable production is maintained with minimal antimicrobial use, balanced by preventive health measures and robust governance. AMR neutrality is ambitious but achievable, and economics can provide useful tools for charting the path forward.

Keywords

Antimicrobial use – Economics – Livestock – One Health – Resistance – Sustainability.

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Background

Soon after the beginning of the golden age of antibiotics in the early 1940s, Alexander Fleming alerted the world, during his Nobel Prize award speech, that the imprudent use of antibiotics would result in the development of resistance, hampering the ability to control infections [1]. In the mid-1950s, researchers in Japan found evidence that antibiotic resistance could be genetically transferable, transforming prevailing views by demonstrating that clusters of resistance genes could disseminate through bacterial conjugation across pathogen populations [2]. By the late 1960s in the United States of America, over 80% of *Staphylococcus aureus* isolates from both hospital and community settings were resistant to penicillin [3]. More recently, researchers have estimated that a total of 1.91 million deaths per year will be attributable to antimicrobial resistance (AMR) by 2050 [4]. Additionally, and despite the challenges in estimating its economic burden, the global economy has been projected to contract 3.8% by 2050 due to AMR [5].

It can be argued that the actual magnitude of the AMR threat was buffered by the discovery and development of new antimicrobials, which equipped mankind with new tools to fight infectious pathogens [2]. However, new antimicrobial discovery has plummeted over the past decades, a result of the high research and development costs and low market price of products [6]. The lack of new antimicrobials with diverse mechanisms of action, and their imprudent use, have given infectious pathogens the perfect natural-selection environment to become resistant, and to perpetuate their abilities intra- and intergenerationally.

If exposure to antimicrobials is a condition for pathogens to develop resistance, livestock production systems are expected to contribute to this crisis. Research has indicated that in 2017, 73% of global antimicrobial sales were for livestock farming, including for growth promotion and prophylaxis [7,8]. Also, livestock can serve as a reservoir for resistance genes that can transfer to human pathogens through direct contact, food chains and environmental pathways [9].

International recognition of this One Health problem has translated into concrete commitments [10], yet implementation of mitigation actions remains uneven. The challenge is fundamentally economic: antimicrobial use (AMU) in livestock has historically delivered private benefits (reduced disease losses, improved feed conversion, labour savings) while imposing diffuse public costs through resistance emergence [11]. This market failure[1] persists because the externalities[2] of AMU are inadequately priced, information asymmetries favour short-term productivity gains, and collective action problems inhibit coordinated responses [12,13].

Anthropogenic AMR arises from AMU in human healthcare and plant and animal production. Acknowledging that the frontier between sectors is heavily porous, this article takes an explicitly economic perspective on the transition towards 'AMR neutrality' in livestock systems. The focus is on understanding trade-offs, identifying effective incentive structures, and charting feasible pathways that acknowledge both the promise of successful transitions and the constraints that may slow progress.

Where we are: economic realities of antimicrobial use in livestock

The economic logic of antimicrobial use

For decades, antimicrobials have been deeply embedded in the economic calculus of livestock production. At the farm level, AMU reduces disease occurrence and severity and hastens growth, enhancing profitability (through decreased mortality and morbidity and improved feed efficiency), acting as a relatively inexpensive form of insurance against high disease risk in intensive livestock farming [14,15]. For example, while investigating the impact of restricting AMU for beef production in feedlots in the USA, Lhermie *et al*. found that compared to unrestricted use of antimicrobials, limiting their use to treatment or forgoing their use completely would lead to a median net revenue loss of US$ 66 and US$ 96 per animal, respectively [16].

This economic logic extends beyond individual farms. Feed manufacturers, veterinary pharmaceutical companies, livestock traders and processors have built business models that assume easy access to antimicrobials. Genetic selection programmes and the intensification of livestock farming have also contributed to the development of production systems and value chains that require antimicrobial support to function

1. The failure of free markets to allocate resources efficiently due to factors such as information asymmetry, concentrated market power/monopolies and externalities.
2. The costs or benefits of an economic activity that affect third parties who did not choose to incur them and that are not reflected in market prices.

efficiently [17]. The result is path dependency: production systems have evolved and are difficult to modify without significant transition costs.

The hidden costs: externalities and market failures

The fundamental economic problem is that market prices for livestock products do not reflect the full social costs of AMU [18]. When farmers administer antimicrobials, they and consumers capture the benefits through potentially healthier animals, improved productivity and lower prices for animal products. On the other hand, AMU at farm level favours the natural selection of pathogens resistant to the antimicrobials used, which spread through environmental pathways, wildlife and food products, generating costs (negative externalities) that are spatially and temporally distant from the original AMU decision (e.g. treatment failures in human medicine and associated costs, reduced biodiversity, ecosystem disruption) [12,19]. Quantifying these externalities is challenging but essential to better align private and public incentives. And even though not all AMR traces to livestock AMU, even conservative estimates suggest that the societal costs substantially exceed the private benefits captured by producers [13].

Global variation: divergent contexts and imperatives

The economics of AMU differ dramatically across global contexts. In high-income countries, livestock systems are typically intensive and highly regulated, operating in markets with high private standards, and are supported by robust veterinary infrastructure. These systems have the capacity to invest in alternatives to AMU, such as vaccines and biosecurity, though economic incentives have not consistently favoured such investments [20]. In low- and middle-income countries (LMICs), the situation is markedly different. Livestock often serve multiple functions: food security, nutrition, income generation, cultural roles, and risk management for vulnerable populations. Production systems range from pastoral systems and smallholder subsistence farming to rapidly expanding intensive operations. Veterinary Services may be limited, the cold chain infrastructure may be inadequate for vaccine delivery, and the regulatory capacity may be weak. In these contexts, antimicrobials represent an accessible technology for managing animal health risks that threaten household food security and livelihoods [20].

This divergence has profound implications. Policies designed for well-resourced intensive systems that have managed to reduce AMU may be inappropriate or counterproductive in resource-limited settings. LMIC producers face a development challenge: expand livestock production to meet growing demand for animal-source foods and improve rural incomes and livelihoods, while managing disease risks with limited alternatives to AMU [19].

In the context presented, the economic challenge is to decouple livestock productivity from antimicrobial dependence while maintaining food security, farmer livelihoods and animal welfare. This requires understanding not just the costs of transition towards livestock production systems less reliant on antimicrobials, but also the mechanisms by which successful transitions have occurred and can be scaled.

Where we could go: towards antimicrobial resistance neutrality

From carbon to antimicrobial resistance neutrality: an economic analogy

AMR neutrality can be conceptualised through an analogy with carbon neutrality. Both AMR and greenhouse gas (GHG) emissions arise from diffuse, cumulative human activities that generate externalities extending beyond the decision-maker. GHG neutrality seeks to balance anthropogenic GHG emissions with equivalent removals through natural sinks or technological capture [21,22]. Likewise, AMR neutrality refers to balancing the antimicrobial 'emissions' originating from human, plant and animal use with the capacity of health, agricultural and environmental systems to prevent, mitigate or reverse resistance emergence. AMR neutrality is grounded on the assumption that AMU is a major driver of AMR [23-27] and, as such, needs to be underpinned by prudent use and effective antimicrobial stewardship [28,29].

In this framework, antimicrobial consumption and waste correspond to emissions, while stewardship, innovation and containment measures function as removals. Neutrality is reached when AMU is offset by the system's preventive and restorative capacity. Viewing AMR through this lens places it within the broader family of global commons challenges, those characterised by diffuse sources, delayed feedback loops and collective action requirements [30]. This analogy provides a rationale for integrating AMR mitigation into sustainability frameworks that already address climate, biodiversity and pollution. Economically, this transition involves replacing antimicrobial-intensive health management with capital and operational prevention expenditures such as investments in biosecurity infrastructure, vaccination programmes, genetic improvement for disease resistance, improved nutrition and housing, enhanced surveillance and diagnostic capacity, and training for animal health workers. It also requires institutional changes: stronger regulatory frameworks, better surveillance systems, incentive structures that reward prevention, improved private standards, stewardship programmes for farmers and animal health professionals and mechanisms to fairly distribute transition costs.

Figure 1 synthesises the suggested framework, illustrating the transition from antimicrobial-dependent livestock systems (left) through context-specific pathways (centre) towards AMR neutrality (right).

Evidence from high-income countries: successful transitions

Several high-income countries have demonstrated that substantial AMU reductions are achievable without detrimental economic consequences, providing valuable proof of concept for AMR neutrality.

Denmark's Yellow Card initiative is perhaps the most extensively documented example. Implemented in 2010, this regulatory approach sets farm-level AMU thresholds based on benchmarking[3] against similar production types. Farms exceeding thresholds receive 'yellow cards' and must reduce use within nine months or face intensified oversight and potential sanctions. Between 2009 and 2019, Danish pig production achieved approximately 47% AMU reduction while maintaining production levels and export competitiveness [31].

The Netherlands implemented an even more dramatic transition. Following a political crisis over extended-spectrum beta-lactamase-producing bacteria in poultry in 2009, the Dutch government established mandatory reduction targets: 50% by 2013 and 70% by 2015, using 2009 as the baseline. The livestock sector achieved these targets, with a 56% reduction by 2012 and sustained reductions thereafter. The policy prohibited routine prophylactic use, required veterinary justification for all AMU, and established farm-level monitoring with benchmarking. Economic impacts were carefully managed through transition support, industry engagement in policy design, and simultaneous investments in alternatives [32]. The Dutch experience demonstrates that rapid, substantial reductions are economically feasible when policy commitment is clear, transition

3. Comparison of performance metrics across similar units to identify best practices and opportunities for improvement.

pathways are supported and collective action problems are overcome through regulation [33].

France's antibiotic-free pork production illustrates market-driven transitions. French producers developed differentiated products marketed under premium labels. This approach allows consumers willing to pay for reduced AMU to do so while maintaining conventional production for price-sensitive markets. Economic viability depends on sufficient price premiums to offset higher production costs resulting from improved biosecurity and additional preventive and control measures [34]. While these markets demonstrate consumer willingness to pay for AMR-related public goods,[4] they currently represent only a small segment of total production (about 15%) rather than transforming entire sectors, highlighting the limitations of purely market-based approaches [35]. Government supervision of AMU reduction through a voluntary programme also showed the possibility of transitioning towards less AMU without damaging revenue in the long term, with sound substitution of antimicrobials used for revenue insurance purposes along with vaccination and other infection prevention tools [36].

Norway's slow-growing chicken breeds offer insights into how genetic selection can alter production economics. The Norwegian company Norsk Kylling transitioned from fast-growing to slow-growing chicken breeds, accepting longer production times and higher feed costs in exchange for improved animal welfare, reduced disease incidence and lower antimicrobial requirements [37,38]. The Netherlands has similarly moved towards slow-growing breeds in poultry production. These transitions were economically viable because they aligned with consumer preferences for welfare-enhanced products and because regulatory frameworks supported differentiation rather than lowest-cost production [39,40]. These cases illustrate how genetic selection, production system design and market positioning interact to create economically sustainable alternatives to AMU-dependent systems.

4. Resources or services that are non-excludable and non-rivalrous, which markets under-provide because providers cannot capture full benefits.

A study on farrow-to-finish pig farms in Belgium demonstrated that substantial reductions in AMU can be economically beneficial when coupled with improved management strategies. The authors reported that farms implementing tailored biosecurity measures and vaccination protocols had a € 2.67 increase in enterprise profit per finisher pig per year, suggesting that prophylactic antimicrobial treatments may be more expensive than strategic investments in farm biosecurity and herd health management [41].

While these findings collectively suggest that moving towards AMR neutrality may be technically and economically feasible, the transition trade-offs are highly context-dependent, reflecting the heterogeneity in production systems, markets and the regulatory environment, and, as such, cannot be universally extrapolated.

Discussion: charting the path to antimicrobial resistance neutrality

The successful transitions in Denmark, the Netherlands, France and Norway show that substantial reductions can be achieved while maintaining the viability of the livestock sector. However, these examples also reveal that transitions require coordinated action across multiple levels, careful management of costs and risks, and sustained political commitment.

The path forward must acknowledge both the urgency of the AMR threat and the legitimate concerns of producers, particularly in resource-limited settings, about livelihoods, food security, animal welfare and equitable distribution of transition costs. Economics provides tools for navigating these tensions: valuing externalities, designing efficient incentive structures, identifying least-cost transition pathways and ensuring that policies are evidence-based and context-appropriate.

Achieving AMR neutrality requires coordinated action across multiple scales, each involving distinct economic mechanisms and stakeholders. The following are four proposed priority actions for policy-makers, international organisations, value chain actors and researchers, organised from farm to global level to illuminate the levers available and barriers that must be overcome at each scale.

Making the costs of antimicrobial resistance visible in economic terms

Economic decision-making requires clear information about costs and benefits. Currently, AMR's costs remain largely invisible in market prices and farm-level accounting, creating the externality problem that drives excessive AMU [12,19].

The economic challenge at the farm level is that reducing AMU requires substituting cheap antimicrobials with more expensive prevention strategies. Key investments include biosecurity infrastructure, vaccination programmes, improved housing and husbandry (lower stocking densities, better ventilation), genetics for disease resistance and enhanced management training [42]. These investments yield public goods (reduced resistance risk) alongside private returns. Without mechanisms to capture social benefits or regulations requiring investment, under-provision of AMR mitigation measures is likely [43].

To fill in that knowledge gap and make these trade-offs explicit, disease burden assessments that quantify full economic costs of AMU and AMR in livestock production at national and regional levels, using standardised methodologies to enable comparison across contexts [44], should be conducted. The outputs from these assessments would provide inputs for agricultural policies, trade agreements and investment decisions, ensuring that full societal costs are considered alongside private returns.

Additionally, and considering that everyone is a stakeholder in the effectiveness of antimicrobials, adjusting communication to different sectors of society (policy-makers, value chain actors, consumers) is critical. Making costs visible creates economic justification for action and helps build political will for policy change. It also enables more efficient targeting of interventions towards practices with the highest resistance risks relative to benefits.

Aligning incentives along the value chain

Current incentive structures often work against AMU reduction. The value chain for livestock production begins with the input industries – pharmaceutical and feed – which need to be involved in the strategy for AMR neutrality. Farmers who allocate resources to animal disease prevention may not capture the benefits from the investment, especially where food system businesses demand low farmgate prices that discourage investment. Consumers may claim concern about AMR, but this does not always translate into paying higher prices. And governments may unwittingly subsidise intensive production without conditions.

Value chain actors can shift incentives through procurement policies and certification schemes. Major retailers implementing AMU standards across suppliers can overcome collective action problems [45], though economic impacts depend on how costs are distributed [46]. Third-party certification can enable price premiums, but effectiveness is limited by a critical gap: while stated preference studies suggest substantial consumer willingness to pay for AMR-prudent production, revealed preferences show much more limited uptake of premium products [47,48]. Price sensitivity, particularly in low-income populations, constrains market-driven transitions.

At the national level, some governments possess powerful economic tools: regulatory restrictions on specific uses and critically important antimicrobials; fiscal instruments such as resistance-weighted taxes – where higher tax rates are applied to higher resistance risk and importance for human medicine of different antimicrobial classes – that internalise externalities and subsidies for alternative investments; investment in public goods like surveillance systems, diagnostic laboratories and extension services; and monitoring systems that enable benchmarking and targeted interventions, as demonstrated in Denmark and the Netherlands. In LMIC contexts, however, these tools must be adapted to account for limited regulatory capacity, informal value chains and the imperative to balance AMR concerns with food security and livelihoods [49,50].

In regions operating within a single market or under trade agreements, harmonisation of regulation regarding production standards is essential to prevent competitive disadvantages and regulatory arbitrage[5]. Coordinated standards would ensure that producers in stricter jurisdictions are not penalised for higher compliance costs, while still allowing flexibility to account for differences in production systems, resource availability and development levels.

Improved alignment of incentives also requires stronger coordination along the value chain. Contractual arrangements, shared investment mechanisms and fair pricing models can distribute the costs and benefits of prudent production more equitably. Commitments by processors and retailers to source from farms meeting AMR-related standards must be supported by a willingness to compensate suppliers for the additional costs of improved practices. Value chain coordination through integration or stable relationships can ensure prevention investments are appropriately rewarded.

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5. The practice of exploiting differences or gaps between regulatory systems to reduce costs or constraints without changing the underlying economic activity.

Economic instruments can reinforce these shifts. Resistance-weighted taxes on antimicrobials alongside targeted subsidies for biosecurity and vaccination, and preferential trade treatment for AMR-prudent production, can create clear financial signals that favour sustainable practices [51].

A further priority is to restructure the economics of Veterinary Services. Separating prescribing from drug sales, as implemented in some countries [52,53], could help redefine the role of veterinarians as animal health advisors and foster professional incentives with AMU reduction goals.

When incentives are aligned across the system, those who can reduce AMU most efficiently are rewarded for doing so, rather than being penalised relative to competitors who externalise the societal costs of AMR.

Investing in preventive health, innovation and data systems

There is no incentive for markets to provide public goods, and AMU reduction is no exception. Because the benefits of reduced AMR accrue broadly across society while the costs of transition are concentrated among producers, government investment is essential to build the enabling capacity for sustained AMU reduction.

Strengthened surveillance systems are a foundational public good. Baseline surveillance data is essential to operationalise AMR neutrality: without robust understanding of current AMU patterns and AMR prevalence, targets risk being either insufficiently ambitious or unrealistically stringent. Defining what ‘neutrality’ means in specific contexts requires context-specific baseline data and ongoing monitoring to assess whether systems are maintaining or restoring antimicrobial efficacy over time. Governments should invest in integrated monitoring of both AMU and AMR at farm, national and global levels, including diagnostic infrastructure, laboratory networks and interoperable data systems that enable real-time reporting and early warning. Farm-level benchmarking systems, as successfully implemented in Denmark and the Netherlands, can further identify opportunities for reduction through benchmarking and transparency.

Fostering investment in research and development is also needed on alternatives to antimicrobials (probiotics, prebiotics, bacteriophages, immunomodulators and other emerging technologies) and vaccines. Regarding the latter, innovative delivery platforms, such as thermostable vaccines or mass-administration strategies, could be prioritised to overcome infrastructure limitations and ensure accessibility in less resourceful contexts.

Building veterinary and extension capacity is equally important. This includes training animal health workers, developing evidence-based best-practice guidelines and creating extension materials adapted to local production realities. Expanding the reach of veterinary and advisory services provides the human capital necessary to translate policy objectives into practical farm-level change.

Finally, investment is needed in the development and validation of rapid diagnostics and biomarkers capable of distinguishing bacterial from viral infections and identifying pathogens at the point of care. These tools are essential for targeted rather than empirical therapy, improving both treatment efficacy and antimicrobial stewardship.

Together, these investments create the structural and technological conditions for effective and lasting reductions in AMU. They constitute classic public goods (high-return, non-excludable assets that markets alone will under-supply) requiring sustained, collective financing through public and international support [5].

The precautionary principle

While uncertainty remains around the precise contribution of livestock AMU to human resistance burdens, all evidence points to the existence of such cause and effect, and the consequences of this relationship (systemic loss of antimicrobial efficacy) are likely to be catastrophic and largely irreversible. Indeed, from an economic perspective, such high-consequence, low-probability risks justify precautionary action even before full quantification of costs and benefits is possible [54].

Clear, ambitious reduction targets should therefore be established at national and global levels, drawing on the best available data yet favouring precaution where uncertainty remains. The European Union's commitment to a 50% AMU reduction in livestock by 2030 provides an ambitious model, though context-specific targets should be established based on local baseline data, production systems and available alternatives while maintaining precautionary ambition [55]. Action should begin immediately: resistance continues to emerge and spread, and postponement forecloses future options as resistant strains become entrenched. Policy implementation can be refined as new data accumulate, but uncertainty must not be an excuse for inaction.

Precaution also implies prioritisation. Restrictions should first target the uses of prophylaxis and growth promotion, the use of critically important antimicrobials in livestock, and other practices that impose high selection pressure [56].

At the global level, AMR's transboundary nature requires international action. Divergent standards create competitiveness concerns and potential races to the bottom. International harmonisation through the World Organisation for Animal Health, Codex Alimentarius and trade agreements can level playing fields. Global surveillance systems enable early detection but require sustained funding [57].

Applying the precautionary principle does not imply uninformed or arbitrary action; it means acting on the best available evidence while acknowledging uncertainty, rather than allowing uncertainty to paralyse response to a rapidly escalating global threat. These priorities must be pursued with attention to context and equity. Transitions in LMICs require sustained international engagement, encompassing not only funding but also technology transfer, capacity building and co-development of context-appropriate solutions. Priority should be given to countries undergoing rapid livestock intensification, where production practices are still being established. Supporting AMR-prudent infrastructure and management during expansion phases prevents lock-in of antimicrobial-dependent systems that would be costly to retrofit later. High-income countries carry responsibilities to act domestically and to support global mitigation efforts, recognising that resistance respects no borders.

Success depends on multisectoral collaboration. Reducing AMR in livestock cannot be achieved by agricultural ministries alone; it requires coordinated policy across the health, environment, finance, trade and development sectors. One Health frameworks provide the necessary architecture for such integration, yet practical implementation remains uneven and slower than envisioned across many jurisdictions.

Conclusion

The pursuit of AMR neutrality reflects a collective insurance policy against a foreseeable systemic failure. Achieving AMR neutrality in livestock systems is an ambitious yet attainable goal. Evidence from countries that have successfully reduced AMU demonstrates that such transitions are both technically and economically feasible. The stakes could not be higher: AMR threatens human and animal health, global food security and the very foundation of modern medicine. Preserving antimicrobial efficacy for future generations is a collective responsibility that transcends borders, sectors and political cycles. Progress will require courage to challenge entrenched interests, creativity to tailor solutions to diverse contexts, and commitment to maintain momentum over the long term. Economics can guide efficient pathways, but success ultimately depends on shared resolve to value long-term global health over short-term profit.

Économie de la résistance aux antimicrobiens chez les animaux d'élevage : tracer la voie vers la neutralité en matière de résistance aux antimicrobiens

J.S. Afonso, S. Babo Martins, G. Lhermie, C.M. Morel & J. Rushton

Résumé

La résistance aux antimicrobiens (RAM) constitue une menace majeure pour la sécurité sanitaire mondiale. Face au constat que l'utilisation infondée ou excessive d'antimicrobiens dans les élevages contribue fortement à l'émergence et à la propagation de la RAM, les dirigeants mondiaux ont pris l'engagement de réduire significativement leur utilisation d'ici 2030. Cet article analyse les contraintes économiques actuelles ainsi que les trajectoires de transition réussies, en faisant ressortir les aspects économiques de l'objectif d'une « neutralité RAM » dans les élevages, c'est-à-dire un état dans lequel la production est maintenue et pérennisée, tout en ayant un recours minimal aux antimicrobiens, grâce à l'application de mesures de prévention et à une gouvernance solide. La « neutralité RAM » est un objectif ambitieux mais atteignable ; l'économie offre des outils intéressants pour définir et piloter les trajectoires de transition.

Mots-clés

Animaux d'élevage – Économie – Pérennité – Résistance – Une seule santé – Utilisation des antimicrobiens.

Economía de la resistencia a los antimicrobianos en la ganadería: trazar el camino hacia la neutralidad en materia de resistencia a los antimicrobianos

J.S. Afonso, S. Babo Martins, G. Lhermie, C.M. Morel & J. Rushton

Resumen

La resistencia a los antimicrobianos (RAM) representa una amenaza fundamental para la seguridad sanitaria mundial. El uso excesivo e indebido de antimicrobianos en los sistemas de producción ganadera ha destacado como un factor importante en la aparición y propagación de la RAM, lo que ha llevado a los líderes mundiales a dedicar esfuerzos para reducir su uso de aquí a 2030. A través del análisis de las realidades económicas actuales y las vías de transición exitosas, este artículo examina las dimensiones económicas para lograr la neutralidad en materia de RAM en la ganadería, un estado en el que se mantiene una producción sostenible con un uso mínimo de antimicrobianos, equilibrada con medidas sanitarias preventivas y una gobernanza sólida. A pesar de que es un objetivo ambicioso, la neutralidad en materia de RAM se puede alcanzar, y la economía puede aportar herramientas útiles para trazar el camino a seguir.

Palabras clave

Economía – Ganadería – Resistencia – Sostenibilidad – Una sola salud – Uso de antimicrobianos.

References

[1] Rosenblatt-Farrell N. The landscape of antibiotic resistance. Environ. Health Perspect. 2009;117(6):A244-50. Available at: https://pubmed.ncbi.nlm.nih.gov/19590668 (accessed on 3 February 2026).

[2] Davies J, Davies D. Origins and evolution of antibiotic resistance. Microbiol. Mol. Biol. Rev. 2010;74(3):417-33. https://doi.org/10.1128/mmbr.00016-10

[3] Lowy FD. Antimicrobial resistance: the example of *Staphylococcus aureus*. J. Clin. Invest. 2003;111(9):1265-73. https://doi.org/10.1172/JCI18535

[4] Naghavi M, Vollset SE, Ikuta KS, Swetschinski LR, Gray AP, Wool EE, *et al*. Global burden of bacterial antimicrobial resistance 1990–2021: a systematic analysis with forecasts to 2050. Lancet. 2024;404(10459):1199-226. https://doi.org/10.1016/s0140-6736(24)01867-1

[5] Jonas OB, Irwin A, Berthe FCJ, Le Gall FG, Marquez PV. Drug-resistant infections: a threat to our economic future. Washington DC (United States of America): World Bank Group; 2017. 172 p. Available at http://documents.worldbank.org/curated/en/323311493396993758 (accessed on 3 February 2026).

[6] Blaskovich MAT, Cooper MA. Antibiotics re-booted – time to kick back against drug resistance. NPJ Antimicrob. Resist. 2025;3(1):47. https://doi.org/10.1038/s44259-025-00096-1

[7] Van Boeckel TP, Glennon EE, Chen D, Gilbert M, Robinson TP, Grenfell BT, *et al*. Reducing antimicrobial use in food animals. Science. 2017;357(6358):1350-2. https://doi.org/10.1126/science.aao1495

[8] Mulchandani R, Wang Y, Gilbert M, Van Boeckel TP. Global trends in antimicrobial use in food-producing animals: 2020 to 2030. PLOS Glob. Public Health. 2023;3(2):e0001305. https://doi.org/10.1371/journal.pgph.0001305

[9] Pandey S, Doo H, Keum GB, Kim ES, Kwak J, Ryu S, *et al*. Antibiotic resistance in livestock, environment and humans: One Health perspective. J. Anim. Sci. Technol. 2024;66(2):266-78. https://doi.org/10.5187/jast.2023.e129

[10] World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), United Nations Environment Programme (UNEP), World Organisation for Animal Health (WOAH). Implementing the global action plan on antimicrobial resistance: first quadripartite biennial report. Geneva (Switzerland): WHO; 2023. 197 p. Co-published by FAO, UNEP and WOAH. Available at: https://www.who.int/publications/i/item/9789240074668 (accessed on 3 February 2026).

[11] Roskam JL, Oude Lansink AGJM, Saatkamp HW. The relation between technical farm performance and antimicrobial use of broiler farms. Poult. Sci. 2020;99(3):1349-56. https://doi.org/10.1016/j.psj.2019.10.054

[12] Roope LSJ, Smith RD, Pouwels KB, Buchanan J, Abel L, Eibich P, *et al*. The challenge of antimicrobial resistance: what economics can contribute. Science. 2019;364(6435):eaau4679. https://doi.org/10.1126/science.aau4679

[13] Innes GK, Randad PR, Korinek A, Davis MF, Price LB, So AD, *et al*. External societal costs of antimicrobial resistance in humans attributable to antimicrobial use in livestock. Annu. Rev. Public Health. 2020;41:141-57. https://doi.org/10.1146/annurev-publhealth-040218-043954

[14] Lhermie G, Ndiaye Y, Rushton J, Raboisson D. Economic evaluation of antimicrobial use practices in animal agriculture: a case of poultry farming. JAC Antimicrob. Resist. 2022;4(6):dlac119. https://doi.org/10.1093/jacamr/dlac119

[15] Coyne L, Arief R, Benigno C, Giang VN, Huong LQ, Jeamsripong S, *et al*. Characterizing antimicrobial use in the livestock sector in three South East Asian countries (Indonesia, Thailand, and Vietnam). Antibiotics (Basel). 2019;8(1):33. https://doi.org/10.3390/antibiotics8010033

[16] Lhermie G, Sauvage P, Tauer LW, Chiu LV, Kanyiamattam K, Ferchiou A, *et al*. Economic effects of policy options restricting antimicrobial use for high risk cattle placed in U.S. feedlots. PLoS One. 2020;15(9):e0239135. https://doi.org/10.1371/journal.pone.0239135

[17] Kirchhelle C. Pharming animals: a global history of antibiotics in food production (1935–2017). Palgrave Commun. 2018;4(1):96. https://doi.org/10.1057/s41599-018-0152-2

[18] Food and Agriculture Organization of the United Nations (FAO). The state of food and agriculture 2023: revealing the true cost of food to transform agrifood systems. Rome (Italy): FAO; 2023. 150 p. https://doi.org/10.4060/cc7724en

[19] Laxminarayan R, Duse A, Wattal C, Zaidi AKM, Wertheim HFL, Sumpradit N, *et al*. Antibiotic resistance – the need for global solutions. Lancet Infect. Dis. 2013;13(12):1057-98. https://doi.org/10.1016/s1473-3099(13)70318-9

[20] Wall BA, Mateus A, Marshall L, Pfeiffer DU, Lubroth J, Ormel HJ, *et al*. Drivers, dynamics and epidemiology of antimicrobial resistance in animal production. Rome (Italy): Food and Agriculture Organization of the United Nations; 2016. 68 p. Available at: https://openknowledge.fao.org/handle/20.500.14283/i6209e (accessed on 3 February 2026).

[21] Chen JM. Carbon neutrality: toward a sustainable future. Innovation (Camb). 2021;2(3):100127. https://doi.org/10.1016/j.xinn.2021.100127

[22] Allen MR, Friedlingstein P, Girardin CAJ, Jenkins S, Malhi Y, Mitchell-Larson E, *et al*. Net zero: science, origins, and implications. Annu. Rev. Environ. Resour. 2022;47(1):849-87. https://doi.org/10.1146/annurev-environ-112320-105050

[23] Chantziaras I, Boyen F, Callens B, Dewulf J. Correlation between veterinary antimicrobial use and antimicrobial resistance in food-producing animals: a report on seven countries. J. Antimicrob. Chemother. 2014;69(3):827-34. https://doi.org/10.1093/jac/dkt443

[24] Dorado-García A, Mevius DJ, Jacobs JJH, Van Geijlswijk IM, Mouton JW, Wagenaar JA, *et al*. Quantitative assessment of antimicrobial resistance in livestock during the course of a nationwide antimicrobial use reduction in the Netherlands. J. Antimicrob. Chemother. 2016;71(12):3607-19. https://doi.org/10.1093/jac/dkw308

[25] Agersø Y, Aarestrup FM. Voluntary ban on cephalosporin use in Danish pig production has effectively reduced extended-spectrum cephalosporinase-producing *Escherichia coli* in slaughter pigs. J. Antimicrob. Chemother. 2013;68(3):569-72. https://doi.org/10.1093/jac/dks427

[26] Callens B, Cargnel M, Sarrazin S, Dewulf J, Hoet B, Vermeersch K, *et al*. Associations between a decreased veterinary antimicrobial use and resistance in commensal *Escherichia coli* from Belgian livestock species (2011–2015). Prev. Vet. Med. 2018;157:50-8. https://doi.org/10.1016/j.prevetmed.2017.10.013

[27] Tang KL, Caffrey NP, Nobrega DB, Cork SC, Ronksley PE, Barkema HW, *et al*. 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. Lancet Planet. Health. 2017;1(8):e316-27. https://doi.org/10.1016/s2542-5196(17)30141-9

[28] Magnusson U, Sternberg Lewerin S, Eklund G, Rozstalnyy A. Prudent and efficient use of antimicrobials in pigs and poultry. Food and Agriculture Organization of the United Nations (FAO) Animal Production and Health Manual No. 23. Rome (Italy): FAO; 2019. 44 p. https://doi.org/10.4060/CA6729EN

[29] Patel SJ, Wellington M, Shah RM, Ferreira MJ. Antibiotic stewardship in food-producing animals: challenges, progress, and opportunities. Clin. Ther. 2020;42(9):1649-58. https://doi.org/10.1016/j.clinthera.2020.07.004

[30] Mastrangelo ME, Cumming GS. Restoring stabilizing feedback loops for sustainability. One Earth. 2024;7(5):794-805. https://doi.org/10.1016/j.oneear.2024.03.004

[31] Lopes Antunes AC, Jensen VF. Close to a decade of decrease in antimicrobial usage in Danish pig production – evaluating the effect of the yellow card scheme. Front. Vet. Sci. 2020;7:109. https://doi.org/10.3389/fvets.2020.00109

[32] Speksnijder DC, Wagenaar JA. Reducing antimicrobial use in farm animals: how to support behavioral change of veterinarians and farmers. Anim. Front. 2018;8(2):4-9. https://doi.org/10.1093/af/vfy006

[33] Bergevoet R, van Asseldonk M, Bondt N, van Horne P, Hoste R, de Lauwere C, *et al.* Economics of antibiotic usage on Dutch farms: the impact of antibiotic reduction on economic results of pig and broiler farms in the Netherlands. Wageningen Economic Research Policy Paper No. 019-026-2019. Wageningen (the Netherlands): Wageningen Economic Research; 2019. 16 p. Available at: https://edepot.wur.nl/475403 (accessed on 3 February 2026).

[34] Sneeringer S, MacDonald JM, Key N, McBride WD, Mathews K. Economics of antibiotic use in U.S. livestock production. Economic Research Report No. 200. Washington DC (United States of America): United States Department of Agriculture, Economic Research Service; 2015. 100 p. Available at: https://www.ers.usda.gov/publications/pub-details?pubid=45488 (accessed on 3 February 2026).

[35] Roguet C, Hémonic A. Les filières « porcs élevés sans antibiotiques » en France : caractéristiques, atouts, limites et perspectives : projet européen ROADMAP. Proc. 54es Journées de la recherche porcine; 2022 Feb 1-2; Paris. Institut du porc, Le Rheu, France, p. 321-6. Available at: https://ifip.asso.fr/documentations/42675-les-filieres-porcs-eleves-sans-antibiotiques-en-france-caracteristiques-atouts-limites-et-perspectives-projet-europeen-roadmap (accessed on 3 February 2026).

[36] Lhermie G, Ferchiou A, Ndiaye Y, Justinia G, Lisbona D, Koralewski M, *et al*. Évaluation socio-économique de la réduction d'usage des antibiotiques dans la filière porcine : le plan Ecoantibio 1. INRAE Prod. Anim. 2022;35(4):345-56. https://doi.org/10.20870/productions-animales.2022.35.4.7334

[37] Forseth M, Moe RO, Kittelsen K, Skjerve E, Toftaker I. Comparison of carcass condemnation causes in two broiler hybrids differing in growth rates. Sci. Rep. 2023;13(1):4195. https://doi.org/10.1038/s41598-023-31422-0

[38] Compassion in World Farming. ChickenTrack: 2022 European report. Godalming (United Kingdom): Compassion in World Farming International; 2022. 36 p. Available at: https://www.ciwf.org.uk/media/7453677/european-chickentrack-2022.pdf (accessed on 3 February 2026).

[39] Sandøe P, Hansen HO, Forkman B, van Horne P, Houe H, de Jong IC, *et al*. Market driven initiatives can improve broiler welfare – a comparison across five European countries based on the Benchmark method. Poult. Sci. 2022;101(5):101806. https://doi.org/10.1016/j.psj.2022.101806

[40] Slegers Y, Hostens M, Matthijs MGR, Stegeman JA, de Wit JJ. Broiler flocks in production systems with slower-growing breeds and reduced stocking density receive fewer antibiotic treatments and have lower mortality. Poult. Sci. 2024;103(11):104197. https://doi.org/10.1016/j.psj.2024.104197

[41] Rojo-Gimeno C, Postma M, Dewulf J, Hogeveen H, Lauwers L, Wauters E. Farm-economic analysis of reducing antimicrobial use whilst adopting improved management strategies on farrow-to-finish pig farms. Prev. Vet. Med. 2016;129:74-87. https://doi.org/10.1016/j.prevetmed.2016.05.001

[42] Food and Agriculture Organization of the United Nations (FAO). The FAO action plan on antimicrobial resistance 2021–2025. Rome (Italy): FAO; 2021. 46 p. https://doi.org/10.4060/cb5545en

[43] Ait Ouakrim D, Cassini A, Cecchini M, Plachouras D. Challenges to tackling antimicrobial resistance. Cambridge (United Kingdom): Cambridge University Press; 2000. The health and economic burden of antimicrobial resistance; p. 23-44. https://doi.org/10.1017/9781108864121

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

[45] Umber JK, Moore KA. Assessment of antibiotic stewardship components of certification programs in US animal agriculture using the antibiotic stewardship assessment tool. Front. Sustain. Food Syst. 2021;5:724097. https://doi.org/10.3389/fsufs.2021.724097

[46] Hughes A, Roe E, Hocknell S. Food supply chains and the antimicrobial resistance challenge: on the framing, accomplishments and limitations of corporate responsibility. Environ. Plan. A. 2021;53(6):1373-90. https://doi.org/10.1177/0308518X211015255

[47] Zhou Y, Zhang A, van Klinken RD, Jones D, Wang J. Consumers' perspectives on antibiotic use and antibiotic resistance in food animals: a systematic review. NPJ Sci. Food. 2025;9(1):29. https://doi.org/10.1038/s41538-025-00381-3

[48] Bradford H, McKernan C, Elliott C, Dean M. Consumers' perceptions and willingness to purchase pork labelled 'raised without antibiotics'. Appetite. 2022;171:105900. https://doi.org/10.1016/j.appet.2021.105900

[49] Mbugua S, Mhone AL, Morang'a A, Gathura P, Onono J, Muloi DM, *et al*. Veterinary antimicrobial use legislation: a comparative policy analysis of Kenya and Denmark. One Health. 2025;21:101260. https://doi.org/10.1016/j.onehlt.2025.101260

[50] Kisoo L, Muloi DM, Oguta W, Ronoh D, Kirwa L, Akoko J, *et al*. Practices and drivers for antibiotic use in cattle production systems in Kenya. One Health. 2023;17:100646. https://doi.org/10.1016/j.onehlt.2023.100646

[51] Morgan ALK, Moran D, Van Boeckel TP. Taxation of veterinary antibiotics to reduce antimicrobial resistance. One Health. 2023;17:100650. https://doi.org/10.1016/j.onehlt.2023.100650

[52] Powell A, Bard AM, Rees GM. Assessing veterinarians' opinions of antimicrobial stewardship initiative acceptability for farm practice in Wales. Vet. Rec. 2024;195(10):e4799. https://doi.org/10.1002/vetr.4799

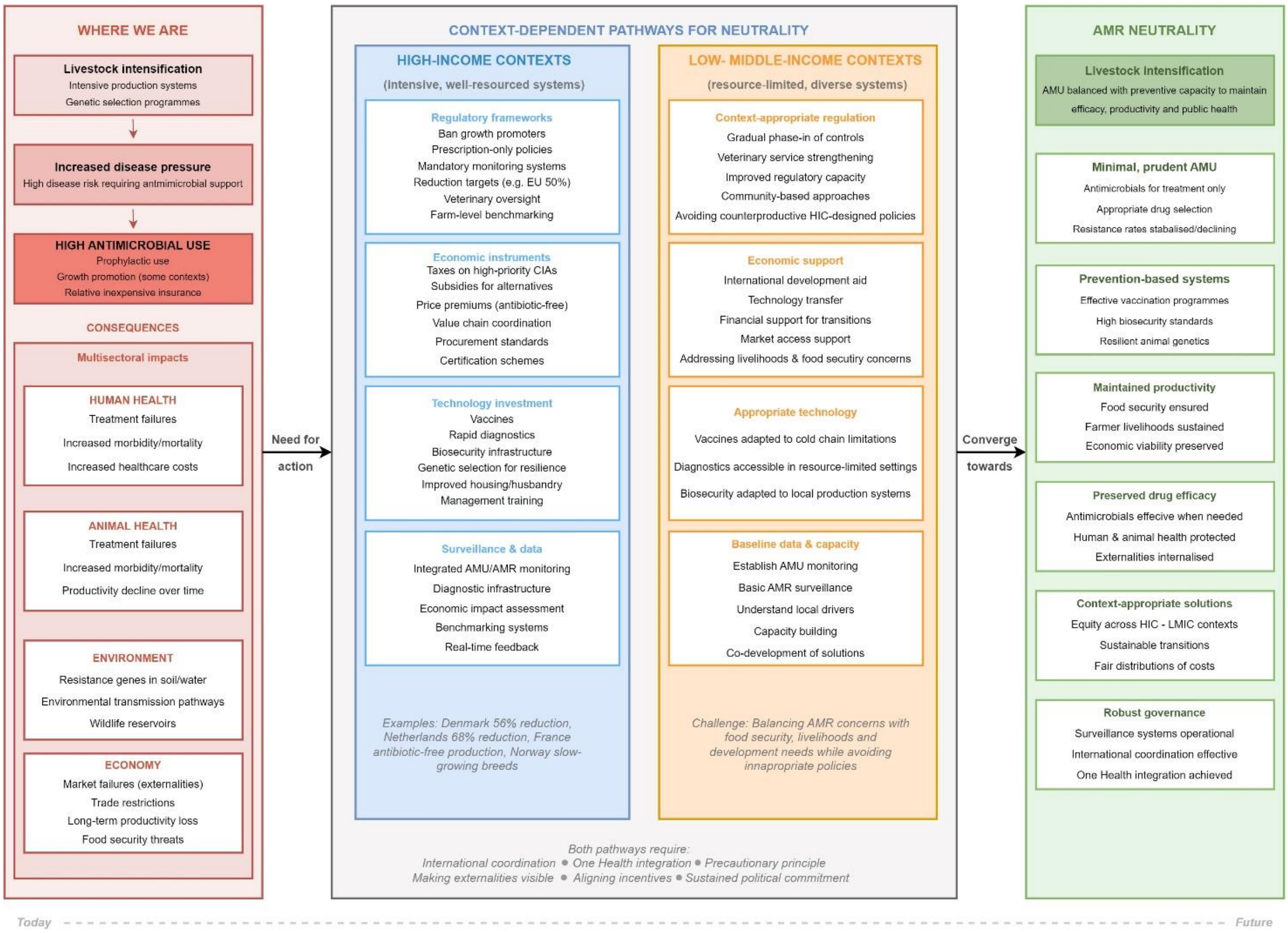
[53] Grave K, Wegener HC. Comment on: veterinarians' profit on drug dispensing. Prev. Vet. Med. 2006;77(3-4):306-8. https://doi.org/10.1016/j.prevetmed.2006.01.010

[54] Johnson T. Stewardship and social justice: implications of using the precautionary principle to justify burdensome antimicrobial stewardship measures. Monash Bioeth. Rev. 2024;42(Suppl. 1):1-15. https://doi.org/10.1007/s40592-024-00224-z

[55] Simjee S, Ippolito G. European regulations on prevention use of antimicrobials from January 2022. Braz. J. Vet. Med. 2022;44:e000822. https://doi.org/10.29374/2527-2179.bjvm000822

[56] Elbehiry A, Marzouk E. From farm to fork: antimicrobial-resistant bacterial pathogens in livestock production and the food chain. Vet. Sci. 2025;12(9):862. https://doi.org/10.3390/vetsci12090862

[57] Pinto Ferreira J, Battaglia D, Dorado García A, Tempelman K, Bullon C, Motriuc N, *et al*. Achieving antimicrobial stewardship on the global scale: challenges and opportunities. Microorganisms. 2022;10(8):1599. https://doi.org/10.3390/microorganisms10081599



AMR: antimicrobial resistance
AMU: antimicrobial use
CIAs: critically important antimicrobials
HIC: high-income country
LMIC: low- to middle-income country

Figure 1

Economic framework for achieving antimicrobial resistance neutrality in livestock systems

Illustration of the transition from antimicrobial-dependent livestock systems (left) through context-specific pathways (centre) towards AMR neutrality (right)