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What and how can we learn from complex global problems for antimicrobial resistance policy? A comparative study combining historical and foresight approaches

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ABSTRACT

Objectives: To (i) develop a methodology for using historical and comparative perspectives to inform policy and (ii) provide evidence for antimicrobial-resistance (AMR) policymaking by drawing on lessons from climate change and tobacco control.

Methods: Using a qualitative design, we systematically examined two other complex, large-scale policy issues—climate change and tobacco control—to identify what relevance to AMR can be learned from how these issues have evolved over time. During 2018–2020, we employed a five-stage approach to conducting an exploratory study involving a review of secondary historical analysis, identification of drivers of change, prioritisation of the identified drivers, scenario generation and elicitation of possible policy responses. We sought to disrupt more 'traditional' policy and research spaces to create an alternative where, stimulated by historical analysis, academics (including historians) and policymakers could come together to challenge norms and practices and think creatively about AMR policy design.

Results: An iterative process of analysis and engagement resulted in lessons for AMR policy concerning persistent evidence gaps and uncertainty, the need for cross-sector involvement and a collective effort through global governance, the demand for new interventions through more investment in research and innovation, and recognising the dynamic relationship between social change and policy to change people's attitudes and behaviours are crucial towards tackling AMR.

Conclusion: We draw on new methodological lessons around the pragmatism of future- and policy-oriented approaches incorporating robust historical and comparative analysis. The study demonstrates proof of concept and offers a reproducible method to advance further methodology, including transferrable policies that could tackle health problems, such as AMR.

1. Introduction

Antimicrobial resistance (AMR) is a major threat to public health. It has been estimated that if antimicrobial resistant infections continue to occur at current rates, they may be among the leading causes of death, globally, by 2050 [1]. The potential effect for human health has been described as 'apocalyptic' [2,3].

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AMR has been framed by some as a 'wicked problem'—because of the dynamic complexity in how it evolves and the nature of the collaborative, multi-sector policy response required to manage it [4]. More recent analysis labelled AMR a 'super wicked problem', arguing that AMR has four further defining features: (i) time available for solving the problem is running out; (ii) those who are responsible for solving the problem are themselves contributing to the problem; (iii) key actors often have weak or no mandate to address the problem; and (iv) the future is discounted in an irrational way by political actors [5]. Littmann and Simonsen argued that understanding AMR in this way has important implications for policy responses [5]. First, it indicates that AMR will not be addressed through technological innovation alone; rather, path dependencies to the use of antimicrobials need to change. Second, and perhaps more importantly, the idea of a 'solution' for AMR is misplaced as resistance is a naturally occurring condition that can never be eliminated [5].

AMR is often framed as a unique problem because of its complexity and global effects [5]. Treating the problem as unlike anything ever seen before, however, risks missing the opportunity to learn from the past or other complex problems. In this paper, we looked systematically at other complex and large-scale policy issues to identify what can be learned from how these other problems have evolved over time. We focused specifically on climate change and tobacco control, considering their similarities and differences in 11 main respects, as previously described [6].

Transferable learning from tobacco control may come from understanding how smoking became a public health problem, and then how different actors came together to address this problem and the evolution of tobacco control measures. At an international level, the World Health Organization (WHO) Framework Convention for Tobacco Control, 2003 (FCTC) is the most prominent policy instrument, but it took decades of effort to establish [7]. Downplayed by some as a potential comparator to AMR because it lacks the same transnational nature and constant evolution [8], closer analysis of historical developments that led to the implementation of the FCTC could inform lessons for international action on AMR, particularly at a time when a binding global treaty on AMR is being considered [8].

Climate change brings further points of comparison with AMR. Both issues represent common pool resource problems [9] in that they share the characteristics of Ostrom and Ostrom's [10] classification of non-excludability of certain goods (in this case, antibiotics and a protected environment). At the same time, the consumption of the good in question by one individual affects the ability of others to enjoy the same good in the future. As such, both areas can suffer from well-described collective action challenges including free riding, the tragedy of the commons, and conflict between individual rationality and optimal group outcomes [9–11].

Both climate change and AMR raise moral and ethical dilemmas, stemming from international (and intergenerational) differences in preferences and priorities [12,13]. Efforts to tackle AMR need to address the balance between ensuring access to antibiotics (especially in low-resource settings) and reducing excess use of antibiotics [14]. Similarly, international efforts to tackle climate change need to agree on the extent to which individual countries' and regions' past contributions to the issue should be reflected in the relative distribution of costs associated with proposed solutions [15].

Comparisons have been drawn between AMR and climate change to emphasise the scale of the threat posed by AMR and to advocate for global action [16]. Others have drawn comparisons in suggesting potential policy and governance solutions, arguing that 'despite its limitations the IPCC (Intergovernmental Panel on Climate Change) has been the most successful attempt in history to empower scientific consensus to inform global policy and practice' and therefore could be a model for AMR to follow [17].

Although comparisons have been drawn between these 'wicked' problems, few have involved a systematic comparison or made explicit a method of comparison. In this study, we aimed to bring together historical and future-orientated perspectives to identify lessons that can improve the effectiveness and efficiency of AMR policymaking. Future-orientated methods such as scenario planning have become routine within policy making, offering a potentially risk-free space for policymakers and other stakeholders to visualise different strategies for the future [18]. At the same time, Bradfield et al. argue that these methods do not take full advantage of learning from historical analysis [19]. Haddon et al. argue that historical insights might offer 'instructive parallels' and that methods to embed historical analysis more routinely in policymaking processes should be pursued [20]. From the outset, we acknowledge that the notion of 'learning from history' is contentious—argued to be naïve and incongruous with historical analysis that does not have the purpose of producing actionable findings [21]. In seeking to draw learning from history [21], we were not seeking neat answers for policy, but rather to use historical analysis and the consideration of historical perspective to provide questioning and provocation within future-oriented thinking. Others have sought to historicise policy in order to 'past-proof' policy in health-related areas [22]. In common with these, we take history to refer to the past and the discipline but deliberately look to learning from other policy areas for AMR.

The vision of our exploratory study was to attempt to disrupt more 'traditional' policy and research spaces and think creatively about AMR policy design. Our aims were to (i) explore methodological development in the use of historical and comparative perspectives to inform policy; and (ii) provide evidence for AMR policymaking, drawing from other policy areas. We hoped such an approach would help us to understand what had worked well or less well in other policy areas and offer recommendations for what could be considered, or avoided, for AMR. We detail our iterative methodological approach with findings and critical reflections from each stage and consider implications for future methodologies and, crucially, learning for AMR policy.

2. Material and methods

2.1. Study design

Based on Bradfield et al.'s [19] proposed method for systematically incorporating history into scenario development, we elaborated an approach comprising five sequential stages, each informing the next (Fig. 1). Stages 1–3 consisted of historical and comparative analysis of AMR, climate change and tobacco control policy. Stages 4 and 5 considered the future of AMR policymaking through the development and testing of plausible but challenging scenarios for the future of AMR. Findings from the five research stages were then synthesised to draw overarching lessons for policy and methodological development. Stages 1 and 2 involved desk reviews and formative research to scope the phenomena without one-to-one interviews, hence exempt from ethical approval. However, stages 3, 4 and 5 detailed interviews and individual data usage, including beliefs—ethical approval was obtained from the University of Exeter (Ref: Mar19/D/203). The analysed research stages, numbered consecutively from one to five, and their respective methods and findings are detailed hereinafter.

2.2. Stage 1: Orientating the present

A rapid review of secondary historical analyses in each of the three policy areas was conducted to understand the devel-

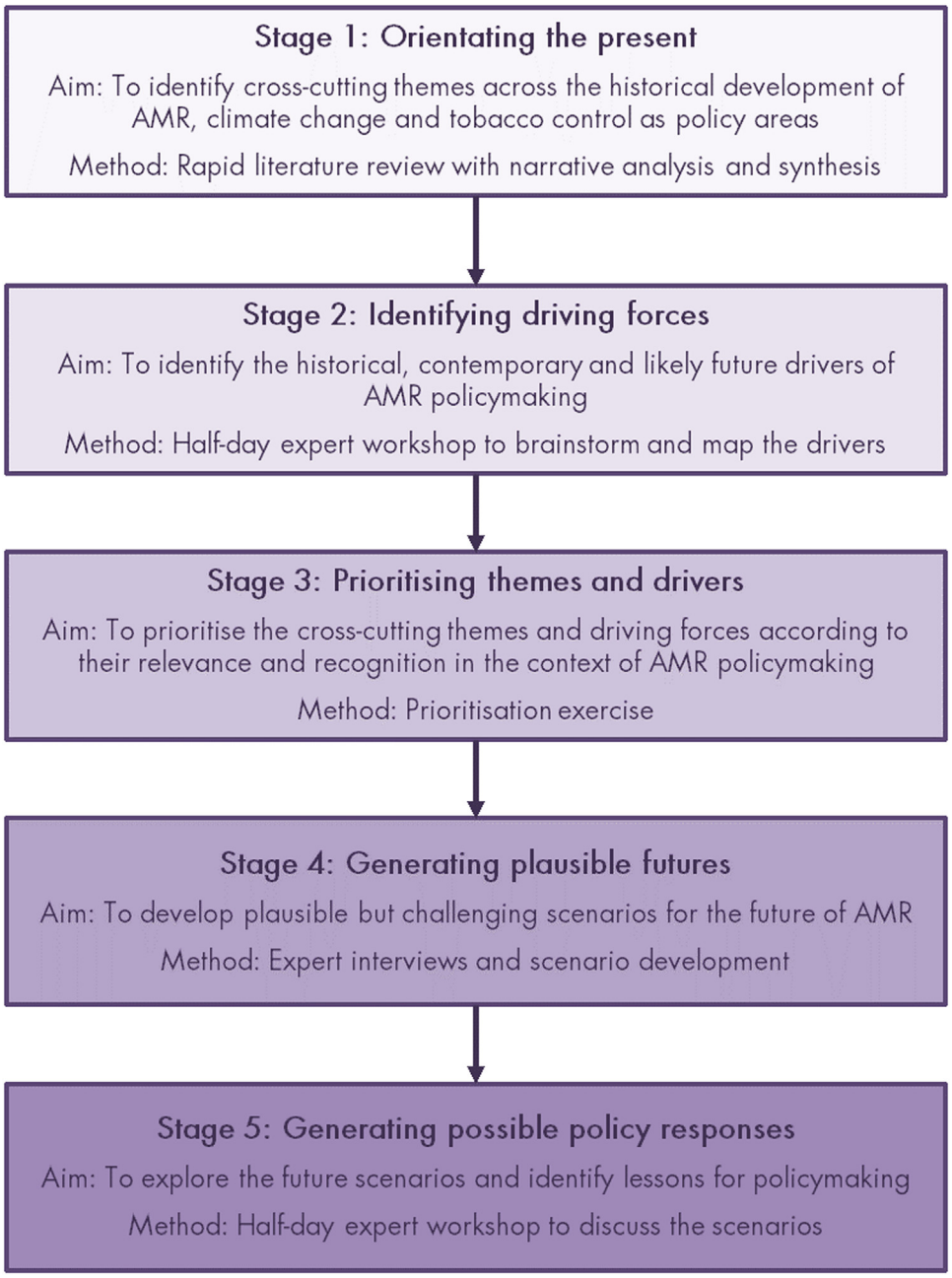

Fig. 1. Overview of the study stages, aims and methods. AMR, antimicrobial resistance.

opment of each area's problem definition and policymaking over time, and to identify cross-cutting themes across the areas. The same methodology (described below) was used for each of the three policy areas, to facilitate cross-analysis and synthesis of findings.

2.2.1. Methods

2.2.1.1. Literature identification. We adopted a pragmatic approach whereby, guided by three members of our team (a historian, AMR; a political scientist, climate change policy; a historian, tobacco control), we identified and prioritised key literature to review to inform our understanding of each field's policy development. Primary and additional literature were identified through a snowballing search of bibliographies of our topic-specific main references (ie, tobacco control [23–29], climate change [9,30–38], and AMR [39–61]).

2.2.1.2. Data extraction. A member of the research team developed a preliminary data extraction framework. This was piloted by three members of the research team, each reviewing and extracting information from two references. The extraction framework was refined through team discussion, and common interpretation was checked.

The final extraction framework included the following categories:

- General information about the reviewed source
- Timeline for problem definition and policy development
- Main players in problem definition
- Main players in policy development
- Factors that played a role (either positive or negative) in problem definition and/or policy development
- Other comments and literature to review

Data extraction was conducted by three members of the research team and discrepancies or uncertainties resolved through team meetings.

2.2.2. Analysis

Using a narrative approach, three researchers produced a policy brief for each area describing findings, the history of problem definition and policy development and key lessons for policy planning. Cross-cutting themes were drawn from the three areas through a research team workshop, including two historians, where briefs were reviewed independently and then collectively. A combined policy brief including cross-cutting lessons for policy planning was produced to inform stage 2 (see Supplementary Material, section I).

2.3. Stage 2: Identifying driving forces

In Stage 2, we sought to test and further develop our historical analysis and to identify historical, contemporary and likely future drivers influencing AMR policymaking. We conducted a half-day workshop in London, UK (September 2018) with academics and policymakers to consider parallels and contrasts across the policy histories of the three areas. This stage was considered formative and introductory research; no individual data were used but only at the aggregated level.

2.3.1. Methods

2.3.1.1. Participants. The workshop had 18 participants, consisting of academics, including historians, and policymakers in the areas of AMR, climate change and tobacco control. Participants were assigned to five facilitated small groups, each focused on a different theme and composed of individuals with varying expertise.

2.3.1.2. Workshop activities.

2.3.1.2.1. Discussion of cross-analysis themes. The first activity involved critical consideration of the five cross-cutting themes in formed through historical analysis in Stage 1, including issues of accuracy, relevance and potential missing themes. In groups (each focusing on one theme) and plenary, participants were asked to discuss the themes and consider the following questions.

- Has the theme, as currently described, accurately captured a feature of the three issues? If not, how could it be revised?
- What have been the most important events that shaped how each issue evolved relative to this theme, and what was their impact?
- How have policymakers responded to the challenges related to this theme in each area, and have these approaches been successful?
- Are there any important unknowns related to this theme?

2.3.1.2.2. Brainstorm and mapping of drivers. Participants were asked to focus on their assigned theme and discuss both the drivers that have affected the three policy issues over time and the drivers that might arise as important in the next 10–20 years. As a prompt, participants were provided with a copy of the PESTLE framework [62], a tool used to help identify the influence of the political (P), economic (E), social (S), technological (T), legal (L) and environmental (E) landscapes.

Participants were asked to write each driver on a sticky note and to position it on axes to indicate the driver's importance and uncertainty for AMR as a policy issue. Participants were also asked to record any 'surprise' events (e.g. wars, financial crises, natural disasters) that have influenced or could potentially influence the issues.

2.3.2. Analysis

After the workshop, the research team organised the drivers identified by participants according to the PESTLE framework. The drivers were also classified on scales of importance and uncertainty. Certainty/uncertainty relates both to the evolution of the driver itself and the likelihood of the driver affecting AMR as a policy issue.

2.4. Stage 3: Prioritising the themes and drivers

Themes and drivers were prioritised through a research team workshop. Priority was given to those themes that had the most relevance for AMR policymaking, but that had perhaps not received adequate recognition or implementation in the context of AMR thus far.

2.4.1. Methods of analysis

The research team considered each theme in turn against the following questions, according to 'relevance' and 'recognition':

Relevance of the theme

- How is this policy theme relevant?
- How does it matter in the context of the UK?
- How does it change behaviour?

Recognition of the theme

- Is it underappreciated in policy making?
- Is it a weak signal?
- How is it discussed and described?
- Are people talking about it?

The following was then asked of each prioritised theme:

- What do we know, including any key events or turning points and the factors involved, about each theme?
- What do we not know but may be useful to explore in interviews?

Drivers were prioritised on the basis of being 'certain' (i.e. will definitely happen) (Table 1). We then identified a set of priority drivers that were uncertain but likely to be important for AMR in the future, to incorporate into the scenarios.

2.5. Stage 4: Generating plausible futures

We drew on findings from stages 1–3 and conducted stakeholder interviews and a horizon scanning exercise to develop plausible but challenging scenarios for future AMR policymaking.

2.5.1. Methods

2.5.1.1. Interviews. To supplement the historical reviews and workshop insights, we conducted semistructured interviews (N = 8) with academics, policymakers and an industry representative. The aim was to help us refine the set of prioritised themes and drivers of change developed in Stage 3, and to inform the development of future scenarios grounded in what had already happened in each area. Participants included two experts in AMR, three in climate change, and three in tobacco control. The interviews were conducted by telephone and lasted between 30 and 60 minutes. With consent, the interviews were audio recorded.

Summarised interview data were recorded in a pre-developed analysis template. This approach was informed by the framework method, with rows in the matrix representing individual interviewees (cases) and columns representing interview questions (codes) [63]. After each interview, interviewers summarised the information provided of relevance to each interview question in the matrix—supported by interview recordings and the interviewer's own notes—in a process known as charting [63]. The combined

Table 1
Drivers identified by Stage 2 workshop participants as being important for AMR policy, organised according to the PESTLE framework.

	Certain	Uncertain
Political Drivers	• Better stewardship (without affecting access) • High level engagement with the evidence • Global body engagement • Global consensus e.g. WHO, FAO • EU 1998 Plan on AMR (historical)	• Leadership *(identified as medium certainty)* • Governance • Political contingency • Perceived value of global bodies • Conflict between agencies • Global fragmentation (e.g. withdrawal of US support for UN or WHO) • War
Economic Drivers	• Economic growth (GDP) • Health system pressures and resource limits (funding, staff, technology) • Low economic cost of technology • Financial incentives • Ability to monetise the problem	• Data on AMR deaths • Critical numbers (makes the effect more visible and direct)
Social Drivers	• Increasing world population (human and animal) • Demographics, e.g. ageing population (comorbid chronic diseases) • Public health and primary prevention of infection • Migration and population mobility • Health inequalities affecting on antibiotic use and access to care • Cultural differences across countries	• Consumer pressure on food production systems • Public narratives and the media • Personal experience • Increased personal responsibility for own health
Technological Drivers	• Growing evidence about the scale of the problem (e.g. O'Neill Review) • Improved surveillance of resistance in humans in HICs • Scientific evidence (understanding and acceptance) • Cheap antibiotics (easy to use, quick fix to change)	• New antibiotics *(identified as medium certainty)* • Strength of scientific evidence *(identified as medium certainty)* • New drugs and alternative products • Improved surveillance of resistance in humans in LMICs • Improved surveillance in animals and environment (more certain in HICS) • Data-driven approaches (e.g. informatics) • Alternative practices
Legal Drivers		• Regulation of antimicrobial product use (e.g. legislation with penalties) • Regulation of the business environment
Environmental Drivers	• Infectious disease outbreaks	• Emerging diseases • Relationship between medical systems

AMR, antimicrobial resistance; GDP, gross domestic product; WHO, World Health Organization; UN, United Nations; HICs, high-income countries; LMICs, low- and middle-income countries; EU, European Union; FAO, food and agriculture organization; US, United States.

matrix of all interview data was subsequently reviewed by one researcher (CL), and then evaluated and verified by other researchers. From this synthesis, we derived a final set of cross-cutting themes to inform scenario development.

2.5.1.2. Scenario development. We developed a set of future scenarios for AMR policy, each focused on one of the finalised themes. The scenarios were developed based on insights from the interviews, the earlier historical review and the accelerated horizon scanning exercise. Each scenario was structured to include the following information:

- A general explanation of what things are like with respect to the thematic area in 2030, illustrated with specific examples of recent events or news headlines, and an overview of the associated challenges that have developed.
- Indications of how some of these events relate to similar events that have occurred or are occurring in relation to climate change and tobacco control policy.
- A 'wildcard event', defined as a significant future event that could plausibly happen in the scenario.

We also developed a master scenario introducing life in 2030, incorporating aspects of social, political and economic context.

2.6. Stage 5: Generating possible policy responses and overarching lessons

A workshop was held (May 2019 in London, UK) with academics (including historians), policymakers and an industry representative with expertise in the areas of AMR, tobacco control and climate change to explore the possible future scenarios for AMR and to identify lessons for policymaking. The workshop was informed by the master scenario of life in 2030 and the four future scenarios (Stage 4), each with an associated wildcard event.

2.6.1. Methods

2.6.1.1. Committees. Participants (N = 20) were assigned to one of four groups, each representing fictional governmental 'advisory committees' and focusing on a different theme. The research team sought to ensure that each committee's participants represented all three policy areas and at least three stakeholder groups (historians, other academics, policymakers and industry).

2.6.1.2. Activities.

2.6.1.2.1. Discussion of thematic scenarios. To consider how AMR may evolve as a policy issue in the future, each of the four committees was asked to discuss the scenario related to their thematic

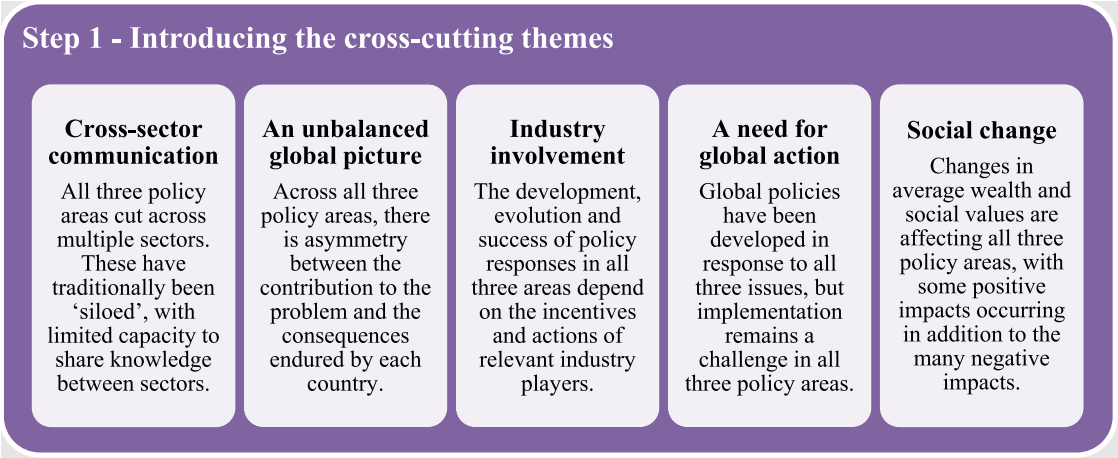

Fig. 2. Evolution of the cross-cutting themes, Step 1.

focus, consider a set of questions related to the scenario (Supplementary Material, section II), and discuss how they would advise a fictional UK government in 2030. A brief plenary discussion followed the committee discussion.

2.6.1.2.2. Discussion of wildcard events. Next, each committee was presented with a wildcard event related to their committee theme and a separate set of questions (Supplementary Material, section II). Committees were asked to reconsider and challenge their recommendations considering the wildcard event, and to discuss the additional questions. A final plenary discussion followed.

2.6.2. Analysis

After the workshop, notes from each committee were written up and key conclusions identified. Lessons for policymaking across the four thematic areas were then synthesised through an internal research team workshop.

3. Results

We present our findings by stage number hereinafter.

3.1. Stage 1: Orientating the present

We found five cross-cutting themes (Fig. 2) from the review of historical development, which evolved in later stages (Figs. 3 and 4).

The first cross-cutting theme was the importance of *cross-sector communication*. In each policy area, relevant sectors have traditionally been 'siloed', with limited capacity to share knowledge between sectors. Early efforts to control tobacco use lacked political support, in part because treasuries received considerable tax revenues from tobacco products [64]. In the case of climate change, early policymaking viewed it as a purely technical issue, failing to consider relevant perspectives from fields such as the social sciences. Like climate change, AMR is an issue that cuts across multiple sectors, which remained siloed in their approach to prevention and control for much of the history of AMR response. The effect of AMR was discussed independently in medicine and veterinary medicine for several decades before AMR policies began referring to the need for a 'One Health' approach integrating human health, animal health and the environment [3,65–67].

The second theme was that of *an unbalanced global picture*. Across all three issues, we observed asymmetry between the extent of each country's contribution to the problem and the extent to which each country endures and will continue to endure the consequences of the problem. In the case of tobacco control, for example, high-income countries' tobacco companies have marketed aggressively in low- and middle-income countries (LMICs) [68], an important consequence of which is that tobacco use is now a major health burden in many LMICs [7,68]. In the case of climate change, 'subsistence' emissions, so named because they represent the emissions required to lift populations out of poverty, have been contrasted with the additional 'luxury' carbon emissions enjoyed by more affluent populations elsewhere [7,69]. Finally, it is those populations of the many countries that currently lack adequate access to antibiotics that will suffer the greatest consequences from rising rates of resistance [9].

The third theme referred to *industry involvement*. The development, evolution and success of mitigation strategies for all three issues depended, at least to some extent, on the incentives and actions of industry. Some tobacco companies, for example, have downplayed evidence of harm and lobbied against regulation [10,11,70]. In the case of climate change, while the fossil-fuel industries have successfully lobbied against regulation and exploited perceived uncertainties in the science, innovative new low-carbon industry sectors have demonstrated the economic opportunities of stricter regulation [71]. Finally, the history of AMR policy has involved important interplay between public health officials, the pharmaceutical industry and the livestock industry [3]. A lack of incentives for antibiotic development by industry is now seen as a major obstacle to progress [12].

A need for global action was the fourth cross-cutting theme. We identified that global policies have been developed in response to all three issues, but in all three implementation remains a challenge. In tobacco control, international networks grew, diversified and became more formalised over the half century preceding adoption of an international treaty. In the case of climate change, initial attempts to agree an international, top-down approach have given way to greater 'polycentricity' and voluntarism [31,32,72]. Global policies to address AMR have developed along a similar trajectory to those in tobacco control, in that initial local efforts have gradually become more coordinated to form an international response [3,40].

Our fifth and final cross-cutting theme was *social change*. Changes in wealth and values are proving important for all three issues. Tobacco and antibiotics both became widely available in the first half of the 20th century, and both have been marketed as lifestyle enhancers, symbolising prosperity [3]. Pursuit of particular lifestyles is also an important factor in climate change. Societal shifts in attitudes have already had a major effect on tobacco use [73], but behaviours related to carbon emissions and antibiotic consumption have so far undergone a much less dramatic change.

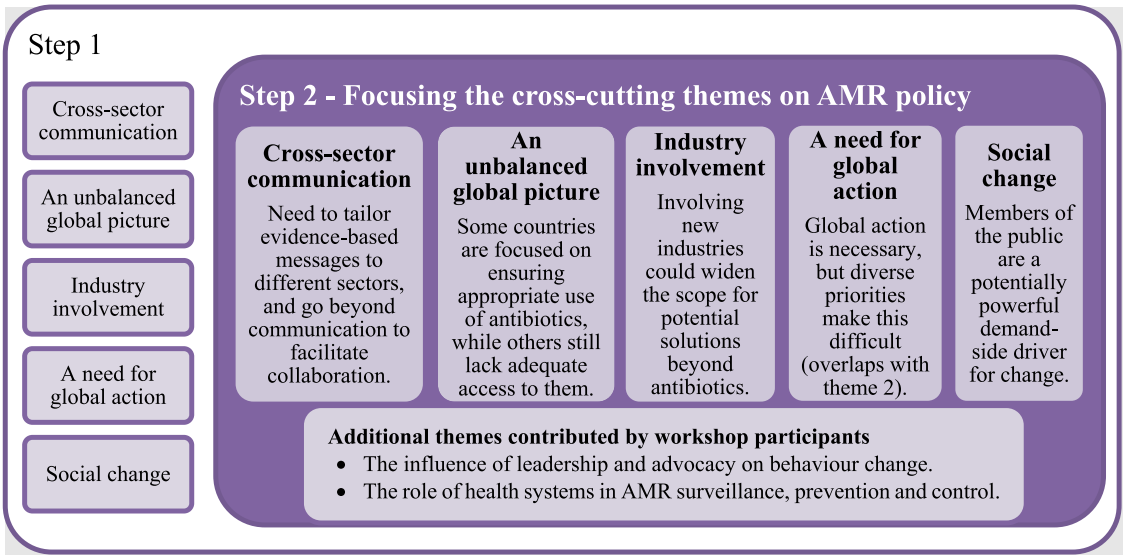

Fig. 3. Evolution of the cross-cutting themes, Step 2. AMR, antimicrobial resistance.

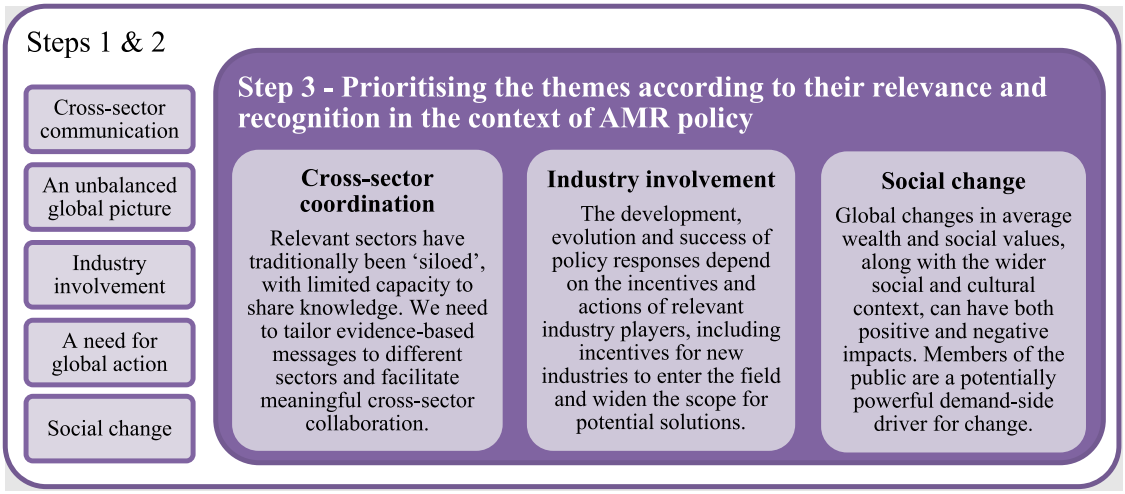

Fig. 4. Evolution of the cross-cutting themes, Step 3. AMR, antimicrobial resistance.

3.2. *Stage 2: Identifying driving forces*

The held workshops brought to light that most participants agreed with the descriptions of the five cross-cutting themes identified in Stage 1, but their discussions provided additional nuance for each as follows:

1. Cross-sector communication: Participants emphasised the importance of having accurate evidence about each policy issue and tailoring messaging to the interests of actors in different sectors. They also highlighted that it is necessary to go beyond communication to facilitate cross-sector engagement and collaboration.
2. An unbalanced global picture: Discussion focused on the priorities at play in different countries, with particular attention given to the sharp contrast between countries lacking adequate access to antibiotics and those focused on ensuring appropriate use.
3. Industry involvement: Participants discussed the possibility of introducing new industry players to the field of AMR, widening the scope for potential solutions beyond antibiotic development.
4. A need for global action: There was general agreement that AMR would benefit from a more global approach, although it was recognised that there are different issues and challenges to address in different settings.
5. Social change: Members of the public, acting as patients and consumers, were identified as a potentially powerful demand-side driver for change.

Several other elements that had not been identified as cross-cutting through Stage 1 were highlighted, including the role of health systems in addressing AMR, the importance of leadership and advocacy and of wider social context and cultural factors in shaping behaviour related to all three policy issues. We revised our cross-cutting themes based on this discussion (Fig. 3).

The AMR policy drivers identified (Table 1) broadly reflected the factors at play in the issues discussed in the thematic analysis.

3.3. *Stage 3: Prioritising the themes and drivers*

From the themes above, participants selected three themes as the most relevant to AMR policymaking but without adequate recognition in the UK: (i) cross-sector coordination (previously cross-sector communication but broadened in response to expert

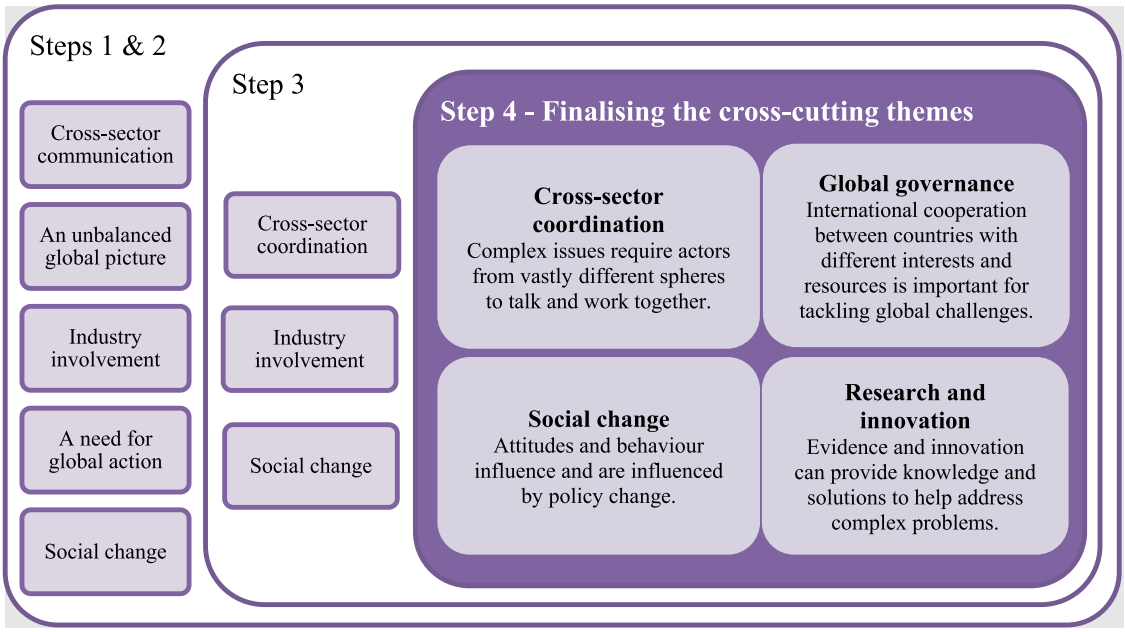

Fig. 5. Evolution of the cross-cutting themes, Step 4.

reflections on the proposed themes); (ii) industry involvement; and (iii) social change.

3.4. Stage 4: Generating plausible futures

Our analysis of the interview data helped us to finalise our set of cross-cutting themes. During discussion of the importance of cross-sector coordination, several interviewees emphasised the need for global cooperation. This was particularly the case among those interviewees with expertise in climate change, who highlighted global climate action through the IPCC as offering important lessons for AMR policy. These discussions led us to reinstate the theme concerning the need for global action, which we renamed as 'global governance'.

Additionally, we noted that there were overlaps between our themes discussing cross-sector coordination and the role of industry, namely in the role those relevant industries must play in communicating and collaborating with other sectors. We therefore chose to include discussions about industry involvement under the 'cross-sector coordination' theme, and to shift the focus of the existing industry theme to 'research and innovation', which includes industry research. This theme now, in addition to industry, incorporates the role of academia and other players in the field of research and innovation.

The finalised themes that we used to inform development of future scenarios were therefore: (i) cross-sector coordination, (ii) global governance, (iii) social change, and (iv) research and innovation. The full evolution of our cross-cutting themes is presented in Fig. 5.

The full text of the scenarios and wildcard events that we developed to describe possible futures for AMR in 2030 are provided as Supplementary Material (section II). Table 2 offers a summary of the scenario and wildcard developed for each theme.

3.5. Stage 5: Generating possible policy responses and overarching lessons

Overarching lessons for policymaking were drawn from the four committees involved in the workshop, which are detailed one by one hereunder.

First, AMR policy continues to be hampered by knowledge gaps. Notable areas include inadequate surveillance and monitoring, and a relatively poor understanding of the dynamics of AMR (e.g. the relationship between predictors of resistance and resistance itself and the role of the environment in the development and spread of resistance).

For future AMR policy, it will be important to engage a wide range of stakeholders, both domestically and internationally. It is important to understand each stakeholder's priorities and motivations. This is already at least nominally done under the One Health umbrella, but the term is increasingly being used without real commitment to a cross-sector approach. Reframing and clarification may be necessary.

Third, effective public engagement is vital for preventing the future development and spread of AMR. Strategic engagement with the public via the development and dissemination of appropriate narratives is essential in order to motivate public action, avoid the emergence of AMR denial, and make regulation socially acceptable and thus politically possible. Information and knowledge, however, are unlikely to be sufficient to drive the required behaviour change, as has been seen with both climate change and tobacco control. Structural change will also be important.

Finally, the effectiveness of AMR policy will depend on policy changes at other levels and in other sectors. It is important to think locally, regionally and globally when developing AMR policy, as well as to consider wider systems. AMR policymakers should strive to integrate their concerns into all relevant sectors and take advantage of 'windows of opportunity' presented by changes occurring outside their immediate remit—for example, in public health, social attitudes towards food and environmental concerns.

4. Discussion

4.1. Research aims and summary of benefits

The objectives of this research were twofold. First, we aimed to contribute to methodological development in the use of historical and comparative perspectives to inform policy. Second, we sought to provide evidence for UK AMR policymaking by exploring points of learning, both positive and negative, from other policy areas. The

Table 2
Summary of future scenarios and wildcard events.

	2030 Scenario	Wildcard event
Theme 1: Cross-sector coordination	There is now compelling evidence of the links between human health, resistant infections in animals, and resistant pathogens in food and the natural environment, but this evidence remains disputed. There has been improvement in the food industry's involvement in AMR policy, but less so from the water and agricultural industries. Higher temperatures and increased moisture have increased pressure from pests, making it difficult to ban the use of fungicides in agriculture despite a marked rise in fungal-resistant infections in hospitals.	Two scandals occur: 1. Surveillance data reveal inconsistencies in antibiotic usage and resistance levels, revealing that some food business operators have been falsifying information provided to the government. 2. There is an outbreak of carbapenem-resistant infection in humans despite this antibiotic not being authorised for use in animals, creating a scandal resembling that of the 2013 horsemeat scandal.
Theme 2: Global governance	We now have a Global AMR Steering Board and a High-Level Commission on AMR, the latter of which brings together 10 heads of state with experts and executives from other sectors to coordinate a global response to AMR and develop an international agreement. Information presented in the Steering Board's 2028 Scientific and Policy Synthesis report was generally accepted, but critics lament that it failed to comment on areas that are likely to be challenged by vested stakeholders and on areas associated with greater uncertainty. Others criticise the Steering Board's focus on scientific assessment over policy assessment, stating that a meaningful assessment must compare policy options in light of disparate interests and the potential need to impose measures on vested interests.	China signals clearly that it will not support the publication of any evidence or report that suggests policy action that could disrupt its domestic pharmaceutical industries and production of antibiotics.
Theme 3: Social change	Public awareness of the dangers of AMR has become widespread, primarily driven by personal experience with AMR, scientific evidence of its causes and consequences, and media influences. The individual right to use antimicrobials is now widely considered subordinate to the societal right to avoid unnecessary use and prevent AMR, making regulation popular. Consumers are demanding 'Produced Without Antibiotics' from certain products but continue to purchase antibacterial versions of others. Initiatives to discourage antimicrobial use have had unintended consequences. There is a growing movement of people refusing to take antibiotics even when prescribed, and rising rates of hospital-acquired infection have led to people avoiding hospitals altogether. AMR denial is on the rise, with rogue pharmaceutical companies helping to feed this belief and selling antimicrobials without prescription on black markets.	In the quarter-final match of 2030 FIFA World Cup, a key member of the English national football team receives a nasty cut to his shin. This is treated with antiseptic and he plays on, scoring a match-winning goal. A few days later, the player wakes up during the night with a fever, body aches and severe nausea. Newly developed rapid diagnostic tests are run, revealing that the infection is caused by bacteria that are resistant to all available antibiotics. England fans wake up to headlines proclaiming: 'Star striker who fought for quarter-final victory now fighting for his life'. By kick-off time for the semi-final, he is dead.
Theme 4: Research and innovation	UK One Health reports show that progress in reducing use of antibiotics in human healthcare lags behind progress made in the food and farming industry. Research investment has continued to focus on six priority areas: therapeutics, diagnostics, surveillance, transmission, interventions for infection prevention and control, and the role of the environment. The UK's Medical Research Council and National Institute of Health Research just launched a £8m joint initiative to compare trends in resistance in human gut microbes to lifestyle factors. There has been success in the development of nontraditional products to combat infections. A probiotic that was found to be highly successful in fighting recurrent urinary tract infections was approved in Europe in 2026, and its usage has become widespread.	A small company supported by a major US-based public-private partnership, has developed Supersporin, a new class of broad-spectrum antibiotics for treatment of Gram-negative infections. It is hailed as an important symbol of the value of public-private partnerships like this one. Based on the experience of Teixobactin, which became available over the counter, in order to safeguard Supersporin for future use, the public-private partnership has developed strict rules that not everyone agrees with about who can access it and under what circumstances.

AMR, antimicrobial resistance; US, United States; UK, United Kingdom.

approach illustrated the value of drawing a historical perspective into foresight methods, the importance of comparing global policy issues, and the critical role of cross-disciplinary expertise in addressing complex or 'wicked' problems.

4.2. Learning from a historical and comparative approach

The idea that future policy can learn from history can be intuitively appealing, but it is problematic. It risks suggesting there is one 'history' to learn from, whereas history as a discipline is highly interpretive [74]. Furthermore, there are limited documented examples of how historical perspectives or provocations can be embedded within policymaking or futures-oriented methods. The UK government has used historical reviews in foresight work around psychoactive substances, although limited detail was provided on methods of combining historical and futures-orientated perspectives [75].

We found that a rigorous approach to engaging with the history of AMR provided a richer understanding of the extent of the issue and previous attempts to address it, and how that might affect the trajectory of the problem. Thus, we could take a fuller measure of what worked in the past and what did not—and how that understanding could inform the ideas that were generated about what needs to be done in the future.

AMR is often considered to be a unique problem. We wanted to test this idea by comparing AMR to other large-scale and complex global problems to see whether this approach might yield transferable lessons to inform future AMR policymaking. We found that comparison enabled identification of cross-cutting themes. This helped us to understand what has worked and what has not in other issue areas, and what might be considered (or avoided) for AMR.

Finally, while much has been said about the importance of interdisciplinarity and multiple perspectives in addressing a given issue [76], in practice this can be hard to achieve and has less often involved history or other humanities subjects. We sought to bring together academics and practitioners across disciplinary perspectives (e.g. historians and epidemiologists); knowledge across the 'one health' spectrum of AMR issues; and subject matter experts on AMR, climate change and tobacco control. We found that this combination of perspectives enriched our understanding of both the policy challenges and the benefits and drawbacks of potential solutions. Involving historians not only enabled the historical analysis but ensured caution and scepticism to the degree we could extrapolate forward.

Bringing together these three principles—that is, learning from history, comparing otherwise singular issues and enrolling a diversity of perspectives—yielded four main lessons for future AMR policymaking, as described below.

4.3. Learning for policy

Because of the commonality in the nature of the problem, our findings suggest learning for models of governance in AMR. Our study highlighted the perception that knowledge gaps and uncertainty would continue to hamper progress in AMR policy. Understanding pathways of resistance in the environment, including transmission, were highlighted as important areas [77–79]. Decisionmakers are confronted with incomplete and emerging knowledge on the phenomena they wish to tackle. By contrast, the relationship between key drivers of climate change and their outcomes can be modelled with increasing levels of sophistication, albeit with continued uncertainty regarding assumptions and other inputs [80,81]. The evolution of climate change illustrates that more sophisticated and precise efforts to understand the dynamic relationship and potential effect of policy should be pursued in relation to AMR policy. In particular, models that attempt to capture the complexity of One Health drivers and effects of policy interventions are only in relatively early development [82]. Our findings also show it will be important to develop robust mechanisms to work with available evidence, especially in areas where research is emerging, and that is based on novel approaches. The IPCC has faced criticism in being unable to take account of such research and consider novel and nontechnical forms of evidence [34,83].

Our research also highlighted that there remains work to be done in terms of achieving cross-sector approaches and engagement of stakeholders nationally and internationally. Again, lessons from the IPCC provide a warning of the potential dangers of an overly technical and narrow problem formulation. Initial exclusion of insights from nontechnical fields such as social policy meant that the IPCC succeeded in demonstrating the problems of climate change but struggled to adequately capture the social and cultural aspects of its effect and possible counteraction [34,83].

Analysis of climate change and tobacco control over time suggests the benefit of being able to take advantage of 'windows of opportunity'. Tobacco control gained more traction when it was seen as not solely a health issue but an economic one [84]. In a similar way, clean air policies have been suggested as an area of opportunity to make indirect progress on climate change [85]. While the UK has an AMR strategy and policy that covers multiple sectors, there is less integration across policy areas. The recent Long-Term Plan for the English National Health System (NHS), for example, has only brief inclusion of AMR. Increasing the integration of AMR across policy areas may help to increase the chances of capitalising on any windows of opportunity. AMR should be embedded within health services design [86].

Finally, social change and effective public engagement will be vital and have a complex relationship with policy. UK AMR strategy to date has focused on information and awareness, and 'public engagement' is synonymous with educational activities [87,88]. Research has similarly focused on individual behaviour change. More recent research and critiques of the field have highlighted the need to expand beyond knowledge exchange and behaviour change to consider other broader structures, including social, political, cultural and environmental elements [89,90] and the multiple rationalities of parties involved [90]. This has yet to permeate policy approaches, however. Our learning from tobacco control and climate change has shown the importance of being alert to broader social change and the need for collective action.

4.4. Study limitations

Our historical analysis was based on secondary rather than primary sources due to time and resource constraints. Although some of the experts who participated in the study were policymakers who had a direct role in designing AMR policy at the UK and international level, they were not enrolled in the study to provide a historical account, but rather to reflect on future policy making. Future studies would benefit from review of policy documents and interviews with participants in the evolution of each issue.

The secondary sources reviewed were identified by subject matter experts on our team. We also conducted searches based on the bibliography of each identified source, additional keyword searches in research databases, and review of sources recommended to us by experts who participated in later phases of the study. This pragmatic approach ensured that we reviewed a large and diverse set of relevant sources, but it was not a comprehensive literature review.

We experienced challenges associated with our efforts at cross-disciplinary engagement, as has been reported by others [91–93]. Some experts on climate change and tobacco control were reluctant to contribute their knowledge in an area outside their expert domain. We took steps to reduce these apprehensions by clearly explaining the rationale for the project approach to all potential participants and by facilitating cross-disciplinary dialogue among those who chose to take part, but we do not feel that we fully surmounted this difficulty.

Our comparison of the three policy areas sought to identify potentially transferrable lessons from across fields and contexts. We appreciate the attendant risks that this entails—for example, that findings from one policy area may be the result of context-specific factors that render them 'false positives'. The results from this study therefore require further exploration and testing before adoption of the principles identified. This study adopted a novel approach to policy research based on historical, comparative and foresight analysis. We consider our approach to represent a strong proof of concept and thus a worthy starting point from which future historical and comparative foresight methods could be developed.

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Supplementary materials

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