



Prioritising antimicrobial resistance interventions from a One Health perspective: lessons and applied tools for diverse contexts

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Summary

Antimicrobial resistance (AMR) is a complex and multifaceted One Health challenge. Its inherently interconnected and cross-sectoral nature complicates the evaluation and prioritisation of interventions, particularly when inter-sectoral One Health effects are relevant. Despite growing recognition of the need to assess AMR interventions from a One Health perspective, significant methodological gaps remain – particularly in quantifying the connections between the human, animal and environmental sectors and incorporating these interdependencies into the prioritisation of interventions.

This article summarises a set of tools that have been developed and implemented to support more comprehensive assessments of AMR interventions by the Selecting Efficient Farm-level Antimicrobial Stewardship Interventions from a One Health perspective, or SEFASI, consortium. The tools are grouped into four categories based on the type of insight they provide: i) quantifying and characterising AMR burden, ii) understanding AMR dynamics, iii) understanding sector-specific intervention impacts and iv) evaluating cross-sectoral economic costs and effects. These tools utilise a range of methods including statistical, mathematical, static and dynamic modelling techniques.

Although the use of tools presented is constrained by the availability of epidemiological and economic data, they represent an important step towards addressing the cross-sectoral complexity of AMR. This work introduces practical approaches and highlights how integrating methods with diverse objectives across contexts can enhance understanding and prioritisation of cross-sectoral strategies. It also underscores the value of conceptual and applied frameworks to guide data collection, strengthen capacity for evaluating One Health AMR interventions, and support evidence-based decision-making.

Keywords

Antibiotics – Antimicrobial resistance – Denmark – Economic evaluation – Farm-level interventions – One Health – Senegal – United Kingdom.

Required citation

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Introduction

Antimicrobial resistance (AMR) is a major health and economic challenge [1-3]. It is driven in part by antimicrobial use (AMU) and pollution across human medicine, veterinary practice, agriculture and the environment, making it a One Health issue [4,5]. Addressing AMR with a One Health approach requires understanding cross-sectoral transmission dynamics, while also accounting for sector-specific objectives and constraints to inform context-sensitive decision-making.

In health policy more broadly, decision-making is often informed by explicit consideration of an intervention's costs, health impacts, distributional consequences and feasibility of implementation as well as the underlying burden of disease [6,7]. While this information supports structured prioritisation approaches, decisions are also influenced by institutional and political factors [8].

Applying such structured approaches to AMR, however, presents distinct challenges due to the interconnected nature of the problem [9,10]. From a One Health perspective, AMR is characterised by complex connectivity,¹ with transmission dynamics generating cascading effects both within sectors (for example, between different hospitals) and across sectors (human, animal and environmental). As a result, AMR interventions that target a single sector, such as antimicrobial stewardship on farms or hand hygiene initiatives in hospitals, can produce diffuse and sometimes unpredictable effects across the wider One Health network. The difficulty of disentangling these effects makes it challenging to evaluate and prioritise AMR interventions [6].

Capturing these cross-sectoral dynamics requires analytical methods capable of reflecting system behaviour over time and across One Health sectors. This need is highlighted in the recent Organisation for Economic Co-operation and Development (OECD) AMR recommendations [11]. Yet the development of such methods remains constrained due to limited understanding of these cross-sectoral dynamics, persistent

1. Connectivity in a One Health antimicrobial resistance (AMR) context is the set of biological, environmental and socio-technical links that enable AMR, resistance genes, antimicrobials and selective pressures to circulate both within and between the human, animal and environmental sectors.

data gaps and a lack of standardised evaluation frameworks. In addition, individual study findings are often context-specific, reflecting variations in cross-sectoral interactions, AMR epidemiology and national policy environments. This results in varying relevance and importance of considering inter-sectoral effects in intervention evaluation, as explored in detail by Aluzaitė *et al.* [12]. In some contexts, extending the scope of analysis to include cross-sectoral dynamics alters analytical outcomes. In others, the impacts are negligible, leading to differing implications for decision-making.

This task is further complicated by challenges in attributing costs and benefits across sectors and in managing trade-offs between diverse types of impacts [6,13,14]. These complexities underscore the importance of explicit approaches and context-sensitive tools to support decision-making across different One Health settings.

This article presents tools and studies developed by the international One Health research consortium Selecting Efficient Farm-level Antimicrobial Stewardship Interventions from a One Health perspective (SEFASI)² to support cross-sectoral economic evaluations of AMR interventions. Focusing on the stages of early prioritisation and economic evaluation, it introduces a set of tools designed to examine how intra- and inter-sectoral system dynamics shape the costs and effects of interventions relevant to decision-making. By outlining the development and application of these tools across diverse contexts, the article illustrates how their combined use can provide a more comprehensive understanding of AMR and strengthen evidence-based prioritisation of interventions.

SEFASI: collaboration and contextual engagement

The SEFASI consortium applied standard international multidisciplinary teamwork approaches, with additional innovations. Monthly international stakeholder meetings, online scientific presentations and shared digital tools enabled continuous coordination, knowledge exchange and joint development of resources, supported by two in-person meetings of project scientists with key stakeholders in London and Dakar. Models were

2. <https://www.lshtm.ac.uk/research/centres-projects-groups/sefasi>

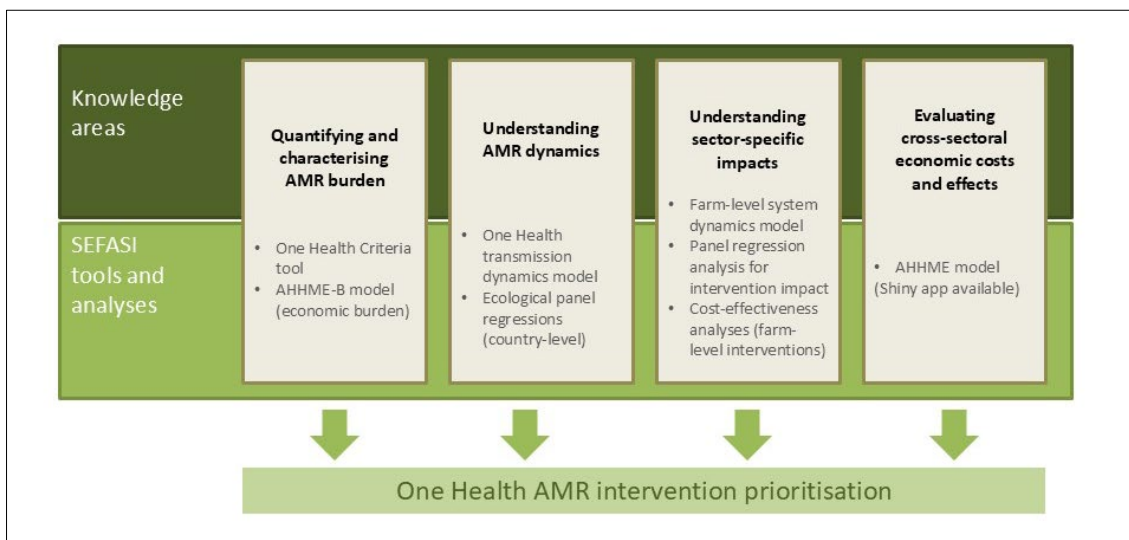
shared via GitHub code repositories, and each country's team incorporated mixed technical expertise in transmission modelling, system dynamics and regression, enabling cross-site understanding beyond single-sector perspectives. Despite this, individual country teams retained a sector-specific focus (e.g. animal health focus in Senegal and Denmark, healthcare focus in the United Kingdom). A key lesson was that engaging stakeholders across the One Health sectors early in intervention prioritisation activities and model design can enhance participation, as seen with increased health sector involvement in Denmark and broader stakeholder engagement in the United Kingdom. Early in-person workshops, such as those conducted in Senegal, proved particularly effective and merit wider adoption. Notably, feedback workshops with local stakeholders, designed to share findings and co-develop recommendations, directly supported the formulation of Senegal's AMR National Action Plan.

SEFASI knowledge areas for evidence-based decision-making

This section summarises the SEFASI consortium's contributions to support evidence-based prioritisation of AMR interventions, organised into four key knowledge areas: burden, dynamics, within-sector impacts and cross-sector impacts ([Fig. 1](#); [Table 1](#)). Rather than outlining theoretical prioritisation approaches, principles or criteria, this work developed tools and quantitatively explored the complex dynamics and connectivity that underpin AMR across three countries (Denmark, the United Kingdom and Senegal).

- Burden: Estimates of AMR burden support intervention prioritisation by aligning disease impact, unmet need and policy objectives [7].
- Dynamics: Understanding the AMR transmission and selection processes across the human, animal and environmental sectors can inform assessments of intra-sectoral and cross-sectoral effects. As patterns of AMU and intervention outcomes differ, context-specific analyses are often needed.
- Within-sector: A thorough assessment of within-sector intervention effects is important for both parameterisation and structural design of broader One Health cross-sectoral models to capture the wider, indirect effects.
- Cross-sector: A key contribution of the SEFASI project was the development of a framework for integrating information across sectors, enabling systematic comparisons of interventions from both economic and broader system-level perspectives.

Overall, the SEFASI work highlights key knowledge areas that can be used for quantitative analysis and prioritisation and helps identify which data need to be collected and how existing knowledge can be used. [Figure 1](#) outlines the tools developed, taking a general perspective on the problems they address, with details of key results and their implications for policy described in [Table II](#). The resources and publications available for each of the tools are summarised in [Table I](#).



AHHME: Agriculture-Human-Health-MicroEconomic
 AHHME-B: Agriculture Human Health MicroEconomic Burden
 AMR: antimicrobial resistance
 SEFASI: Selecting Efficient Farm-level Antimicrobial Stewardship Interventions from a One Health perspective

Figure 1

SEFASI tools and analyses categorised based on knowledge areas

Figure 1 outlines key knowledge areas for evidence-based decision-making, under which SEFASI-developed tools are grouped. Details on the individual tools and associated publications are provided in the main text, [Table I](#) and [Table II](#).

Quantifying and characterising antimicrobial resistance burden

To support the prioritisation of AMR interventions, it is important to understand where the burden is highest and who is most affected. Estimating the broader attributable costs of AMR can help identify priority areas and assess the potential impact of interventions [15]. Drawing on the joint SEFASI insights, the team identified a range of considerations associated with the distribution of cross-sectoral effects and related considerations for intervention prioritisation, developing the One Health Criteria pre-assessment tool. Alongside this, a simplified top-down economic approach for quantifying AMR burden estimates, the Agriculture Human Health MicroEconomic Burden (AHHME-B), was developed.

The One Health Criteria tool

The One Health Criteria pre-assessment tool³ is a qualitative framework designed to support intervention prioritisation by considering the expected types of intervention effects (including inter-sectoral One Health effects), the feasibility of implementation and the availability of knowledge and data for evidence-based decision making. It encourages assessment of the setting's ecosystem connectivity, systemic societal factors (such as governance, societal priorities and availability of infrastructure) and the relevance of One Health effects, supporting context-specific intervention prioritisation [12].

Agriculture Human Health MicroEconomic Burden

SEFASI developed the AHHME-B model, which estimates the health and economic burden of AMR at a national level. This compartmental mathematical model accounts for outcomes including agricultural productivity, labour productivity, healthcare costs and life years lost to disease. Unlike intervention-based models that compare 'intervention' and 'no-intervention' scenarios, AHHME-B estimates burden by comparing the current situation to a range of counterfactual scenarios (such as differing resistance prevalence and AMR growth rates in humans and animals). It can be applied to assess the burden of a specific resistant pathogen or provide a broader estimate of overall AMR burden. The model can be used for evaluating pathogen-focused interventions (e.g. vaccination) as well as those addressing more general drivers, such as AMU. The model is open source (available on GitHub) and is also available as an interactive Shiny app that is more suitable for exploring dynamics ([Table I](#)). Applying the model to specific settings requires quantitative modelling expertise, though the app can be used if the specified parameters are available.

³. The One Health Criteria tool, introduced by Aluzaitė *et al.* [12], will be further developed with a potential to develop an interactive web-based tool.

Understanding antimicrobial resistance dynamics

Assessment of the impact of AMR interventions, such as reduced antibiotic use in livestock, would benefit from an understanding of the mechanisms driving AMR, including the relative roles of selection and transmission in shaping the overall AMR burden and intervention effects. Transmission-dynamic mathematical models are a useful tool for examining the potential outcomes of these interventions under varying mechanistic assumptions and scenarios [16-18]. However, few existing models have been calibrated to empirical data, with the model of AMR across One Health settings in Thailand being a notable exception [17]. This limited use of data is a commonly observed challenge in AMR modelling, as noted in recent systematic reviews [19]. SEFASI aimed to fill this gap by adapting the aforementioned Thai model [17] and then fitting it to data from the three countries in this project to gain novel cross-sectoral and between-country insights. Alongside this mechanistic exploration, the team demonstrates the power of panel regression modelling [20] by using it on the detailed data available from Denmark to show how statistical analysis can help to untangle the contribution of antibiotic use in different sectors to the ecological dynamics of AMR.

One Health transmission dynamics model

An adapted One Health transmission-dynamic modelling framework incorporating antibiotic use and resistance across animals, humans and the environment was developed. It was demonstrated how such a model could be used by fitting the model to data from the United Kingdom, Senegal and Denmark and exploring the impact of different intervention packages. Targeting spread of bacteria was found to have the biggest impact on resistance levels, although the uncertainty was large. Future work to collect high-quality, longitudinal and comparable data, in particular from environmental sources, is key to enhance the specificity of model results to improve prioritisation of interventions and support targeted design. Better data would allow these tools to improve comparison of multiple interventions or assess details of a single technology, such as coverage, sensitivity, specificity and target populations, before adoption. This model is available with open access R code ([Table I](#)) to support use, but its application would require quantitative modelling expertise.

Ecological panel regressions (country-level)

Tailoring panel regression to a One Health application, this work sought to establish the relationship between AMU in animal agriculture and the development of AMR in humans,

relying on rich data from Denmark. Using national-level panel data, ecological panel regressions were conducted at the pathogen, drug and resistance levels. This helped reveal the functional relationship between AMU in animals and AMR in humans. The tool used publicly available AMU and AMR surveillance data from the Danish Integrated Antimicrobial Resistance Monitoring and Research Programme⁴ and is implemented in R [20]. However, this approach was limited by the statistical power of the open dataset and suggested that animal AMU explained only a small part of the AMR variation in humans. It also could not account for many other covariates.

Understanding sector-specific impacts

In developing cross-sectoral models, simplifications of sector-specific dynamics are necessary. However, there is often limited guidance on which within-sector effects are most relevant and should be included. Prioritising and parameterising these simplifications require identifying the key components of each system and drawing on detailed within-sector understanding and simulations, particularly where more comprehensive single-system data are available.

Peri-urban poultry farming was selected as a priority area due to its rapid growth in Senegal [21], and a system dynamics tool was developed to assess the economics of interventions and reductions in antibiotic use. Panel regression and cost-effectiveness analyses were also applied to data from Denmark, where comprehensive analysis of AMU has been well established. These analyses illustrate the approaches to selecting/considering different types of intervention impacts. This work can also support wider cross-sectoral models.

Farm-level system dynamics model

A new system dynamics poultry model was developed, taking the perspective of a peri-urban chicken farmer making decisions about what interventions to apply, balancing the

4. The Danish Integrated Antimicrobial Resistance Monitoring and Research Programme, or DANMAP, is the Danish programme for surveillance of antimicrobial consumption and resistance in bacteria from food animals, food and humans.

risks of disease outbreak, AMU and farm economics [22]. Interventions modelled include preventive interventions (applied regardless of whether there is a disease outbreak) and reactive interventions (applied only in response to a disease outbreak). The model was developed in a participatory manner with data, input on the model structure and validation from actors and researchers, following the principles of system dynamics, and with its user-friendly interface can allow for the rapid assessment and trade-off analysis of different scenarios, with easy modification of parameters to suit different contexts. An interactive web-based interface can be easily adapted to the farm type and local context by changing the input parameters [23].

Panel regression analysis for intervention impact evaluation

Furthermore, panel data regression techniques, such as difference-in-differences, and efficiency analysis were applied to evaluate the impact of quantitative restrictions on antibiotic use, in terms of both subsequent AMU and farm-level economic outcomes [24,25]. These analyses can be conducted using R, STATA or Python, but they require longitudinal farm-level data on antibiotic use and economic performance.

Cost-effectiveness analyses (farm-level interventions)

Evidence beyond impacts on AMR transmission or infections is required to assess interventions, including economic considerations for cost-effectiveness. In SEFASI, the cost-effectiveness of alternative farm-level interventions to reduce AMU in the Danish pig sector – such as quotas, taxes, vaccination, biosecurity, extended weaning age, feed/probiotics and phage therapy – was compared. This analysis also relies on farm-level observational data – ideally panel data – to estimate substitution elasticities for inputs targeted by the interventions. The regression analysis for elasticity estimation can likewise be performed in R, STATA or Python. After estimating these elasticities, the cost-effectiveness analysis is implemented using a model in the General Algebraic Modelling System (GAMS). Both the regression and cost-effectiveness tools require farm-level observational data on economic accounts and antibiotic use, as well as expertise in statistical and GAMS programming. These tools are available upon request from the team.

Evaluating cross-sectoral economic costs and effects

Integrating mechanistic understanding of AMR dynamics – encompassing inter-sectoral interactions and detailed within-sector processes – provides the foundation for cross-

sectoral economic evaluations that capture more comprehensive impacts of interventions. SEFASI applies this integration through its principal tool, the Agriculture-Human-Health-MicroEconomic model (AHHME).

The Agriculture-Human-Health-MicroEconomic model

AHHME is a compartmental health-economic tool designed to evaluate the cross-sectoral cost-effectiveness of AMR-related interventions in food animal production. It adopts a One Health perspective, integrating impacts across four key domains: human health, healthcare costs, labour productivity and food animal productivity. The model simulates health transitions in human and animal populations over time, assigning monetary values to health outcomes and comparing 'intervention' and 'no-intervention' scenarios. Users can modify epidemiological, economic and agricultural parameters to tailor the model to specific country contexts. For example, the model was applied to evaluate a hypothetical intervention reducing AMU in pig and poultry farms with assumed effects on i) animal finishing weight and ii) human AMR prevalence in sepsis. Outputs included the net monetary benefit, threshold price for implementation, and quality-adjusted life years gained across income-level scenarios, supported by tornado plots and Monte Carlo simulations. Similarly to the transmission dynamic model, AHHME could be used to assess opportunity costs but also to economically evaluate different interventions. This tool is also available as open access R code and a Shiny app ([Table I](#)), but application to new settings will require quantitative modelling expertise.

Information needs and challenges associated with the use of the above tools

The primary challenge across all tools was limited availability of robust, context-specific data for both epidemiological and economic parameters with the same spatial and temporal resolution, resulting in considerable uncertainty around model estimates. Such data are especially scarce outside of high-income settings [26]. However, there were limited available data on AMR in the environment sector across all SEFASI countries. To address these limitations, practitioners can rely on aggregated datasets, as demonstrated by Emes *et al.* [20], but then are faced with limited ecological understanding and missing covariates. In many settings, certain subsets of granular data are available (e.g. AMU in livestock) but with no other corresponding aspects (e.g. AMR prevalence in the same units of analysis).

There is a circular dependency of model complexity (see Figure 2 in [27]) and data availability: more realistic and complex models require detailed data to inform both parametrisation and structural assumptions. However, modelling tools are useful in the absence of detailed data, as they can help prioritise data-gathering efforts and explore intervention options under explicit expert assumptions [28]. Expanding applications to a wider range of contexts – including different countries, diseases and production systems – would help strengthen confidence in the modelling approaches and their generalisability.

It is important to highlight that considerable uncertainty remains regarding the relationship between AMU and AMR, which is critical for assessing intervention impacts and can be explored within AHHME. Structural uncertainties in modelling AMR transmission pathways further influence outcomes. The current model comprises human, animal and environmental compartments, which could ideally be disaggregated to represent soil, water or distinct livestock systems, contingent on reliable data on transmission between sub-compartments.

Improving the accuracy of AMU intervention impact evaluations from a One Health perspective requires addressing several critical data and resource gaps. Priorities include developing integrated surveillance systems to track AMU and AMR across human, animal and environmental sectors and assess interspecies transmission [29]; producing robust estimates of AMR burden in each sector; collecting standardised farm-level AMU, productivity and economic data, especially in low- and middle-income countries, to inform models such as the system dynamics poultry model and AHMME; incorporating socio-economic and behavioural insights to better understand farmer decision-making and the feasibility of interventions; and strengthening institutional capacity, technical infrastructure and multidisciplinary expertise to support surveillance and modelling.

Although user-friendly dashboards (e.g. Shiny apps) were developed, effective use of these tools in new settings still requires quantitative modelling skills. Capacity development across the AMR field is therefore needed, particularly to support economic evaluation. Combined with improved surveillance, an iterative cycle can emerge: modelling guides evidence generation, better data reduce model uncertainty, and enhanced data collection, including economic and environmental information, strengthens surveillance. This integrated approach would yield broader benefits for AMR control [27].

Discussion

Determining the economic efficiency of AMR interventions is central to supporting evidence-based prioritisation. Incorporating considerations of AMR connectivity into such assessments, however, remains challenging, especially considering cross-sectoral intervention effects. To address this, a suite of practical modelling tools designed to integrate these complexities was developed and applied, allowing local data to be used and extrapolated to estimate national-level impacts of AMR-related interventions. However, this work highlighted major data gaps across One Health sectors, underscoring the need for more systematic and integrated data collection to support robust modelling and AMR control over time and space. This approach complements broader efforts, such as OECD analyses [11], by providing adaptable mechanistic and economic models that operationalise high-level priorities across diverse national and sectoral contexts.

In the SEFASI project, advanced analytical methods were applied to estimate the burden of AMR, assess its impacts and evaluate the cost-effectiveness of farm-level AMU reduction interventions – both within specific sectors and from a One Health perspective. While recent developments in machine learning, artificial intelligence and genomics hold considerable promise for advancing understanding, their utility remains constrained by the same data limitations encountered in SEFASI. Strengthening AMR surveillance and improving the availability of economic data will therefore be essential to generate the fundamental insights needed to assess intervention impacts more accurately.

Data gaps present challenges for both model development and evidence-informed decision-making but should not preclude the use of modelling. Even in data-scarce settings, constructing explicit models is inherently valuable for clarifying and linking the components of the system [27]. Moreover, other ways of filling missing parameters can be found, such as structured expert elicitation [30] or inference from other contexts. Uncertainty and scenario analyses enable the implications of data limitations to be examined explicitly rather than implicitly assumed, while sensitivity analyses can identify which parameters most strongly influence results and thereby inform priorities for future data collection [28,31]. Structural uncertainty can also be explored through alternative model specifications [32]. Importantly, policy and resource allocation decisions must often be made in the absence of complete evidence; in such contexts, modelling provides a coherent framework for integrating available knowledge on what are understood to be the context-specific processes, exploring uncertainty, and supporting decision-making despite persistent gaps in knowledge [33,34].

However, the experience of SEFASI also highlights that lasting progress in AMU policy requires more than improved models or enhanced surveillance systems. Sustainable impact depends on coordinated, cross-sectoral strategies that draw on high-quality, context-specific data and are supported by long-term institutional commitment to One Health integration. Future research should focus on hybrid modelling approaches that combine existing administrative (empirical) data, survey data [20] and novel participatory data collection methods, especially in data-scarce low- and middle-income regions, such as innovative information and communications technology-based and citizen science approaches [35].

From a policy perspective, adaptive and scalable data infrastructures will be critical to ensure that models can be continuously refined in response to emerging evidence. Ultimately, effective ranking and evaluation of farm-level AMU interventions from a One Health perspective will depend on sustained investments in data ecosystems, institutional collaboration and policy alignment – cornerstones of a coordinated global response to AMR.

The tools within SEFASI have gone some way to support rational prioritisation and decision-making processes in a context of high complexity that AMR brings, for example addressing inter-sectoral dynamics and connectivity across systems.

Decision-making from a One Health perspective to prioritise interventions is highly context- and time-specific. Considering the One Health perspective will require further considerations for prioritisation criteria. Combining local feasibility and implementation landscapes, with ecosystem connectivity, and stakeholder criteria will lead to different preferential policies. Moreover, stakeholders who champion evaluating AMR interventions in a One Health approach are needed to provide feedback, parameter estimates, scenarios and data to models and to then take recommendations to decision-makers. The present work's main policy impact was in Senegal, where close interaction with local stakeholders and use of the system dynamics model demonstrated the trade-offs between different combinations of AMU and other measures to improve productivity and disease management, particularly biosecurity measures and vaccinations. This analysis showed how these measures can significantly help to reduce economic losses stemming from outbreaks in peri-urban broiler operations in Senegal. The work demonstrated how such insights could help inform practices at the producer level for veterinarians, extension agents and producers themselves, as well as national policies shaping these interactions. The close interaction with One Health policy-makers,

including at SEFASI meetings, enabled improved communication of outputs and new modelling perspectives. Inter-sectoral analysis found that intervention packages that target AMU on farms, hospitals and the environment together are more effective in improving the impact of individual interventions. Additionally, using AHHME to analyse the potential macroeconomic cost of AMR helps guide policy-makers, donors and investors in implementing interventions.

Future work in this area should consider the fact that in SEFASI a process of continuous feedback cycles was found to be highly important in developing these tools. Regular internal monthly meetings and external consultations with stakeholders (SEFASI Knowledge Hub)⁵ led to the co-development of fit-for-purpose tools, context-specific scenarios and model results that respond to the needs of the future end users. This process also proved useful for learning, adaptation and knowledge diffusion. In particular, the assessment of model sensitivity to key parameters is important for future analyses and provides a useful basis for cross-disciplinary discussions on data needs. Applying these models in other settings and selecting tools based on context-specific requirements would further support testing and validation of the analyses [12].

Conclusion

SEFASI led to the development of practical tools across multiple stages relevant to assessing the importance of cross-sectoral effects on the impact of AMR interventions. Although this represents only an initial step in a longer-term process, integrated collaboration and stakeholder engagement generated new insights and supported the development of tools to strengthen the evidence base for AMR intervention design. Further iterative work is needed to refine model parameterisation and to inform surveillance of the economic, epidemiological, and environmental costs and dynamics of AMR, thereby supporting more robust evidence-based interventions in the future.

5. Further information on the SEFASI Knowledge Hub can be found here: <https://www.lshtm.ac.uk/research/centres-projects-groups/sefasi#knowledge-hub> (accessed on 15 August 2025).

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Prioriser les interventions de lutte contre la résistance aux antimicrobiens dans une perspective « Une seule santé » : enseignements tirés et outils appliqués dans divers contextes

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Résumé

La résistance aux antimicrobiens (RAM) se révèle un défi complexe et multiforme dans le cadre « Une seule santé ». Le phénomène de la RAM est par nature intrinsèquement interconnecté et intersectoriel, ce qui complique l'évaluation des interventions à mener et leur priorisation, en particulier lorsque les effets recouvrant les secteurs qui relèvent de l'approche « Une seule santé » sont importants. Si la nécessité de cette approche pour évaluer les interventions de lutte contre la RAM fait aujourd'hui l'objet d'un consensus croissant, il subsiste d'importantes lacunes méthodologiques – en particulier pour quantifier les liens entre les secteurs de la santé humaine, animale et environnementale et pour intégrer ces interdépendances dans la priorisation des interventions.

Cet article résume un ensemble d'outils élaborés et mis en œuvre par le consortium *Selecting efficient farm-level antimicrobial stewardship interventions from a One Health perspective* (Choisir des interventions efficaces de gestion des antimicrobiens au niveau de la ferme du point de vue de l'approche « Une seule santé » – SEFASI) en appui d'évaluations plus complètes des interventions contre la RAM. Ces outils sont regroupés en quatre catégories selon le type d'éclairage qu'ils apportent : i) quantification et caractérisation de la charge de la RAM, ii) compréhension des dynamiques de la RAM, iii) compréhension des impacts des interventions propres à chaque secteur et iv) évaluation des coûts et effets économiques au niveau intersectoriel. Ils font appel à diverses méthodes, dont des techniques de modélisation statistiques et mathématiques tant statiques que dynamiques.

Si les données épidémiologiques et économiques disponibles peuvent limiter l'application de ces outils, ceux-ci constituent néanmoins une avancée importante pour appréhender la complexité intersectorielle de la RAM. Ce travail présente un certain nombre d'approches concrètes en faisant ressortir le potentiel d'une mise en œuvre intégrée de méthodes poursuivant une diversité d'objectifs et adaptées à des contextes

variés pour améliorer la compréhension et la priorisation des stratégies intersectorielles. Ils soulignent également l'intérêt de disposer de cadres conceptuels et opérationnels pour orienter la collecte de données, renforcer les capacités d'évaluation des interventions « Une seule santé » contre la RAM et étayer la prise de décision en la fondant sur des éléments probants.

Mots-clés

Antibiotiques – Danemark – Évaluation économique – Interventions au niveau des exploitations – Résistance aux antimicrobiens – Royaume-Uni – Sénégal – Une seule santé.

Dar prioridad a las intervenciones contra la resistencia a los antimicrobianos desde una perspectiva del enfoque «Una sola salud»: lecciones y herramientas aplicadas a diversos contextos

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Resumen

La resistencia a los antimicrobianos (RAM) es un desafío «Una sola salud» complejo y multifacético. Debido a su naturaleza intrínsecamente interconectada e intersectorial, la evaluación y la priorización de las intervenciones son complicadas, especialmente cuando las repercusiones intersectoriales del enfoque «Una sola salud» son relevantes. Si bien cada vez se reconoce más la necesidad de evaluar las intervenciones contra la RAM desde una perspectiva del enfoque «Una sola salud», persisten importantes lagunas metodológicas, en particular en lo relacionado con la cuantificación de las conexiones entre los sectores humano, animal y medioambiental, y la integración de estas interdependencias en la priorización de las intervenciones.

Este artículo resume un conjunto de herramientas elaboradas e implementadas para respaldar evaluaciones más exhaustivas de las intervenciones contra la RAM por parte del consorcio SEFASI (Selecting Efficient Farm-level Antimicrobial Stewardship Interventions). Las herramientas se agrupan en cuatro categorías según el tipo de información que proporcionan: i) cuantificación y caracterización de la carga de RAM; ii) comprensión de la dinámica de la RAM; iii) comprensión de las repercusiones de las intervenciones sectoriales, y iv) evaluación de los costos y efectos económicos

intersectoriales. Asimismo, utilizan diferentes métodos, incluidas las técnicas de modelización estadística, matemática, estática y dinámica.

A pesar de que el uso de las herramientas presentadas se ve limitado por la disponibilidad de datos epidemiológicos y económicos, constituyen un avance importante para abordar la complejidad intersectorial de la RAM. Este trabajo presenta enfoques prácticos y destaca la manera en que la integración de métodos con diversos objetivos en distintos contextos puede permitir mejorar la comprensión y la priorización de las estrategias intersectoriales. También hace hincapié en la importancia de los marcos conceptuales y aplicados para orientar la recopilación de datos, fortalecer la capacidad de evaluación de las intervenciones del enfoque «Una sola salud» contra la RAM y respaldar la toma de decisiones basada en pruebas.

Palabras clave

Antibióticos – Dinamarca – Evaluación económica – Intervenciones en las explotaciones – Reino Unido – Resistencia a los antimicrobianos – Senegal – Una sola salud.

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Table I

Baseline descriptors of SEFASI model outputs

Evidence component	Model structure	Population [^]	Intervention types	Costs/ economic analysis	Country ^{&}	Outcome measure/perspective	Availability (links to tools and publications)
Quantifying and characterising AMR burden	One Health Criteria tool	all	N/A	No	N/A	Intervention prioritisation by considering the expected types of intervention effects	Publication [12]: https://doi.org/10.20506/rst.44.3676
	AHHME-B	human, animal	N/A	Yes	N/A	Holistic health-economic burden of AMR at societal level	Interactive AHHME-B modelling tool: https://eveemes.shinyapps.io/AHHME-B/
Understanding AMR dynamics	One Health transmission dynamic model of AMR	all	Reduce transmission, AMU or combinations	Yes	S/E/D	Reduction in resistance burden in each setting	Code repository for the One Health transmission model: https://github.com/gwenknight/SEFASI_transmission_model Publication accepted in <i>One Earth</i> and available upon request to the authors
	Ecological panel regressions (country-level)	human, animal	N/A	No	E/D	Quantifying the ecological relationship between (human and animal) AMU and human AMR	Publication [20]: https://doi.org/10.1016/j.onehlt.2024.100856
Understanding sector-specific impacts	Farm-level system dynamics model	human, animal	AMU-level intervention in livestock, how it affects disease spread & farm income	Yes	S	Economic and epidemiological model to enable rapid assessment and trade-off analysis of different scenarios	Interactive modelling tool: https://exchange.iseesystems.com/public/ilri-policy-and-foresight/amu-in-poultry/index.html Poster publication available [23]: https://hdl.handle.net/10568/152295 Related publications: https://doi.org/10.3389/fvets.2023.1189109 [22] https://doi.org/10.3390/antibiotics12030460

Evidence component	Model structure	Population [^]	Intervention types	Costs/ economic analysis	Country ^{&}	Outcome measure/perspective	Availability (links to tools and publications)
	Panel regression analysis for intervention impact evaluation	animal	Alternative farm-level interventions aimed at reducing AMU in pig farming	No	D	Farm-level intervention impact evaluation on farm productivity and economic outcomes	Publications: https://doi.org/10.1093/erae/jbac009 [24] https://doi.org/10.1111/1477-9552.12439 [25]
	Cost-effectiveness analyses	animal		Yes	D	Ranking of the alternative interventions based on their cost-effectiveness in reducing AMU at farm level towards a defined target	Working paper available upon request
Evaluating cross-sectoral economic costs and effects	AHHME	human, animal	Default setting up for livestock AMU interventions	Yes	S	Holistic health-economic effect of AMR-related (or other) interventions at societal level	Interactive AHHME modelling tool: https://eveemes.shinyapps.io/Model-Code-and-Inputs/ Code repository and CVS input files for the general version and Viet Nam case study for the One Health model of agricultural AMR interventions: https://github.com/Trescovia/AHHME Publication: https://doi.org/10.1016/j.onehlt.2023.100629

[^] All One Health sectors: humans, animals and the environment

[&] Data from these countries used to parameterise the referenced version of the model

AHHME: Agriculture-Human-Health-MicroEconomic

AHHME-B: Agriculture Human Health MicroEconomic Burden

AMR: antimicrobial resistance

AMU: antimicrobial use

S/E/D: Senegal/the United Kingdom/Denmark

Table II

Details of novel tools developed as part of SEFASI, their current applications and result with impact on intervention policy

Tool	Interventions or targets explored	Currently parameterised context	Outcome type	Intervention ranking or insights into One Health interventions	Implications for policy	Limitations
One Health Criteria tool	Does not model interventions	Any	Qualitative insights on context-specific expected types of outcomes, insights on feasibility of implementation and availability of data to inform these. Supports context prioritisation	Provides insight into inter-sectoral effects given the context	- Supports evaluation, prioritisation, implementation and targeting of interventions. -Useful in data-poor-settings	Is a pre-assessment qualitative tool and requires further analyses to inform decisions/support action
AHME-B			Holistic health-economic burden of AMR at societal level	The healthcare system perspective captures only part of the impact of AMR	Consider the broader health-economic burden of AMR, beyond the healthcare system perspective	- Greater model complexity means greater uncertainty - Can be difficult to parameterise, although easier than alternatives - Does not include all relevant outcomes (e.g. impact on food security)
One Health transmission dynamic model of AMR	Reduce transmission, AMU or combinations	Broad One Health assumptions fitted to data on human/animal/environment AMR levels in Denmark, Senegal and the United Kingdom up to 2020 and predicted five-year target impact	Burden of third-generation cephalosporin resistance in humans/animals/environment in Denmark/Senegal/the United Kingdom	- Reducing transmission between human and animals by 50% vs. antibiotic usage in animals by 30% would have a more than three times bigger reduction in AMR - Combinations of targets had impacts mostly driven by transmission reductions	Transmission targeting interventions may have a bigger impact in One Health settings than reducing AMU	Few One Health data meant that determining baseline levels of AMR in each setting was difficult and hence intervention impacts are highly uncertain
System dynamics poultry model	Farm-level interventions related to disease prevention and treatment, AMU	Applied to commercial broiler systems in Senegal with the flexibility to generalize to other countries and systems	Simulate farm productivity and AMU while balancing the risk of disease outbreaks	Preventive interventions (vaccinations) help reduce flock loss in disease outbreaks and AMU can be used more selectively by farmers	Opportunities for reducing AMU from awareness building among producers and veterinarians	- Does not take into account all farm contexts - Does not consider different antimicrobial strains

Tool	Interventions or targets explored	Currently parameterised context	Outcome type	Intervention ranking or insights into One Health interventions	Implications for policy	Limitations
AHHME	Can model any AMR-related intervention that can be expressed in terms of the model's 80-odd parameters. Currently, it has been applied to farm-level antimicrobial stewardship interventions	Example low-, middle- and high-income scenarios	Holistic health-economic effect of AMR-related (or other) interventions at societal level	<ul style="list-style-type: none"> - The healthcare system perspective captures only part of the impact of agricultural AMR interventions - Taking broader outcomes into consideration, agricultural antimicrobial stewardship interventions seem highly cost-effective across countries in almost all scenarios - Methodological assumptions (e.g. willingness-to-pay threshold, discount rate) can be more influential than epidemiological factors 	Use models like this to estimate potential intervention impact and select and design interventions (as part of broader decision-making processes). Look beyond the healthcare system perspective	<ul style="list-style-type: none"> - Greater model complexity means greater uncertainty - Requires knowledge of two key relationships (ecological relationship between AMU and AMR and farm-level impact of interventions), which are generally unclear - Does not include all relevant outcomes (e.g. impact on food security)

AHHME: Agriculture-Human-Health-MicroEconomic
AHHME-B: Agriculture Human Health MicroEconomic Burden
AMR: antimicrobial resistance
AMU: antimicrobial use