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Review

Characterising proximal and distal drivers of antimicrobial resistance: An umbrella review

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ABSTRACT

Introduction: Antimicrobial resistance (AMR) is a multifactorial challenge driven by a complex interplay of proximal drivers, such as the overuse and misuse of antimicrobials and the high burden of infectious diseases, and distal factors, encompassing broader societal conditions such as poverty, inadequate sanitation, and healthcare system deficiencies. However, distinguishing between proximal and distal drivers remains a conceptual challenge.
Objectives: We conducted an umbrella review, aiming to systematically map current evidence about proximal and distal drivers of AMR and to investigate their relationships.
Methods: Forty-seven reviews were analysed, and unique causal links were retained to construct a causality network of AMR. To distinguish between proximal and distal drivers, we calculated a 'driver distalness index (Di)', defined as an average relative position of a driver in its causal pathways to AMR.
Results: The primary emphasis of the literature remained on proximal drivers, with fragmented existing evidence about distal drivers. The network analysis showed that proximal drivers of AMR are associated with risks of resistance transmission (Di = 0.49, SD = 0.14) and antibiotic use (Di = 0.58, SD = 0.2), which are worsened by intermediate drivers linked with challenges of antibiotic discovery (Di = 0.62, SD = 0.07), infection prevention (Di = 0.67, SD = 0.14) and surveillance (Di = 0.69, SD = 0.16). Distal drivers, such as living conditions, access to sanitation infrastructure, population growth and urbanisation, and gaps in policy implementation were development and governance challenges, acting as deep leverage points in the system in addressing AMR.
Conclusions: Comprehensive AMR strategies aiming to address multiple chronic AMR challenges must take advantage of opportunities for upstream interventions that specifically address distal drivers.

1. Introduction

Antimicrobial resistance (AMR) is a complex global public health and societal challenge [1]. AMR was the third leading cause of death in 2019, with 4.95 million deaths associated with AMR and 1.27 million directly attributable to antibiotic-resistant bacterial infections [2]. Furthermore, the continuing emergence of AMR may undermine progress in the attainment of the Sustainable Development Goals (SDGs), which include poverty and inequality reduction, food security, clean water, and sanitation, as well as impairing achieving national and global economic growth [3–8].

Currently, the implementation of interventions aiming to reduce antimicrobial use has faced many challenges and shown limitations in terms of long-term sustainability [5,9–11], indicating a need for collective actions to address its other drivers, which have garnered increased scholarly and policymaking attention. A driver of AMR

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can be defined at different scales as any biological, social, or institutional processes corresponding to the emergence and transmission of resistance [12,13]. Due to this hierarchical nature, interventions designed to address drivers of AMR can occur at different levels. Current AMR strategies have primarily targeted proximal drivers of AMR in order to optimise the use of antibiotics. Actions to address distal drivers such as sanitation and hygiene, universal health coverage, food production and consumption, social norms, and the context within which antibiotics are few [13–15]. Addressing AMR drivers, especially distal drivers linked to the SDGs, is considered key to producing sustainable outcomes [1,16].

Lack of understanding and/or acknowledgement of the complexity of the system may contribute to a lack of diversity in interventions, consequently decreasing the power and impact of actions undertaken [14]. A better understanding of the relationships among drivers of AMR is necessary to develop strategies to comprehensively address the problem [17]. Previous works have attempted to characterise links between drivers and the development and spread of AMR. However, these studies usually focused on the drivers of single sectors or lacked investigation of distal drivers and the interaction between drivers that shape the complex dynamics of the problem [18–24]. A more holistic perspective on AMR drivers emphasises the need to distinguish between proximal and distal drivers and specifies the various levels at which these drivers act in the system. However, no established method or framework currently exists for this purpose.

In this paper, we review existing evidence about drivers of AMR and propose a new approach to study the links between them in order to distinguish between distal and proximal drivers of AMR. Identified relationships among AMR drivers reported in the literature were systematically structured in the form of logical, stepwise chains of causal events [12,25], and network metrics were employed to provide a framework for distinguishing distal and proximal drivers of AMR. This provides the groundwork for future research on the development of more sustainable and effective AMR intervention strategies.

2. Materials and methods

2.1. Study design

To investigate which drivers of AMR have been identified in the scientific literature, we first conducted a systematic literature search. Six bibliographic databases comprising multidisciplinary databases (EMBASE, Web of Science, and Scopus) and specialist databases covering health, agriculture and environmental topics (MEDLINE, Cochrane, and CINAHL) were searched for relevant literature. Snowball sampling techniques (web searches, contacting authors, and checking reference lists) were also used to identify additional reviews during the full-text screening process. The full search strategy and study selection can be found in the supplementary materials (Tables S1, S2, and S3).

As the volume of primary studies and reviews pertinent to the topic is considerable (about 18,000 results for the initial search strategy in MEDLINE), we decided to focus exclusively on secondary studies (review articles). Reviews are sources of evidence synthesis that describe the interactions of drivers in the form of correlations, causal relations or the positive/negative feedback cycles within a sequence of events. Identifying, extracting and connecting interactions between driver, pressure and state from review articles allowed us to explore hidden connections and better understand the functionality of various processes of AMR and their dependencies. We followed the protocol of an 'umbrella review' recommended in the JBI Manual for Evidence Synthesis [26]. We extended this methodology to include not only systematic reviews but any publication published as a review and reduced the required rigour of the appraisal process in order to include as diverse a set of drivers as possible rather than focusing on evaluating the strength of evidence.

2.2. Conceptual framework

2.2.1. DPSIR framework – causality extraction and assessment

In this study, we operationalised the driver-pressure-state-impact-response (DPSIR) framework to code AMR drivers identified in the literature. DPSIR is a simple policy-oriented framework describing causal hierarchies that has been adapted previously to study drivers of AMR [12,13,20,27]. The framework was used as a starting point to characterise the factors influencing AMR via chains of causal links consisting of drivers, pressure and state [12]. The state of AMR was defined as the current prevalence and distribution of resistant bacteria. Pressure was defined as changes in the state of AMR as the result of any antimicrobial use, including misuse and overuse. Drivers of AMR comprise any biological, social, or institutional process corresponding to changes in the emergence of resistance and transmission or determinants of AMR at different scales [12,13].

A qualitative content analysis method was employed to extract pairwise causal relationships of driver-driver, driver-pressure, driver-state, and pressure-state of AMR identified from the review articles [28,29]. We considered a causal relation to be a semantic relation between two events where the occurrence of one event (referred to as the cause event) leads to the occurrence of the other event (referred to as the consequence event) [30]. First, we identified sentences or a paragraph containing the causes and effects and assigned codes for them. The coding process was conducted in MAXQDA software and then exported to Excel. A sentence or paragraph was extracted if it either implicitly or explicitly mentioned causality relationships (Table 1).

When the causal link relationship was mentioned without an explicit link, we traced the primary citation for coding. For example, the sentence 'it is also reported that the enforcement of the *regulatory systems are not rigorous enough* to identify *community drug retail outlets (CDROs) that employ different mechanisms to get around regulatory checks*' explicitly presented only the cause event (underlined here), which is the lack of enforcement of legislation, while the consequence event (italicised here) – the over-counter-sale of antibiotics – is only implicitly mentioned [31]. Furthermore, as the coding process is sensitive to the granularity of information reported, we organised codes with related meanings into groups of drivers and adapted a protocol from Lee et al. [28] to assess causality strength based on the language used and its frequency in documents (Fig. S1).

2.2.2. AMR-intervene framework – driver categorisation

We identified the main sector and governance challenges associated with the driver using the AMR-Intervene framework, specifically the 'Sector' and 'Triggers, goals and challenges' variables [35]. 'Sector' is defined as the occupational area where the different activities of the intervention can take place to address the driver of interest. A driver was assigned to a main sector (human, animal, environment and others) and subsectors. The main governance challenges associated with drivers were categorised into six main challenges of collective action against AMR, defined by the main policies used to tackle the drivers [35]. These challenges of collective action are surveillance (all surveillance activities related to AMR), infection prevention (preventing infectious diseases in the first place, i.e., through immunisation, sanitation, and hygiene, as well as infection prevention in healthcare settings), conservation (targeting overuse and misuse of antibiotics and also limiting antibiotic pollution in the environment), containment (limiting the spread of AMR), access (strengthening access to health including

Table 1
Example of operationalisation DPSIR framework and causality extraction.

DPSIR framework component	**Example:** 'Therefore, intensive animal food production can lead to the selection for the emergence of resistance due to the extended use of antibiotics for growth promotion, disease prevention, and infection treatment' [32].
State	
The current condition of AMR includes the prevalence and distribution of resistant bacteria, which can be found in humans, animals, food, plants and the environment (such as water, soil and air) [33].	The emergence of resistance.
Pressure	
Any use of antimicrobial use or the use of other chemicals which can lead to the co-selection process, including pharmaceuticals, biocides, herbicides, pesticides, disinfectants and heavy metals [34].	The extended use of antibiotics for growth promotion, disease prevention, and infection treatment.
Drivers	
Other factors identified which were not classified as state or pressure were coded as drivers. They include a diverse range of biological and chemical factors, as well as human and institutional actions and processes that operate at various scales (global, regional and local), encompassing various social, demographic and economic dimensions.	Intensive animal food production.

but not limited to access to drugs), and innovation (interventions and policies to support the development of health technologies with the direct goal to address AMR) [36].

2.3. Data extraction and analysis

The processed data were kept in Excel and transferred to R software (version 4.2.1; packages *tidygraph* version 1.2.3) for further analyses and visualisation [37,38]. Network analysis was used to connect and characterise the descriptions of AMR drivers extracted from review papers. We first started by listing all possible causal pathways starting from a given node to AMR. The states of AMR in different sectors were consolidated into a single node, referred to as the general state of AMR (GS), which was selected as the endpoint in the network. Causal chains that did not contain full driver-pressure-state links were removed. The *k*-means cluster analysis method was used to group similar links in the network and to rank the evidence of the reported causalities based on language use and frequency (Fig. S2).

To measure the distalness of each node, we introduced the node distalness index (D_i), defined as the relative position of a given driver of pressure node to the endpoint of the network (GS) in a causal chain (see equation below). To calculate the node's relative position in the causal chain, the number of its descendants (D_t^A) was counted and then divided by the total number of nodes before GS on the pathway (L_t). Because one node can be involved in many causal pathways to the outcome, the average '*distalness*' (D_i) of the node is the mean of all causal pathways (N) from the node to GS. We also calculated network centrality metrics such as eigenvector centrality and betweenness to identify important nodes in the network.

$$D_i^A = \frac{\sum_{t \in N} \frac{D_t^A}{L_t}}{N}$$

3. Results

The search of bibliometric databases identified 2936 reviews. After removing duplicates and performing title/abstract and full-text screening, 47 published reviews were selected for the analysis. These spanned the period from 2002 to 2022, with a majority of studies published in the time frame of 2016 to 2021 (Fig. 1). Of these 47 studies, 28 focused primarily on identifying drivers of AMR within the human sector (Table S4), while a smaller number of studies investigated drivers of AMR in other sectors and/or across multiple sectors, including the animal and environmental sectors. The investigation of the literature led to the initial identification of 166 drivers of AMR. These drivers were subsequently consolidated and recategorised into 48 driver groups (here referred to as 'drivers'), of which 23 were identified as drivers within the human sector, 12 within the animal sector, 5 within the environmental sector, and 8 as contextual drivers (Table 2).

The median number of drivers per paper was 12 (minimum = 5, maximum = 32). The majority of drivers were identified from narrative summaries in which causal relationships were qualitatively reported (40/47), whereas quantitative data regarding the strength of association between drivers were rarely reported (7/47). 'Environmental conditions' and 'pharmacy staff's knowledge about AMR' were reported only once and they were excluded from the network analysis. 'Globalisation' was not included due to its overlap with two other drivers, namely human travel and food trading activities. The full list of definitions and subcategories for each driver and publication details can be found in the supplementary materials (Tables S4 and S5).

From 2384 selected quotations in which causality relationships were mentioned, 217 unique causal links between nodes were retained and the causal network of AMR was constructed. Using quartile rankings of the distalness index, the drivers were categorised into four groups, namely most-proximal drivers, near-proximal drivers, near-distal drivers, and most-distal drivers (Table 2 and Fig. S3).

Fig. 2 shows the distalness index of drivers characterised by major governance challenges. The results indicate that most proximal drivers were found to be associated with containment (D_i = 0.49, SD = 0.14), access (D_i = 0.57, SD = 0.09), and conservation challenge (D_i = 0.58, SD = 0.2). They include drivers regarding transmission of resistant bacterial infection in humans and animals, access to healthcare and quality antibiotics, patient and prescriber factors, economic incentives for prescribing antibiotics and the discharge of waste containing antibiotic residue from anthropogenic activities. Notably, social-cultural factors and drug promotion by pharmaceutical companies are the most distal drivers (D_i = 1.0) of the conservation challenge.

Drivers associated with innovation (D_i = 0.62, SD = 0.07), infection prevention (D_i = 0.67, SD = 0.14) and surveillance challenge group (D_i = 0.69, SD = 0.16) have mean distalness index values close to the grand mean, suggesting that they are intermediate causes of AMR. In addition, our findings indicate that drivers relevant to addressing 'multiple challenges' related to AMR (D_i = 0.83, SD = 0.12) are distal drivers, the majority of which are societal development and governance challenges, including substandard healthcare provision, gaps in policy adoption, implementation, and enforcement; crisis events; leadership and governance capacity;

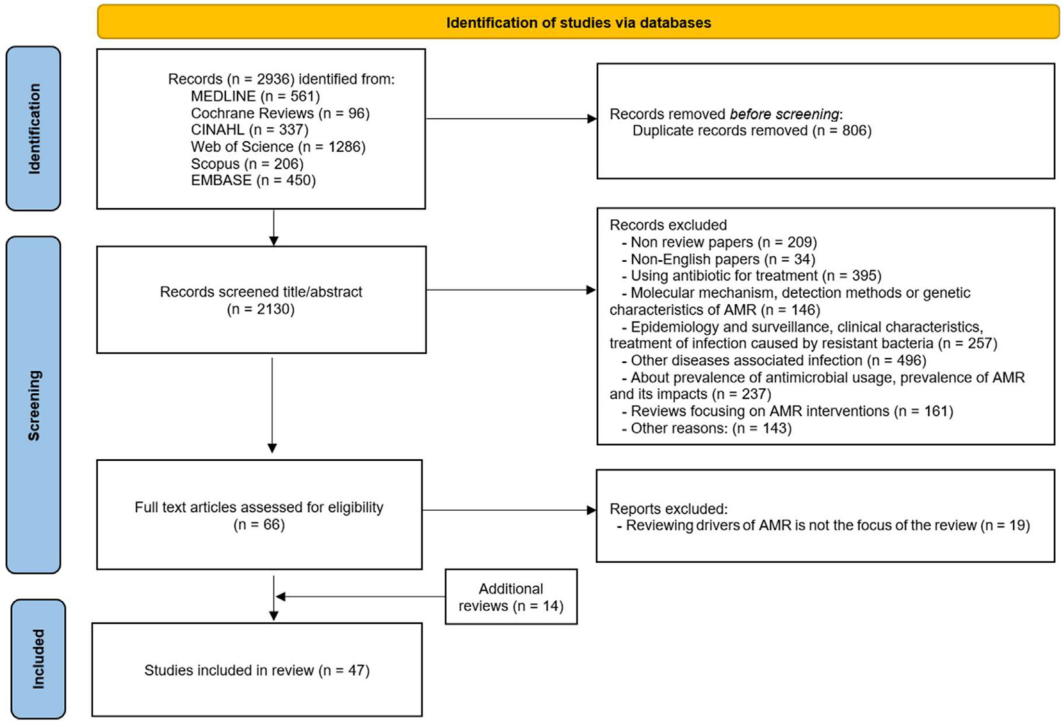

Fig. 1. Process of study selection based on the preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram.

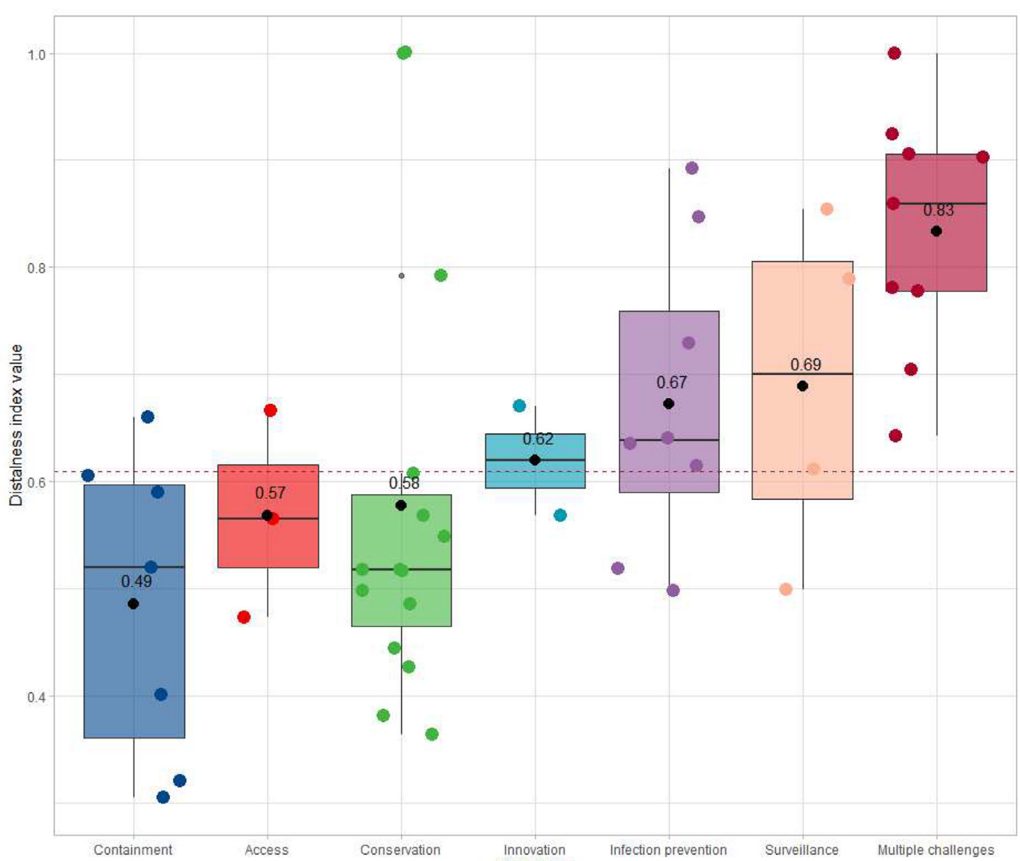

Fig. 2. Distribution of distalness index. The boxplots show the aggregated distalness values of drivers associated with AMR governance challenges (interventions-focused area).

Table 2
AMR drivers identified from the literature.

Abbreviation	Driver	Sector	Governance challenge	Distalness index (D_i) (0–1)	No. of papers
Most-proximal drivers					
INF_A	Risk of infection/colonisation by resistant bacteria in animals	Animal–food	Containment	0.3	10
INF_H	Risk of infection/colonisation by resistant bacteria in humans	Human	Containment	0.32	29
DPR	Inappropriate prescribing by a doctor	Human	Conservation	0.36	31
VPR	Inappropriate prescribing by a veterinarian	Animal–food	Conservation	0.38	6
WDL	Wildlife-associated AMR transmission	Environment	Containment	0.4	6
PAH	Patient expectations and heath-seeking behavior	Human	Conservation	0.43	23
PCS	Patient health status	Human	Conservation	0.44	12
PQA	Shortage of quality antibiotics in the market	Human, animal–food	Access	0.47	14
OTC	Ease of access to antibiotics over the counter	Human, animal–food	Conservation	0.49	30
PGP	Economic incentives for prescribing antibiotics	Human	Conservation	0.5	8
REW	Reuse of untreated animal waste in aquaculture and agriculture	Environment	Infection prevention	0.5	8
LCH	Limited laboratory capacity in human medicine	Human	Surveillance	0.5	17
Near-proximal drivers					
SEW	Discharge of waste from anthropogenic activities	Environment	Conservation	0.52	21
VKA	Veterinarian knowledge and attitude about AMR	Animal–food	Conservation	0.52	5
PKA	Patient knowledge and attitude about AMR	Human	Conservation	0.52	25
FMP	Poor adoption of good husbandry practices	Animal–food	Infection prevention	0.52	12
FTR	Food-animal trading activities	Animal–food	Containment	0.52	6
DKA	Doctor knowledge and attitude about AMR	Human	Conservation	0.55	19
LHC	Limited access to healthcare	Human	Access	0.56	18
DCP	Doctor-patient relationship	Human	Conservation	0.57	13
ARD	Decline in antibiotics research and development	Human	Innovation	0.57	10
IPC	Inadequate infection control measures in hospital	Human	Containment	0.59	13
SHA	Sharing common habitats between humans and animals	Environment	Containment	0.61	9
PDP	Profit-driven pharmacy	Human	Conservation	0.61	7
Near-distal drivers					
SUV	Poor AMR surveillance system in veterinary medicine	Animal–food	Surveillance	0.61	5
AVS	Substandard veterinary system	Animal–food	Infection prevention	0.61	6
WAS	Poor access to water, sanitation and hygiene (WASH) infrastructure	Development and governance	Infection prevention	0.64	18
AGI	Expansion of intensive husbandry farming	Animal–food	Infection prevention	0.64	8
HCQ	Substandard healthcare provision	Development and governance	Multiple challenges	0.64	26
HTM	Human travel and migration	Human	Containment	0.66	13
DMC	Disrupted health services and supply chains	Human	Access	0.67	2
LPR	Economic obstacles in antibiotics research and development	Human	Innovation	0.67	6
LEG	Gaps in policy adoption, implementation, and enforcement	Development and governance	Multiple challenges	0.7	30
LVC	Local living conditions	Development and governance	Infection prevention	0.73	22
DAF	Increasing demand for animal food	Animal–food	Multiple challenges	0.78	10
CRE	Crisis events	Development and governance	Multiple challenges	0.78	4
Most-distal drivers					
SUH	Poor AMR surveillance system in human medicine	Human	Surveillance	0.79	7
FKA	Farmer knowledge and attitude about AMR	Animal–food	Conservation	0.79	5
PHM	Insufficient public health measures	Human	Infection prevention	0.85	9
LCV	Limited laboratory capacity in veterinary medicine	Animal–food	Surveillance	0.85	6
DGE	Environmental changes	Environment	Multiple challenges	0.86	8
FAM	Farm model and financial conditions	Animal–food	Infection prevention	0.89	4
SES	Demographic and individual socio-economic status	Human	Multiple challenges	0.9	27
PGA	Leadership and governance capacity	Development and governance	Multiple challenges	0.91	9
PGE	Population growth and urbanisation	Development and governance	Multiple challenges	0.92	13
SCN	Social-cultural factors	Human	Conservation	1	9
DPP	Drug promotion by pharmaceutical companies	Human	Conservation	1	7
PVT	Country development status	Development and governance	Multiple challenges	1	25

population growth and urbanisation; and country development status.

Evidence involving distal drivers is more fragmented than that for proximal drivers (Fig. 3). We found that the number of reviews covering distal drivers (mean = 11.6, SD = 8.3) was smaller than that covering proximal drivers (mean = 14.6, SD = 8.1). In addition, the minimum set of papers needed to fully characterise the causal pathways from a driver to AMR increased with distalness value (proximal drivers: mean = 1.4, SD = 0.3; distal drivers: mean = 2.0, SD = 0.7; Wilcoxon rank sum test $P < 0.05$).

Nodes with high betweenness and eigenvector centrality values indicate the intersection of several pathways; in other words, AMR

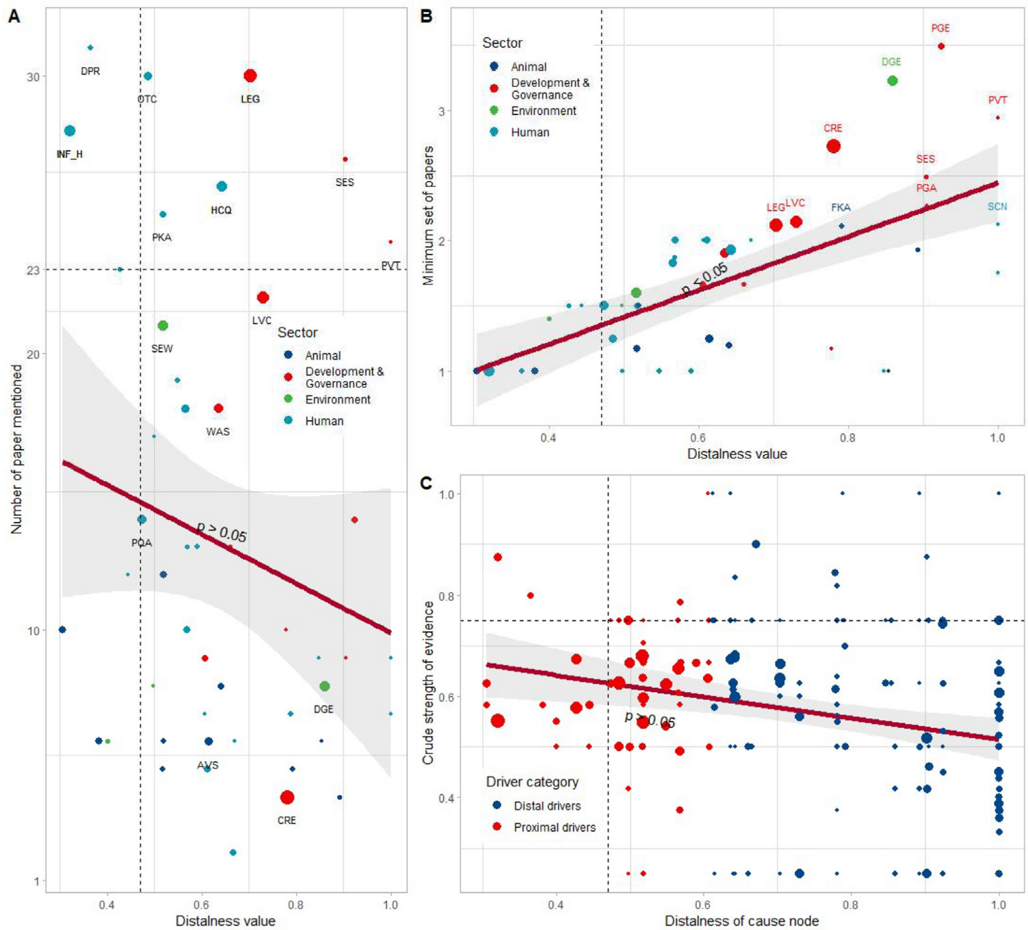

Fig. 3. (A) Scatter plot showing driver distalness index (D_i) against the number of reviews mentioning that driver. Nodes are characterised according to sector. Node size represents for betweenness centrality index. Nodes with a high number of paper mentions or high betweenness values are labelled. (B) Distalness index against the average minimum set of papers to describe the causal pathway from a node to AMR. Nodes are characterised according to sector. Node size represents for betweenness centrality index. (C) Distalness of cause node against average crude strength of evidence. Node size represents the frequency of mention of a causal relationship.

is more likely to occur in the presence of these nodes [39]. These nodes might be important for management since they connect different pathways. We found that contextual factors such as access to sanitation infrastructure; local living conditions; gaps in policy adoption, implementation, and enforcement; and crisis events are distal drivers with high betweenness and eigenvector centrality values. Interestingly, the country level of development and population growth and urbanisation were two distal drivers with low betweenness centrality values but high eigenvector centrality index values. The analysis also revealed that a considerable proportion of the drivers (12/48) identified from the network have a value of betweenness centrality approximating zero (Fig. 4). Results from core-periphery structure (Fig. S2) analyses also highlighted that poor access to water, sanitation and hygiene infrastructure (WAS), country development status (PVT), gaps in policy adoption, implementation and enforcement (LEG), substandard healthcare provision (HCQ), and population growth and urbanisation (PGE) are key distal drivers in the development and spread of AMR in the network identified by our literature review. Interestingly, crisis events (e.g., pandemics, war, natural disasters), although rarely mentioned as direct drivers of AMR, have the potential to impact AMR by exacerbating many other drivers of AMR, including the disruption of health services, travel, and migration, as well as by limiting the access to WASH infrastructure and increasing the burden of bacterial infection. Unsurprisingly, key proximal drivers, including risks of infection in humans (INF_H), patient knowledge and attitudes (PKA), inappropriate prescribing behaviour of doctor (DPR), and ease of access to over-the-counter antibiotics (OTC), are most frequently identified in the literature.

4. Discussion

Our paper presents a novel approach to summarising the complex set of latent relationships between drivers of AMR. By combining meta-review methodology and causal chain network analysis, we systematically structured the links between AMR and its underlying drivers as logical, stepwise chains of causal events. Our findings support the multicausal hypothesis of the problem and show that existing evidence regarding drivers of AMR predominantly focuses on proximal drivers, especially drivers of antibiotics use in human and animal sectors, while evidence regarding distal drivers tend to be fragmented across the causal pathways in which they are implicated. This finding is in line with those of previous studies [40,41], and might be attributable to two main reasons. First, there is no existing framework to distinguish between proximal and distal drivers of AMR, and the identification of distal drivers can be challenging due to heterogeneity in the form and granularity of language. Second, limited data and research are available about the contribution of some distal drivers, such as the impacts of crisis events, climate change and reduced biodiversity, and corruption. This could be due to distal drivers acting diffusely in multiple causal pathways, making it difficult to rigorously establish causality. Given the difficulties of identifying and estimat-

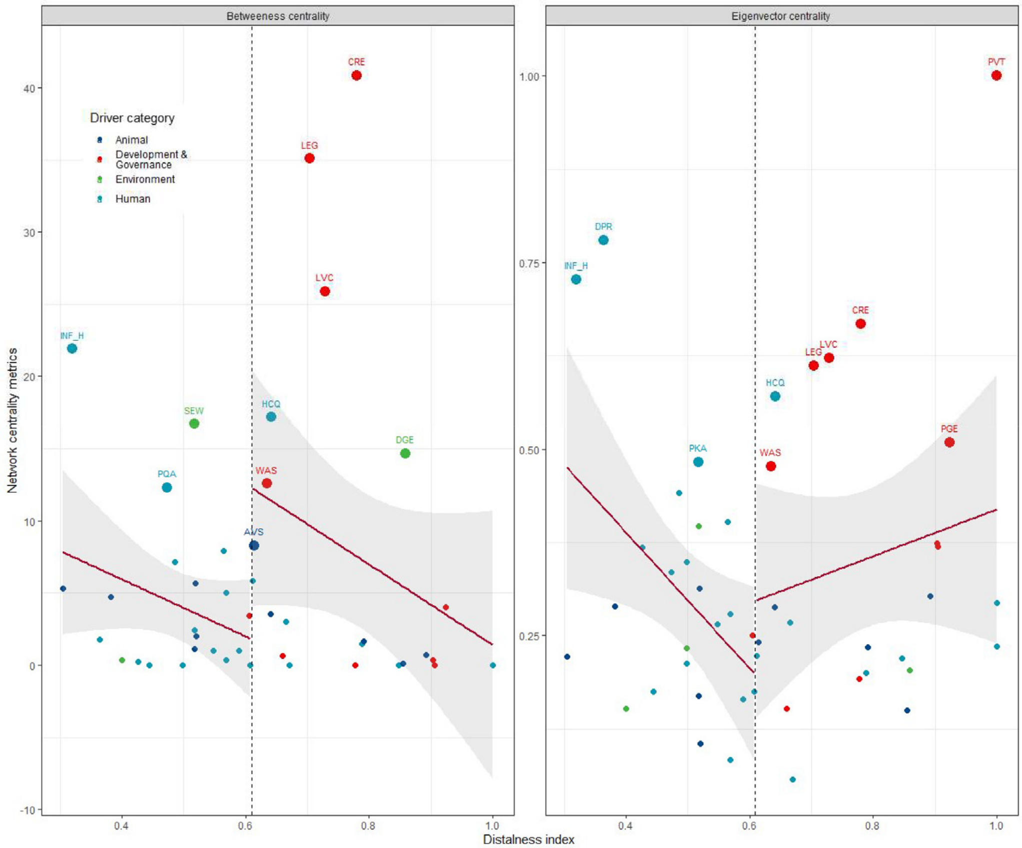

Fig. 4. Distalness index against betweenness and eigenvector centrality index. The dashed vertical line separates proximal and distal drivers.

ing the effects of distal drivers, it is likely that distal drivers are currently underreported in the literature.

Intervening at multiple complementary points in a system is an important resilience strategy [14]. Our findings highlight that effective approaches to combat AMR should include both actions that focus on proximal drivers and interventions that address more distal drivers [24,42]. On the one hand, numerous proximal drivers identified have high betweenness and eigenvector centrality values and are frequently mentioned in the literature. These include the risk of resistance transmission, patient and doctor behaviours, and the availability of quality antibiotics. Assuming the literature adequately reflects driver-AMR relationships, these drivers, which are highlighted in current AMR national action plans, represent important short-term leverage points for management [10,43].

On the other hand, our results reveal that many distal drivers are also key leverage points in the system that are relevant to addressing 'multiple governance challenges' related to AMR. For example, addressing the increasing demand for animal-source foods by shifting consumer choice, demand and behaviour toward 'antibiotic-free' products can address the challenge of reducing antimicrobial use in food production [22,44]. Although existing evidence of how to research and intervene on distal drivers is still limited, not addressing them in an AMR-aware matter could lead to the implementation of activities that only navigate the peripheries of the AMR challenge [45]. In fact, inadequate understanding and acknowledgement of distal drivers might be a plausible explanation for the slow progress in tackling AMR in many countries [2,9,10,46]. The lack of policy coherence in addressing distal drivers of AMR is further evidenced by various actors sharing competing – and sometimes contradictory – explanations of the problem and the range of possible solutions, especially in many low- and middle-income countries [47–51].

We found that distal drivers are often linked with sustainable development challenges, thus actions targeting them may benefit from integration and coordination with SDGs implementation [1]. Further research is needed to evaluate the synergies and tradeoffs of actions targeting specific AMR drivers when integrating AMR control strategy with SDG implementation across the system and to assess the combined impact of multiple interventions applied simultaneously as part of a comprehensive AMR approach [52]. Evaluation should also be conducted in different social-economic contexts across the One Health system. The development of evaluation methods to assess the impact of distal driver interventions on AMR will assist policymakers in selecting an approach that best fits their context in efforts for the development of a multipronged approach to address AMR, which will ultimately support the attainment of the SDGs.

Some limitations of the study are worth highlighting. First, despite efforts to minimise bias, coding inherently requires subjective assessment. In addition, while our approach improves understanding of complex networked casualties, it currently does not take into account when the strength or direction of the relationship is mediated by the level or presence of a third variable (i.e., the negative impacts of flooding, including an increased risk of acute human exposure infections, are mitigated by the quality of drainage infrastructure [53]).

Despite these limitations, our study brings a new understanding of the many drivers of AMR from a social-ecological perspective and paves the way for further research. When more data become available, a network approach should also be complemented with other modelling techniques (e.g., systems dynamic type models) to support the quantification of the impacts of AMR interventions, an important source of evidence for the future governance of AMR [20].

5. Conclusion

Our investigation of the literature revealed that the primary emphasis on actions to address AMR has been on proximal drivers while existing evidence about distal drivers is fragmented. Our study highlights the critical roles of distal drivers in contributing to the issue of AMR through different pathways, which require a multi-pronged strategy to address. The study further highlights the need to explore interventions to address distal drivers, including integration with SDG implementation and assessment of the combined impact of multiple interventions targeting distal drivers simultaneously as part of a comprehensive AMR approach.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jgar.2023.12.008.

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