Agriculture and Human Values (2023) 40:1451–1464
https://doi.org/10.1007/s10460-023-10422-w

Antibiotic responsibility and agricultural publics: diverse stakeholder perceptions of antibiotic use in animal agriculture

David M. Lansing[1] · **Jaime Barrett**[1]

Accepted: 21 January 2023 / Published online: 1 May 2023

Abstract
This paper examines diverse perspectives around the concept of responsibility concerning antibiotic use in animal agriculture. Antibiotic use in agriculture has been identified as a source of antimicrobial resistance, one of the largest public health threats today. In the United States, efforts to curb antibiotic use in farming draws on a diverse range of actors—including farmers, veterinarians, consumers, and public health advocates—and relies on a mix of industry standards and federal guidelines around responsible use. The paper selects a similarly diverse range of people and employs Q methodology to query the points of disagreement and consensus around the practices that constitute responsible antibiotic use in animal agriculture, and who is responsible for antimicrobial resistance. We find a diverse mix of actor types across three discourses, but with clear differences between farmers and public health advocates. We also argue that, in some cases, points of disagreement and agreement are often based on different interpretations of ideas, indicating points of common ground where there might appear to be disagreement, and areas of difference where there appears to be agreement. We argue that these flexible interpretations of some of the key issues around antibiotic use are nevertheless grounded in durable differences in views of what agriculture is and what it should be.

Keywords Antibiotic use · Antimicrobial resistance · Agricultural policy · Q methodology · Agriculture perceptions · Food perceptions

Introduction

How might differently situated people understand responsibility concerning a complex socio-environmental problem, both responsibility for the problem and the most responsible way to fix it? We take up this broad question with regard to antibiotic use in animal agriculture and its contribution to antimicrobial resistance (AMR). Most efforts to govern agricultural antibiotic use in the United States depend on various actors exercising responsible judgment. Rather than mandate specific antibiotic limits, federal policy relies on veterinarians to decide what responsible use is, and to ensure their clients engage in responsible antibiotic practices on a case-by-case basis (e.g. the Veterinary Feed Directive 2015). Another form of antibiotic governance grounded in responsible habits involves consumer buying pressure in the form of labeling. Numerous studies, however, have shown consumers tend to have inconsistent, and often factually incorrect, views on the role of antibiotics in food (Barrett et al. 2021). Thus, while the notion of responsible use is important to current efforts to govern antibiotic use, the term itself is potentially open to varied interpretations across many different types of actors (Brunori et al. 2019). In short, controlling antibiotic use in agriculture is a complex issue that is often poorly understood, with the potential for contrasting perceptions across actors with different social positions, whether they are farmers, veterinarians, regulators, health advocates, or consumers.

Ongoing debates and political contestations over the use of technologies such as genetically modified organisms (Tourangeau 2017) and pesticides (Lehrer and Sneegas 2018) in agriculture show that antibiotic use in agriculture is but one of many complex social and environmental problems without a clear consensus over how these technologies should best be used. Debates over agriculture's contribution

✉ David M. Lansing
dlansing@umbc.edu

[1] Department of Geography and Environmental Systems, University of Maryland Baltimore County, Baltimore, MD, USA

to greenhouse gas emissions, and climate change debates in general, also show that questions regarding who or what is responsible for these problems are often scientifically and politically contested across different social groups (Lansing et al. 2015; Renkenberger et al. 2016; McGregor et al. 2021). Indeed, scholars of environmental politics have shown that longstanding beliefs about contested environmental ideas tend to persist over time (Robbins 2006; Hajer 2015). In debates around complex topics, science is often marshalled in selective ways by actors in order to support their preexisting values (Sarewitz 2004).

In the face of differing perceptions across diverse social worlds, are there still grounds for agreement, and potentially, action? This paper takes up these broader issues with regards to diverse actor perspectives of antibiotic use in the beef and dairy industry. It empirically describes research that examines how diverse actors involved in these products—from farmers to veterinarians to consumers—understand the consequences of antibiotic use in agriculture and evaluates how such actors perceive efforts to mitigate antibiotic use in agriculture. Specifically, we ask: how do diverse actors understand who or what is responsible for AMR? How do such actors understand what constitutes responsible use of antibiotics in agriculture? We employ Q method to examine these perceptions across diverse actors (Watts and Stenner 2012). Our findings suggest the following. First, we find a diversity of subject positions across three main discourses, but with a clear cleavage between agricultural and public health-oriented viewpoints. Second, a closer examination of the various perspectives show that different discourses take up ideas around antibiotic use in slightly different ways, sometimes producing points of difference and agreement that are not as stable as they first appear. These different modes of understanding statements, however, are grounded in broader perspectives about animal agriculture that appear to be distinct across discourses. We suggest that these three discourses fall on a spectrum representing a realist "agriculture as it is" understanding to an idealist "agriculture as it should be" view, as well as a range of perspectives related to agriculture's relationship to the public.

These findings make two contributions to research on antibiotic use in agriculture. First, it extends recent insights on perceptions around what AMR and antibiotic use is in agriculture. Collectively, emerging research on perceptions around this issue shows that people closely associated with agriculture, such as farmers and veterinarians, tend to view the issue through the lens of how best to manage animal health, and by extension, animal welfare. Innes et al. (2021), for example, found among this group a sophisticated understanding of the dynamic movement of AMR across species and ecosystems. Agricultural actors, however, were different from the broader public in that they tended to not think about AMR from a microbiological perspective, but instead, saw the issue through the lens of animal health, where antibiotic use is needed to ensure proper animal welfare. This animal welfare framing of AMR was also dominant in Padda et al.'s (2021) study of dairy farmers (see also Helliwell et al. 2020; Casseri et al. 2022). Research on consumer perceptions of antibiotic use and AMR shows most consumers view antibiotic use by agriculture as a threat to their health (Wemette et al. 2020), and often associate antibiotic use with poor animal welfare (Barrett et al. 2021). This paper extends these insights by examining perspectives around the issue of antibiotic responsibility across both agricultural (e.g. farmers, veterinarians) and non-agricultural (e.g. consumers, public health advocates) actors. Doing so, it directly compares the points of difference and concordance among these actors. By focusing on the issue of responsibility in antibiotic use and AMR among diverse groups, this work gauges not just the level of understanding of AMR in these groups, but also, examines the range of normative commitments around antibiotic use and good agricultural practices more generally.

Doing so, this paper makes a second contribution to the literature on contestation around complex issues in agriculture and the environment, which is understanding the extent to which there might be common ground across differently situated actors. One relatively unresolved issue in environmental politics is whether an actor's perspective on a controversial issue is due to their social position (e.g. farmer, consumer, veterinarian, policy advocate), or if it is unrelated to this, and is instead a more idiosyncratic and personal position (Brannstrom 2011). Insights from science and technology studies suggest that people in different social positions will often use and deploy ideas in slightly different ways (Star and Gresemeir 1989; Shackley and Wynne 1996; Cash 2001). Rather than a broadly shared meaning across different types of actors, discursive concepts such as "sustainability" (Leitch and Davenport 2007) or "responsibility" (Scandelius and Cohen 2016) can be subject to flexible interpretation across different social worlds. This finding raises questions about the extent to which points of disagreement and concordance are based on shared meanings or on divergent interpretations of the same ideas. This study presents evidence that shows points where shared meaning and disagreement are not as durable as they might appear, but also where divergent discourses are indeed grounded in fundamental differences in what agriculture is, and what it should be.

The rest of the paper proceeds as follows. Next, we provide a background on antibiotic use, policy, and perceptions in agriculture. After describing our methods, we then summarize the main discourses found around antibiotic responsibility. This is followed by an extended discussion of how

our interviewees thought about both animal welfare and veterinarians as these topics relate to antibiotics. These are two areas with sharp disagreement and agreement respectively in the Q sort. We then discuss these results with an eye toward describing a broader framework that describes each discourse's stance toward agriculture and how that might inform their views on antibiotics. We conclude by noting research limitations and the policy implications of our findings.

Background

Antibiotics are widely used in animal agriculture, accounting for up to 70% of U.S. antimicrobial drug sales (Cameron and McAllister 2016). There are three main reasons for antimicrobial use in animal industries: treatment, disease prevention, and growth promotion or feed efficiency (Cameron and McAllister 2016). For dairy farmers, the primary reason for antibiotic use in lactating cows is to treat, or prevent, mastitis, which is an infection of the mammary gland that negatively impacts cow comfort and reduces milk production and quality (Oliver et al. 2011; Landers et al. 2012; Okello et al. 2021). Other common conditions that warrant the use of drugs are metritis and hoof rot in adult cows and pneumonia and scours in calves (Wells et al. 1998; Sawant et al. 2005). Dairy farmers must be strategic in their antimicrobial use decisions as the milk of a treated cow must be withheld from sale for a clinically determined time-period to ensure that no drug residue remains. All milk is tested before processing and if it tests over the federally mandated residue limit it must be discarded (FARAD 2022).

The antibiotic needs of beef cattle differ from that of dairy cows due to differences in their life histories, feed regimes, and final product (Landers et al. 2012). Rather than the continuous need to monitor residue from dairy cows, beef producers are concerned about drug residues at the point of slaughter. This allows for more routine uses of drugs not allowable in the dairy industry (Cameron and McAllister 2016). In general, beef calves are most vulnerable to disease during the stressful times of weaning and movement from the cow/calf operation to the feedlot operation. This latter situation involves intermixing of different cattle in a confined setting for the first time. This naturally leads to new exposures, with respiratory infections being a common result (Lhermie et al. 2020). Adult beef cattle are less vulnerable to diseases, but they can develop health issues due to their confined environment and rapid changes in feed composition (Landers et al. 2012; Cameron and McAllister 2016; Lhermie et al. 2020).

In the United States, there has historically been little government regulation of antibiotic use in animal agriculture. It wasn't until 2012 that federal regulations restricting use emerged. In this year, the Food and Drug Administration published guidance documents that encouraged greater veterinary oversight of medically important antimicrobial drugs (Center for Veterinary Medicine 2019). In 2015, the Veterinary Feed Directive was enacted, and the routine use of medically important antimicrobial drugs was banned for growth promotion and feed efficiency uses (Veterinary Feed Directive 2015). Under this directive all uses of medically important antibiotics would require the prescription of a veterinarian. In addition to national regulations, California and Maryland enacted their own state-level regulations for medically important antimicrobial drugs. These laws also require veterinary oversight for antibiotic use (Okello et al. 2021; Abdelfattah et al. 2022).

In addition to residue testing and the FDA's mandates, another key source of antibiotic governance is consumer preference, which has led to the rapid rise of "raised without antibiotics" labels. This has had the biggest impact in the poultry industry, where a number of large poultry integrators have announced their chickens will no longer be fed any antibiotics (Poultry 2018; Singer et al. 2019). While antibiotic free labeling exists in the beef and dairy industry (often under the "organic" label), the longer lives of beef and dairy cows, their more complex health problems, and the more decentralized nature of the beef and dairy industry, have meant antibiotic use still remains essential to most beef and dairy operations (Landers et al. 2012; Cameron and McAllister 2016; Singer et al. 2019). As of 2020 an estimated 62% of sales of medically important antimicrobial drugs are for use in cattle (U.S Food and Drug Administration 2021), with as much as 42% used for beef cattle (Wallinga 2020).

Various public interest groups have argued that current US regulations are inadequate to stop the overuse of medically important drugs in animal agriculture (Keep Antibiotics Working 2022, Wallinga et al. 2022). Though the new revisions to the Veterinary Feed Directive were meant to reduce the use of medically important drugs, many of these drugs are still labeled for preventative uses that allow their continued use in feed and water. For example, an estimated 92% of medically important drugs used in the beef industry are in feed and water (Wallinga 2022). Public health advocates are pushing for the restriction of such drugs to only necessary uses to ensure animal welfare (Hoelzer et al. 2017, Keep Antibiotics Working 2022). In lieu of preventative antimicrobial use, advocates advise instead that the conditions of industrialized agriculture need to be changed so that the need for antibiotics will be drastically reduced (Keep Antibiotics Working 2022).

Methods

This study employs Q methodology, which is a technique for measuring subjectivity (Watts and Stenner 2012). This work involved four phases. First, we created a concourse of 26 statements which represent the discourses around a topic of interest. In Q method, a concourse is a series of diverse items (in this case, statements) that nevertheless share a common referent (in this case, notions of responsibility in antibiotic use). These statements are sorted by relative agreement by participants (Watts and Stenner 2012). In so doing, research subjects impose their own unique stamp on this concourse, allowing the researcher to gauge their subjective view of an issue. We created the concourse for this study by conducting 35 semi-structured interviews with beef and dairy farmers, agricultural extension agents, veterinarians, beef feedlot managers, representatives of beef and dairy industry groups, as well as members of public health, environment, animal welfare, and consumer advocacy groups. We also interviewed meat and dairy consumers not affiliated with the agriculture industry. Beef and dairy farmers were all located in New York, Pennsylvania, Maryland, and Nebraska. Veterinarians, consumers, and feedlot managers were also from these states. Most of the farm, environmental, consumer, and animal advocates were in the greater Washington DC metro area. All but two interviews were recorded and transcribed. We also reviewed documents related to antibiotic use in agriculture from public health think tanks as well as agricultural industry and advocacy groups.

Following a modified grounded theory approach (Charmaz 2006; Brannstrom 2011), interviews were relatively open and wide ranging around issues related to farming, animal health, public health, antibiotics, and numerous other related topics. All interviews, however, did address two core questions: to what extent is agriculture responsible for antimicrobial resistance, and what is responsible use of antibiotics in agriculture? Interview transcripts, field notes, and relevant collected documents were coded through a modified grounded theory process to determine emergent themes. An initial round of coding identified 30 themes related to the responsible use of antibiotics. With this expansive group of themes, over 300 statements were identified for inclusion in the concourse. A second round of coding was conducted, and these themes were further condensed into four main organizing themes, with 26 associated statements. All statements come directly from either interviews or documents. In most cases, the quotes were paraphrased, or cleaned up, for better readability. Prior to selecting participants, the sort was piloted with eight people to test for statement coherence and the online platform. Post-sort interviews were conducted with pilot participants concerning statement coherence and the ease of use of the online platform.

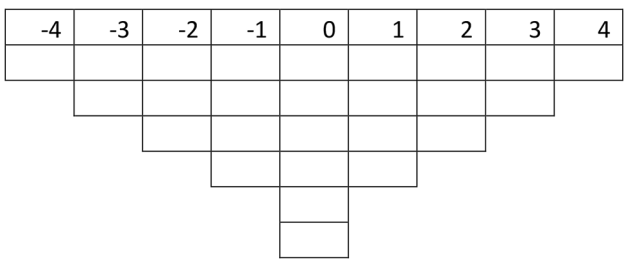

Fig. 1 Q sorting grid used in the study

In our second step we identified participants through purposeful sampling based on their relationship with the topic of interest and asked them to sort the concourse statements by relative agreement. We selected 30 participants to reflect the range of diverse actors that were interviewed and that are affected by antibiotic use in agriculture. Consumers that regularly purchase and consume beef or dairy products were purposively sampled to reflect a range of people based on gender, education, and income, three of the most commonly associated variables with consumer concern of antibiotics (Barrett et al. 2021). Sixteen of the 30 sorts were done by the original interviewees, the remaining had not been interviewed prior to doing the sort. Sorts were conducted online using the Q-Tip online sorting platform (https://qtip.geography.wisc.edu/#/) hosted at the University of Wisconsin. Participants were asked to sort 26 statements into a normally distributed range from −4 (most disagree) to +4 (most agree; see Fig. 1).

Third, after sorting was complete, data was analyzed in KADE Q method software (version 1.2.1). We conducted a factor analysis to identify how each participant's relative agreement with the statements divided participants into different groups. After experimenting with both varimax and judgmental rotation (and also a combination of the two), we settled on a three-factor principal component analysis with a varimax rotation. We used eigenvalues and a scree plot to narrow our solution choice to a 5 factor or a 3 factor solution. Utilizing a crib sheet approach, described in Watts and Stenner (2012, pg. 150), we closely examined both of these solutions, and concluded that, in the 5 factor solution, the extra two factors (factors 4 and 5) had substantial overlap with factors 1 and 2. The larger number of factors did not add more insight over the more parsimonious three factor solution. Data for the factor analysis, along with instructions for what we did can be found in this project's online data repository (https://osf.io/yxk97/?view_only=ea5b6ae1bfe0486e86da28c06acde55a). The final solution accounts for 54% of the variance in sorting, with each factor accounting for at least 10% of the variance (see Table 1). Factors 1 and 2 are negatively correlated (-17.8%; see Table 2). Factors 2 and 3 have a small positive correlation (9.8%), and factors

Table 1 Factor Statistics

	Factor 1	Factor 2	Factor 3
No. of Defining Variables	14	8	6
Avg. Rel. Coef.	0.8	0.8	0.8
Composite Reliability	0.982	0.97	0.96
S.E. of Factor Z-scores	0.134	0.173	0.2
Eigenvalues	8.1015	5.0956	2.9006
% of Explained Variance	27	17	10

Table 2 Factor Score Correlations

	Factor 1	Factor 2	Factor 3
Factor 1	1	-0.1788	0.0985
Factor 2	-0.1788	1	0.2834
Factor 3	0.0985	0.2834	1

1 and 3 have a larger positive correlation (28.3%). The final phase is interpretation of the factors. Preliminary results from our three factor solution were presented to six of the Q sort participants (two high-loaders from each factor) for feedback and critique, which informed our final analysis.

Results

Factor 1: farmer first, food realist

This factor, or discourse, can be thought of as a realistic, unromantic view toward farming, and largely shuns the advice and values of actors that exist outside of the farming world. Industry best practices, government regulations, and

Table 3 Statement ranking by factor. Z-Scores are in parenthesis. Distinguishing statements (at $p < .05$) are in bold

#	Statement	F1	F2	F3
1	The most immediate stakeholders who are harmed by overuse of antibiotics are the animals because then they're exposed to resistant bugs	0 (0.03)	0 (-0.2)	**-1 (-0.81)**
2	It is bad for animal welfare to not give a sick animal antibiotics.	**+4 (2.5)**	**0 (0.33)**	**+2 (1.11)**
3	It is possible to have good farm animal welfare and not use antibiotics	**-1 (-0.7)**	**+2 (0.93)**	**0 (0.37)**
4	The label "no antibiotics ever" should mean the farmer is engaging in animal management practices that lead to the animals having a more naturalistic lifestyle.	**-3 (-1.39)**	**0 (0.28)**	**+4 (1.7)**
5	A farm operation that rarely uses antibiotics is better for farm animal welfare.	**-4 (-1.53)**	**0 (-0.04)**	**+1 (0.53)**
6	Animal antibiotic recommendations should be based on what is best for public health.	**0 (-0.39)**	**+3 (1.26)**	**+1 (0.74)**
7	Agriculture is partly responsible for the rise of antibiotic resistant microorganisms.	**-2 (-0.88)**	**+4 (1.75)**	**0 (0.24)**
8	Responsible use of antibiotics means not using antibiotics except as a treatment of last resort.	**-1 (-0.53)**	+1 (0.49)	+1 (0.61)
9	The main benefit from "antibiotic free" production is in terms of the overall reduction in public health risk.	**-2 (-1.12)**	0 (0.37)	0 (0.17)
10	Implementing antibiotic best practices will decrease the risk of more antibiotic resistant microorganisms.	**+3 (1.01)**	**+1 (0.57)**	**0 (-0.07)**
11	The administration of medically important antimicrobial drugs to entire herds of food-producing animals poses a higher risk to public health than the administration of such drugs to individual animals.	0 (0.23)	0 (0.18)	**-4 (-1.63)**
12	Preserving the effectiveness of antibiotics for human medicine requires ending the routine use of medically important antibiotics for disease prevention in meat and poultry production.	**-1 (-0.58)**	**+2 (0.77)**	**-2 (-1.1)**
13	Every farmer should be allowed to make their own distinct antibiotic decisions.	**0 (0.04)**	**-2 (-1.19)**	+2 (1.12)
14	Any use of medically important antibiotics should require veterinary oversight.	+2 (0.91)	**+3 (1.53)**	+2 (0.76)
15	Dairy and cattle farmers won't overuse antibiotics because their products are tested for antibiotic residues.	**+1 (0.51)**	-4 (-1.74)	-2 (-1.33)
16	Government regulations will decrease the risk of more antibiotic resistant microorganisms.	**0 (-0.53)**	**+1 (0.56)**	-3 (-1.43)
17	Responsible use of antibiotics means following the label's instructions.	**+2 (1.01)**	-1 (-0.28)	0 (0.23)
18	Agriculture is demonized by the public for embracing technology.	**+2 (0.96)**	**-3 (-1.42)**	**-2 (-0.83)**
19	It would be harmful to agriculture if the public makes decisions about how to manage cows.	**+1 (0.67)**	-1 (-0.43)	0 (-0.38)
20	Free range animal farm opertations will not need to use as many antibiotics as farms where the animals are mostly confined	**-2 (-0.87)**	**-1 (-0.2)**	**+1 (0.59)**
21	Having to wait for a veterinarian can lead to more serious health problems because of the lack of timely treatment.	**+1 (0.44)**	-2 (-1.09)	-1 (-0.8)
22	It is justifiable to use penicillin at a higher dose so long as an appropriate withdrawal has been put in place.	**0 (0.28)**	-1 (-1)	-1 (-0.5)
23	Big feedlots use antibiotics in their feed and cows get it whether they need it or not.	**-3 (-1.47)**	**+1 (0.7)**	-1 (-0.52)
24	Very large operations are better able to effectively use antibiotics on their herds than smaller farmers.	**-1 (-0.65)**	-2 (-1.37)	-3 (-1.63)
25	It is more profitable to prevent sickness through a better environment for the animals than using antibiotics.	+3 (1.58)	**+2 (0.97)**	+3 (1.65)
26	If an animal is likely to develop a bacterial infection, preventative treatment of cattle with antibiotics is a responsible use of antibiotics.	**+1 (0.46)**	**-3 (-1.74)**	+3 (1.22)

Table 4 Factor loadings for each sort. **Bold** numbers indicate significant loadings at $p < .05$, majority of common variance required

Sort number	Person Description	Factor 1	Factor 2	Factor 3
9	Agriculture Policy Advocate	**0.8474**	0.0941	-0.0297
5	Dairy Farmer	**0.7552**	-0.3702	0.1291
18	Beef Feedlot Manager	**0.7469**	-0.2935	-0.0207
11	Extension Agent	**0.7344**	-0.3345	-0.1487
23	Extension Agent	**0.7276**	0.1553	0.1769
10	Environmental Policy Advocate	**0.7135**	0.1474	-0.1657
4	Extension Agent	**0.6761**	-0.4771	0.1626
2	Veterinarian	**0.6431**	0.1501	0.3394
28	Veterinarian	**0.6221**	0.1239	0.1207
7	Veterinarian	**0.618**	-0.2384	0.2943
22	Beef and Dairy farmer	**-0.5866**	0.4631	0.1839
19	Beef Farmer	**0.56**	-0.4735	-0.1239
20	Organic Dairy Manger	**0.5212**	0.1277	-0.0716
3	Beef Feedlot Manager	**0.5098**	0.0379	0.3958
16	Veterinarian	0.206	**0.8139**	-0.1812
6	Consumer1	-0.2223	**0.7457**	0.2816
14	Public Health Policy Advocate	0.1231	**0.7361**	0.2236
13	Consumer3	-0.0418	**0.7285**	0.1883
17	Public Health Policy Advocate	-0.0622	**0.6454**	-0.2509
12	Beef Farmer	0.4628	**-0.6345**	0.1139
30	Consumer6	-0.0846	**0.5651**	0.203
26	Veterinarian	0.4771	0.4983	-0.321
21	Organic Dairy Buyer	0.3273	**0.4441**	0.2108
8	Consumer2	-0.3048	0.3325	**0.6286**
24	Extension Agent	0.3182	0.006	**0.624**
29	Consumer5	0.0995	0.2112	**0.6117**
1	Veterinarian	0.4561	-0.0173	**0.5155**
15	Veterinarian	0.3722	0.4011	-0.496
25	Beef Farmer	-0.3574	0.2275	**0.48**
27	Consumer4	0.0525	-0.0338	**0.408**

Demographics for consumers. Consumer1: female, 38 years, college graduate,; Consumer2: female, 37, college; Consumer3: female, 33, college; Consumer4: male, 67, high school graduate; Consumer 5: male, 48, some college; Consumer 6: male, 20, some college. All farmers are owner/operators

consumer labels are accepted as part of farming, but public health concerns, the views of uninformed consumers and general attitude of "the public" at large, are treated with suspicion. Veterinarian decisions are held in high regard, even above those of farmers. This discourse considers farming issues from a position of the perspective of the farm with little consideration for issues beyond the farm itself.

According to this discourse, antibiotic use is essential for good animal welfare. The strongest possible agreement is made with the statement 2 (see Table 3): "it is bad for animal welfare to not give a sick animal antibiotics." (+4). It also disagrees (-1) with statement 3: "it is possible to have good farm animal welfare and not use antibiotics." Aligning with this view, this discourse is also very skeptical of any claims that antibiotic free production is more natural (statement 4, -3), better for the cow (statement 5, -4), or better for public health (statement 9, -3). It is also skeptical that "free range" operations need to use any less antibiotics than conventional one (statement 20, -2). It does, however, agree that better environments for the cow are better for the farm's profitability (statement 25, +3).

While the link between antibiotic use and good animal welfare are clear foundations for this discourse, it has a relatively tempered and practical view of how antibiotic decisions should be made. It trusts veterinarians more than farmers in making judgement calls about antibiotic use. It agrees with the statement "any use of medically important antibiotics should require veterinary oversight."(statement 14, +2), but is more neutral on the statement "every farmer should be allowed to make their own distinct antibiotic decisions." (statement 13, 0). Nevertheless, it also agrees that having to wait for a veterinarian can result in problems if treatment must be timely (statement 21, +1). It has pragmatic views on off-label use. It believes that following the label is a responsible use of antibiotics, but also sees a role for off-label uses too, agreeing with statements that suggest higher doses (statement 22, 0) and preventative use (statement 26, +1), are fine in some circumstances. It is also largely supportive of the effectiveness of food system surveillance (statement 15, +1) and best practice recommendations (statement 10, +3) in preventing the overuse of antibiotics and mitigating against any adverse effects.

This discourse largely denies the link between agricultural antibiotic use and the broader public health problem of antimicrobial resistance. It does not agree that public health should play a role in animal antibiotic decisions (statement 6, 0). It disagrees with the idea that animal agriculture's use of antibiotics contributes to the problem of antibiotic resistance (statement 7, -2) or that preserving the effectiveness of human medicine means ending the "routine use" of agricultural antibiotics (statement 12, -1).

Almost all of the respondents that loaded high on this discourse were either farm owners, farm managers or people closely aligned with animal agriculture such as veterinarians, extension agents, and employees of pro-agriculture NGOs (see Table 4). None of the six consumers that were surveyed were significant loaders on this factor, and none of the respondents working in public health fields aligned with this discourse. Not all farmers loaded high on this discourse, however, and as we will see, the remaining two discourses produced some surprising actor alignments across farmers, consumers, and public health advocates.

Factor 2: public health first, industry skeptic

In many ways, the F2, "public health first" factor has the opposite view of antibiotics in agriculture than factor 1, especially with regards to public health, regulations, and the role of animal welfare. This factor strongly agrees that there is a link between agricultural antibiotic use and the broader public health problem of antimicrobial resistance. Further, it thinks that antibiotic use decisions should be based primarily on this link. This factor sees veterinarians as important front-line actors and thinks that antibiotic decisions should largely be in their hands. Compared with factor one, this factor sees little scope for farmers to make their own autonomous decisions (apart from veterinary and label guidance). This view is related to the discourse's overall strong skepticism of the animal production industry. It expresses skepticism that label instructions will be followed, and has a negative view that larger farm operations can properly manage antibiotic use.

This factor sees strong links between agricultural antibiotic use and public health problems. It strongly agrees that agriculture is partly responsible for the rise of antimicrobial resistant microorganisms (statement 7, +4). It also agrees that agriculture must eliminate much of its antibiotic use to preserve the effectiveness of human medicine (statement 12, +2), and antibiotic recommendations should be driven by public health concerns (statement 6, +3).

In contrast to factor 1, this factor does not consider animal welfare to be tied to antibiotic use. It agrees that good animal welfare is possible without antibiotics (statement 3, +2), and does not agree that it is bad for animal welfare to withhold antibiotics (statement 2, 0). This discourse thinks it is possible for antibiotic free farms to have good animal welfare (statement 3, +2). It does not, however, think this will necessarily be the case (statement 5, 0), and it is skeptical that a "free range" operation will necessarily use less antibiotics than a conventional farm (statement 20, –1).

Similar to factor 1, this discourse agrees that veterinarians should oversee antibiotic use (statement 14, +3). Unlike factor 1, however, it disagrees with the idea that farmers should be able to make their own antibiotic decisions (statement 13, –2). It also disagrees with the idea that waiting for a veterinarian might be bad for the animal in some cases (statement 21, –2). This discourse is also fairly strict in denying that off-label use should be allowed. Higher doses of penicillin (statement 22, –1) and preventative treatment (statement 26, –3) are viewed in a negative light.

This discourse largely does not trust the agricultural industry to be responsible users of antibiotics, or to even follow the existing rules. It sees the industry as being in need of regulation and input from the broader public. This discourse agrees with the idea that large feedlots indiscriminately use antibiotics (statement 23, +1) and it does not think that large farm operations can better manage their antibiotics than smaller farmers (statement 24, –2). It strongly disagrees with the idea that current residue testing regimes prevent farmers from overusing antibiotics (statement 15, –4). Somewhat paradoxically, the discourse does view government regulations as an effective way to decrease the risk of antimicrobial resistant organisms (statement 16, +1). Unlike factor 1, this view does not have a problem at all with public input into agriculture, disagreeing with the notion that public decision making would be harmful for agriculture (statement 19, –1), or that the public "demonizes" agriculture (statement 18, –3).

High loaders on this factor included consumers, workers at public health NGOs, and public health-oriented veterinarians. One beef farm operator was a negative loader on this factor, essentially meaning that they disagree with most aspects of this discourse. One high loading respondent works in the dairy industry. Notably, this person works in the organic dairy industry for a company that makes large-scale purchases of organic milk for dairy products; they also own a small dairy farm.

Factor 3: libertarian pastoral

The final significant factor, F3, libertarian pastoral, can be characterized as holding antibiotic free production, and natural farming methods more generally, in very high regard. It is, however, also skeptical of claims that on-farm antibiotic use produces wider public health harms, and disagrees with most forms of regulation and control of antibiotic use. In short, this discourse views antibiotic free production as good, but not necessarily because of the consequences of AMR, and only if the farmer is not coerced into this in any way.

On balance, this discourse is skeptical that antibiotic use in agriculture is responsible for AMR. It is neutral on the statement that agriculture is "partly responsible" for AMR (statement 7, 0), however, it does not believe that ending the routine use of antibiotics in agriculture is important for preserving the effectiveness of human medicine (statement 12, –2). It also does not think that giving entire herds antibiotics poses a higher risk to public health (statement 11, –4). Similar to factor 1, this discourse believes that withholding antibiotics is bad for animal welfare (statement 2, +2). It also believes that preventative use of antibiotics is a form of responsible use (statement 26, +3).

Despite its views on animal welfare, and its skepticism toward the problem of AMR, this discourse holds antibiotic free operations in high regard. It regards farms that rarely use antibiotics as being good for animal welfare (statement 5, +1). This seems to contradict its agreement

that withholding antibiotics is bad for animal welfare, but this view fits in with the overall idea that antibiotic-free production is a signal that the farm is more "natural" and healthy for the animal. The discourse agrees that free range operations will not need as many antibiotics as conventional operations (statement 20, +1), and, like the other two factors, strongly supports the idea that it is more profitable to prevent sickness through a better environment than using antibiotics (statement 25, +3).

This discourse has a strong tendency to discount the effectiveness of inspections and regulations in preventing AMR. And of the three factors, it has the highest regard for farmer autonomy. It strongly disagrees that government regulations will prevent AMR (statement 16, –3). It also doubts that antibiotic best practices will decrease the risk of AMR (statement 10, 0), and that residue testing will prevent farmers from overusing antibiotics (statement 15, –2). Like the other factors, it agrees that antibiotic use should be done under the oversight of a veterinarian (statement 14, +2).

While there is skepticism about the role of regulations in dealing with AMR, this discourse does not share the skepticism of the broader public seen in the Farmer First (F1) discourse. This discourse does not agree that the public demonizes agriculture (statement 18, –2), nor does it think that agriculture would be harmed if the public made decisions about agricultural practices (statement 19, 0).

This discourse had the most diverse actor types of all three factors. It included three consumers, and the consumers were diverse in terms of education, income and gender. It included the type of consumer that research has shown to be concerned about antibiotics (female, highly educated, high income), but also male, low education, middle-income, and male, some college, middle income consumers. Other high loaders include a veterinarian, a small beef farm owner, and a dairy extension officer (who also has a dairy farm). No one explicitly associated with public health concerns loaded high on this factor.

Hidden agreement, false disagreement: animal welfare and veterinarians

In this section we engage in a deeper analysis of two statements: perspectives on animal welfare (statement 5, an area of sharp disagreement between discourses) and veterinarian involvement in antibiotics (statement 14, an area of consensus). Our analysis of pre- and post-sort interviews shows that high loaders on each of these discourses are likely referring to slightly different things when they register their agreement or disagreement. In doing so we wish to show that the level of disagreement and consensus is not as strong as results might indicate. We argue that these ideas are being interpreted through value-based frames around which agriculture is perceived, and affects how actors are interpreting the statements.

Both the Farmer First (F1) and Libertarian Pastoral (F3) discourses strongly agree that antibiotic use is essential for animal welfare, and that denying antibiotics to animals would be bad for them. Public Health (F2), however, disagrees with this idea. While this might appear to be a point of sharp disagreement, closer analysis of interviews shows that there is little direct disagreement on this point at all. Pre- and post-sort interviews with high loaders on the Public Health (F2) discourse show clear agreement that antibiotics are needed for animal health. Instead, antibiotic use is viewed as a symptom of a wider food system gone awry, a system with animals stocked too closely together, given inappropriate feed, and transported together in ways that facilitate disease. In discussing the "no antibiotics ever" food label, here is how a public health advocate put it:

> "I think when we pay more for no antibiotics ever, it's—we want that money to be going towards better animal management practices. We want reduced stocking density. We want good nutrition. We want better biosecurity measures to prevent disease risk. The risk is that farmers are taking that market signal and they're just converting it into having almost the same system but just taking away that animal health tool of the antibiotics." (Interview 24)

This person expressed a typical concern among public health and animal welfare advocates. They are worried that the label will result in only less antibiotic use among farmers but without more systemic changes to the food system this label could catalyze.

Contrast that statement with the attitudes found among many farmers and veterinarians we interviewed, who saw eliminating antibiotics as borderline cruel. From one high loader on Farmer First (F1):

> "We can't afford to not treat these animals well and this perception of not [using], of limiting the antibiotic use is scary because then you get animals that might not be treated well, they might not get what's needed to cure them and make them healthy and well… but we've had consumers that we've had conversations with, that, you know, well, "you shouldn't use antibiotics". Well, I've got a calf over here with pneumonia, if I just give it antibiotics for three days it'll be fine. If I don't give it antibiotics in five days, it's gonna be dead. What would you prefer me to do, and the suffering that calf will do till it dies, before it dies, yes it will be extreme." (Interview 9)

Here, antibiotic use is a tool through which various ongoing health problems can be solved. The best antibiotic use is that which works to solve the problem.

We suggest that the disagreements on animal welfare found in the Q sort exist because the idea of antibiotic use exists as a flexible concept that can take on multiple meanings for different actors. For the F2, Public Health loaders, antibiotic use is a symptom of a wider food system that is unhealthy. For Farmer First (F1) and Libertarian Pastoral (F3) antibiotics aren't a symptom but a cure, and a necessary part of the everyday process of running a farm.

A similar kind of discursive flexibility can be seen with the broad agreement across discourses concerning the role of veterinarians in responsible antibiotic use. Figure 2 shows a selection of the explicit statements concerning responsible use of antibiotics. Only veterinary supervision garners agreement across all three discourses. Like the disagreement around animal welfare, the consensus around veterinarians is more fragile than it first appears, and for the same reasons. Each actor views the idea of veterinarians differently.

Farmer First (F1) loaders accept veterinarians as an indispensable part of the process. This discourse even ranks veterinarian judgement higher than the autonomy of farmers. While there is surely variety among the kinds of veterinarians and the kinds of veterinarian/client relationships that exist, one consistent theme that emerged from interviews was the relatively close relationships between veterinarians and their clients, especially with relation to antibiotic drug use decisions. Interviews consistently showed that veterinarians were the primary source of information about antibiotics for farmers. One feedlot manager did a good job of summarizing an attitude we saw across a number of interviews with both farmers and veterinarians.

> "I think the vets I worked with had as much respect for me as I did for them. We had a constant conversation, and that's part of it is when the vet knows what you know, then you have a real relationship there… Every vet I've ever worked with has been that way…I can tell ya that I had as much education on the feed lot side of it talkin' to a vet while we're flushin' a cow or pullin' a calf or somethin' like that. I think that the relationship between you and your vet is really important." (Interview 34)

In contrast, F2, Public Health also accepts veterinarians, but sees their role as the bare minimum, and one of a number of additional regulations that should occur. In a post-sort interview, one public health advocate put it like this:

> "… veterinarians don't all make the right decisions, but they're at least trained. I mean, so I think that's where I come from. I don't, actually believe that there, you know, is a solution to the problem without other things happening, but they're better than no decision whatsoever, you know, no expertise whatsoever, except for the producer." (Interview 36)

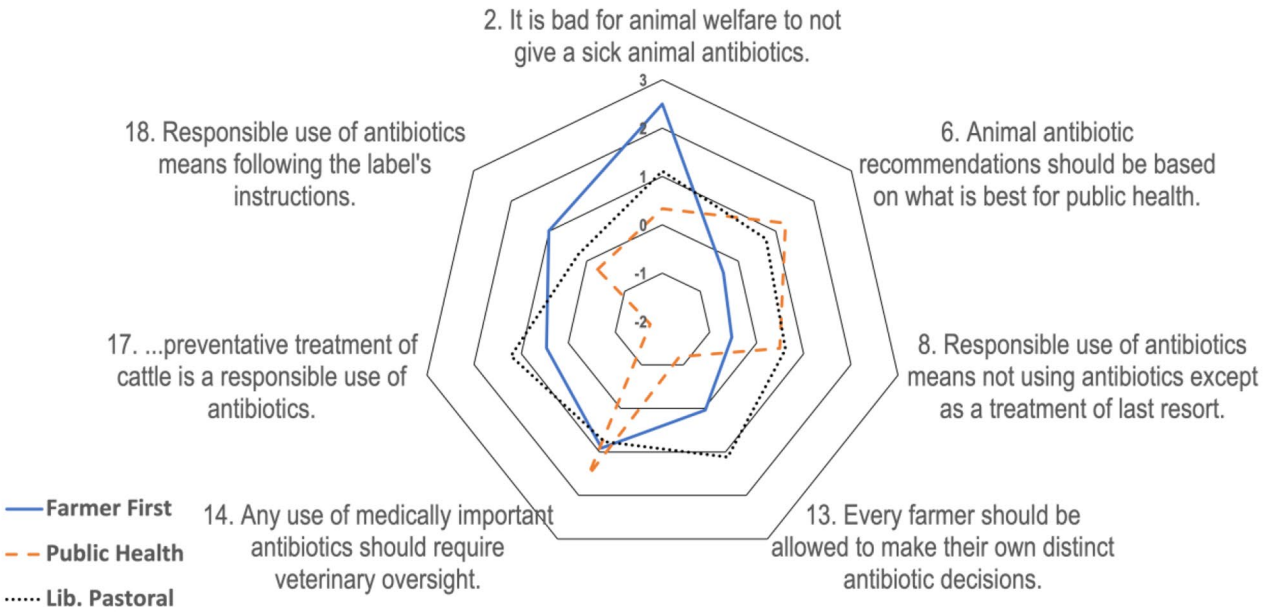

Fig. 2 Comparison of select responsible use statements across three factors. Factor lines are ordered by the Z score for each statement. Statements above a "zero" indicate agreement with the statement, statements below "zero" indicate disagreement. See Table 3 for more specific Z scores. Statements are labeled by their number in Table 3. Statement 17 is a paraphrase, please see Table 3 for full statement

In short, points of agreement and disagreement, while real across discourses, are not as durable as they first appear. Hidden under disagreement around antibiotic and animal welfare is a baseline acknowledgement that antibiotics are sometimes needed. And hidden behind agreement about veterinarians being necessary is disagreement around whether they are sufficient for controlling AMR. For space reasons we have confined our analysis to just two kinds of attitudes on display (animal welfare and veterinarians), but we believe they are sufficient to make our point: different actors understand these statements in slightly different ways, and points of disagreement and concordance are often more complex than they first appear. How and why our research subjects made these particular interpretations is what we will turn to next.

Frames for understanding agriculture

We suggest that the high loaders on each of the three discourses interpret the statements through a broader view of what agriculture is, and should be, in the world, and this frame affects each actors' stance toward the various statements. We suggest that these discourses understand agriculture as falling along two perspectives, each with their own spectrum of views: (1) a realist vs. idealist view of agriculture, and (2) an insular vs. open perspective. For the realist, agricultural decisions constitute a series of immediate problems to be addressed. Questions about the desirability of the larger food system within which such decisions are made rarely enter into this calculation. We do not want to imply that a respondent with this "realist" perspective does not think about, or understand, problems within the wider food system, and the political, cultural, and economic issues that animal rearing is engaged with. Quite the opposite, in interviews many of the high loading respondents in the Farmer First (F1) discourse expounded at length on the many problems, and opportunities, our current food system has. When it comes to questions around responsible antibiotic use, however, such issues typically become bracketed out and antibiotics become understood through the prism of daily practical advantages of antibiotics and the ongoing health needs of animals.

In contrast, the "idealist" views many animal health decisions as symptoms of a farming system gone awry. Rather than bracketing out issues of the political economy of food in thinking about antibiotic decisions, the idealist views them as integral to each other. Many people we interviewed might be idealists concerning agriculture, but also have a full understanding of the practical reasons for antibiotic use. The idealist's view of antibiotics, however, is not grounded in the immediate needs of a farm, but rather, in the wider food system of farmers, regulators, integrators, feedlots, cooperatives, and grocery stores. We do not wish to suggest these are binary perspectives, but should be thought of as a range. Both Public Health (F2) and Libertarian Pastoral (F3) are closer to an idealist perspective of agriculture (though with different kinds of ideals) while Farmer First (F1) is more grounded in a realist perspective.

A second frame for thinking about agriculture is around one's view of the public and its relationship to agriculture. Farmer First (F1) and Libertarian Pastoral (F3) had more insular views of agriculture. They agreed with statements that suggest the public is largely ignorant of agriculture (statements 18 and 19). Libertarian Pastoral (F3) was more extreme in its rejection of the public, disagreeing with any statements that acknowledge the positive role of regulations and inspections. Farmer First (F1) has a more moderate view that tended to give positive assessments of regulations. We believe the more tempered view of the Farmer First (F1) discourse, which was comprised entirely of those close to the farming industry, comes from its realist stance. It was a common view for farmers we interviewed to recognize that understanding consumer sentiment, and adapting to various government regulations, was critically important for their farm. Indeed, in our interviews with farmers, this kind of "forced engagement" with the consuming public is a source of a great deal of fear, anxiety, and even anger. Public ignorance of agriculture was a continual theme that came up in our interviews with farmers. Here is how one high loading respondent put it.

> "Dairy farms don't even trust to talk to the public anymore. I'm surprised anyone is talking to you (referring to the interviewer)…because you feel like the public is an enemy sometimes. So you can't. And over the phone they can't trust that you're not looking for an animal rights angle to go after them." (Interview 5)

As this quote suggests, among farmers there is a strong fear of more radical publics, usually coded as animal rights activists, who are working full-time to demonize agriculture.

At the opposite end is a perspective that views the wider public's concerns as a priority for agricultural practices. This is strongly reflected in the F2, Public Health discourse, which prioritizes public engagement above all else. This discourse disagreed with statements 18 (–3) and 19 (–1), which characterized the public as being actively harmful for agriculture and strongly agreed with statement 12, which stated that preserving public health effectiveness is linked to changing agricultural antibiotic practices. As one high-loading Public Health (F2) consumer put it, most people recognize that technology adoption in agriculture can be a good thing.

"I guess it depends on the type of technology. Right? So, if you can, if you can embrace technology, that helps make things like cleaner and more efficient then that's a good thing and I think a lot of people would like that…if you're doing something more efficient kind of like, how, now we're saving energy by capturing methane gases from these cows, I can see a lot of people really liking that." (Interview 35)

Discussion and conclusion

The results from the Q sort show some clear cleavages, but also points of overlap, across different types of actors. The F1, Farmer First views agriculture as it is practiced. It is accepting of antibiotic use and tends to minimize the broader risk of AMR. This discourse contains no consumers or public health advocates, only those closely involved with farming (farmers, veterinarians, and extension agents). This finding parallels Lehrer and Sneegas' (2018) study on pesticide risk, where they found that those most accepting of risk tended to be industry insiders (see also Schall et al. 2018). Here a similar dynamic is at play, where the risk of AMR coming from the farm is minimized within a discourse that is comprised entirely of those close to farming practices. Similarly, the Public Health (F2) discourse is composed of many people with close contact to issues of AMR, public health and consumer advocates, and they tended to agree with the heightened risk of antibiotic use. The clear differences between these two discourses lend some support to the argument that discourses around environmental issues can be attributed to a person's structural position—whether it is farmer, veterinarian, or consumer (Hajer 1995; Robbins 2006; Brannstrom 2011). In this case of Farmer First (F1) and Public Health (F2), we can see a clear divide between farmers on one side, and consumers and public health advocates on the other.

The third discourse, Libertarian Pastoral (F3), however, is more idiosyncratic, and has a diversity of respondents. This suggests some limits to the thesis that discursive agreement is shaped by one's social position. It is the only discourse that includes both consumers and farm-adjacent actors (farmers, extension agents, veterinarians), though no public health orientated people loaded high on this discourse. It is a pro-farmer discourse in many ways, and tends to minimize the risk of antibiotic use. However, it also elevates the value of "naturalness", and in this way it has parallels with Public Health (F2). Antibiotics are a symptom of a farm that are less natural, even if the discourse is not specifically concerned about antibiotics.

A close reading of the different factors, along with an analysis of interviews suggests that, in many cases, points of agreement and disagreement are based on variable interpretations of the statements and terms within the Q-sort itself. Our analysis of how various high loaders think about antibiotics and animal welfare, along with the status of veterinarians suggests that this is the case. In short, the discursive flexibility around the concepts of animal welfare and veterinarians seen across actors suggest some forms of agreement and disagreement that are not as strong as they first appear.

Research from discourse studies and science and technology studies can help us understand these varied interpretations. Discourse scholars have developed the concept of "strategic ambiguity" to show how concepts such as "sustainability" or "responsibility" might be deployed and used in slightly different ways across diverse groups in ways that enhance cooperation (Leitch and Davenport 2007; Scandelius and Cohen 2016). Social studies of science scholars have made similar points around ambiguity and cooperation across different social actors by working through the metaphor of the boundary. Star and Greisemer's (1989) well-known concept of boundary objects describes ideas and objects such as maps and classification schemes that are flexible enough for them to be meaningful and useful across diverse social groups, but still able retain a core meaning across these same groups. Boundary objects help facilitate the translation of meaning across distinct social domains, allowing for forms of cooperation and communication that might not otherwise exist. Shackley and Wynne (1996) have extended this idea to introduce the concept of boundary ordering devices, which are a suite of tactics that scientists use to translate their work for policy makers in ways that minimize uncertainty so as to maintain their authority to policy audiences, but do so in a way that does not undermine the legitimacy of their scientific work to other scientists. A number of scholars have investigated how these devices and tactics are deployed in various agricultural contexts by "boundary organizations" (Cash 2001; Goldberger 2008; Klerkx et al. 2012). Within each of these cases there are modalities of flexible interpretation that help enable forms of translation that allow agricultural projects to be understood and engaged with by actors across many different social worlds.

While most of this scholarship explores how conceptual ambiguity opens the door for cooperation across social groups, the results here show how this process can cut both ways. There does appear to be agreement around the role of veterinarians across all three discourses, even if all three factors likely view the role of veterinarians slightly differently. But conceptual ambiguity can work the other way as the disagreement around animal welfare shows us. There is likely a baseline, shared understanding that antibiotics are

needed for animal welfare, but one group sees their use as a symptom of much larger problems while others view their use as indispensable. To date, writings on boundary objects, boundary ordering devices, or strategic ambiguity tend to focus on how the flexibility of these concepts, objects, and practices allow for cooperation. This study shows how it can also produce forms of ambiguous disagreement. In this case, the shifting meanings of animal welfare can be thought of as a sign of more fundamental frameworks for viewing agriculture, frameworks that are not necessarily compatible.

The trust given to veterinarians across all three discourses parallels Fortané's (2019) finding among veterinarians in France, who have been able to position themselves as key intermediaries between farmers and the public. The importance of animal welfare in the Farmer First (F1) and Libertarian Pastoral (F3) discourses, and the high loading farmers in both of these discourses parallels findings by Innes et al. (2021), who found similar attitudes among farmers and veterinarians respectively.

The novelty of this study is it allows a direct comparison of perspectives across a more diverse group of interested actors. Doing so, we can see that the differences across these discourses currently mirror the main forms of antibiotic governance in the United States today. Our results show a consensus about veterinarians, and indeed veterinarians are the lynchpin of the one federal policy meant to curb agricultural antibiotic use (the Veterinary Feed Directive). Our results suggest, however, that this agreement among diverse actors around veterinarians might be more broad than deep. What might be one actor's maximum tolerance of government intervention is another actor's starting point for further regulation.

In this study we asked how might differently situated people think about how to address a complex environmental and agricultural problem. We wished to understand if there are differences in perspectives based on one's social position, and where there might be points of agreement and dissensus across diverse groups. Q methodology was used to help highlight diverse actor perspectives around issues of responsibility in agricultural antibiotic use: whether agriculture is responsible for AMR and what responsible agricultural antibiotic use should look like. We found a complex picture, with one discourse comprised of a diverse group of people including farmers, consumers, and veterinarians (Libertarian Pastoral, F3). Other discourses represented a clear cleavage between farmers and non-farming publics (Farmer First, F1 and Public Health, F2). A close examination of statements around which there is both agreement (veterinarians) and disagreement (animal welfare) shows that caution must be taken when understanding individual interpretation of statements. Nevertheless, a critical reading of these statements and the discourses presented as a whole, along with our interview analysis, show clear differences in how agriculture is thought about and its role in responsible antibiotic use. A practical-minded, insular farm focused view has clear salience with farmers, but little attraction to non-farming publics while an idealistic, public facing perspective attracted little support from farm-adjacent actors. The discourse with the most diverse support (Libertarian Pastoral, F3) is one that was both idealistic, but also insular. While antimicrobial resistance may be a public problem, not everyone views agricultural practices as a matter of public concern.

Acknowledgements The authors would like to thank all interview subjects and Q sort participants for their time. The authors received funds from United States Department of Agriculture, National Institute for Food and Agriculture grant #2018-68003-27467. The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

IRB Statement The research described in this manuscript was conducted with the approval of University of Maryland Baltimore County's Institutional Review Board, Protocol # 197, project Y18DL10104.

References

Abdelfattah, E. M., P. S. Ekong, E. Okello, D. R. Williams, B. M. Karle, T. W. Lehenbauer, and S. S. Aly. 2022. Factors Associated with Antimicrobial Stewardship Practices on California Dairies: one year Post Senate Bill. *Antibiotics* 27 (11): 165. https://doi.org/10.3390/antibiotics11020165.

Barrett, J. R., G. K. Innes, K. A. Johnson, G. Lhermie, R. Ivanek, A. Greiner, Safi, and D. Lansing. 2021. Consumer perceptions of antimicrobial use in animal husbandry: a scoping review. *PLOS ONE* 16 (12): e0261010. https://doi.org/10.1371/journal.pone.0261010.

Brannstrom, C. 2011. A Q-Method analysis of Environmental Governance Discourses in Brazil's northeastern soy Frontier. *The Professional Geographer* 63 (4): 531–549. https://doi.org/10.1080/00330124.2011.585081.

Brunori, G., D. Maye, F. Galli, and D. Barling. 2019. Symposium introduction—ethics and sustainable agri-food governance: appraisal and new directions. *Agriculture and Human Values* 36(2): 257–261. https://doi.org/10.1007/s10460-019-09929-y.

Cameron, A., and T. A. McAllister. 2016. Antimicrobial usage and resistance in beef production. *Journal of Animal Science and Biotechnology* 7: 68. https://doi.org/10.1186/s40104-016-0127-3.

Cash, D. W. 2001. "In order to aid in diffusing useful and practical Information": Agricultural Extension and Boundary Organizations. *Science Technology & Human Values* 26 (4): 431–453. https://doi.org/10.1177/016224390102600403.

Casseri, E., E. Bulut, S. L. Soto, M. Wemette, A. Stout, A. Greiner Safi, R. Lynch, P. Moroni, and R. Ivanek. 2022. Understanding Antibiotic Resistance as a perceived threat towards dairy cattle through beliefs and Practices: a Survey-Based study of dairy farmers. *Antibiotics* 11: 997. https://doi.org/10.3390/antibiotics11080997.

Center for Veterinary Medicine. 2019. CVM GFI #213 New Animal Drugs and New Animal Drug Combination Products Administered in or on Medicated Feed or Drinking Water of Food-Producing Animals: Recommendations for Drug Sponsors for Voluntarily Aligning Product Use Conditions with GFI #209. *U.S. Food and Drug Administration*. FDA.gov. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/cvm-gfi-213-new-animal-drugs-and-new-animal-drug-combination-products-administered-or-medicated-feed Accessed: April 16, 2022.

Charmaz, K. 2006. *Constructing grounded theory: a practical guide through qualitative analysis*. Sage.

FARAD, Food Animal Residue Avoidance Databank. 2022. ELDU and Time, Withdrawal. http://www.farad.org/eldu-and-withdrawal-time.html. Accessed July 27, 2002.

Fortané, N. 2019. Veterinarian 'responsibility': conflicts of definition and appropriation surrounding the public problem of antimicrobial resistance in France. *Palgrave Communications* 5 (1): 1–12.

Goldberger, J. R. 2008. Non-governmental organizations, strategic bridge building, and the "scientization" of organic agriculture in Kenya. *Agriculture and Human Values* 25 (2): 271–289. https://doi.org/10.1007/s10460-007-9098-5.

Hajer, M. A. 1995. *The politics of environmental discourse: ecological modernization and the policy process*. New York: Clarendon Press.

Helliwell, R., C. Morris, and S. Raman. 2020. Antibiotic stewardship and its implications for agricultural animal-human relationships: insights from an intensive dairy farm in England. *Journal of Rural Studies* 78: 447–456.

Hoelzer, K., N. Wong, J. Thomas, K. Talkington, E. Jungman, and A. Coukell. 2017. Antimicrobial drug use in food-producing animals and associated human health risks: what, and how strong, is the evidence? *BMC Veterinary Research* 13 (1): 211. https://doi.org/10.1186/s12917-017-1131-3.

Innes, G. K., A. Markos, K. R. Dalton, C. A. Gould, K. E. Nachman, J. Fanzo, A. Barnhill, S. Frattaroli, and M. F. Davis. 2021. How animal agriculture stakeholders define, perceive, and are impacted by antimicrobial resistance: challenging the Wellcome Trust's Reframing Resistance principles. *Agriculture and Human Values* 38 (4): 893–909. https://doi.org/10.1007/s10460-021-10197-y.

Keep Antibiotics Working. 2022. *Keep Antibiotics Working*https://www.keepantibioticsworking.org. Accessed August 6, 2022.

Klerkx, L., S.v. Bommel, B. Bos, H. Holster, J. V. Zwartkruis, and N. Aarts. 2012. Design process outputs as boundary objects in agricultural innovation projects: functions and limitations. *Agricultural Systems* 113: 39–49. https://doi.org/10.1016/j.agsy.2012.07.006.

Landers, T. F., B. Cohen, T. E. Wittum, and E. L. Larson. 2012. A review of antibiotic use in Food Animals: Perspective, Policy, and potential. *Public Health Reports* 127 (1): 4–22.

Lansing, D. M., K. Grove, and J. L. Rice. 2015. The neutral state: a genealogy of ecosystem service payments in Costa Rica. *Conservation and Society* 13 (2): 200–211. https://www.jstor.org/stable/26393198.

Lehrer, N., and G. Sneegas. 2018. Beyond polarization: using Q methodology to explore stakeholders' views on pesticide use, and related risks for agricultural workers, in Washington State's tree fruit industry. *Agriculture and Human Values* 35 (1): 131–147. https://doi.org/10.1007/s10460-017-9810-z.

Leitch, S., and S. Davenport. 2007. Strategic ambiguity as a discourse practice: the role of keywords in the discourse on 'sustainable' biotechnology. *Discourse Studies* 9 (1): 43–61. https://doi.org/10.1177/1461445607072106.

Lhermie, G., P. Sauvage, L. W. Tauer, L. V. Chiu, K. Kanyiamattam, A. Ferchiou, D. Raboisson, H. M. Scott, and D. R. Smith, and Y. T.Grohn. 2020. Economic effects of policy options restricting antimicrobial use for high risk cattle placed in U.S. feedlots. *Plos One* 15 (9): 1–19. https://doi.org/10.1371/journal.pone.0239135.

McGregor, A., L. Rickards, D. Houston, M. K. Goodman, and M. Bojovic. 2021. The biopolitics of cattle methane emissions reduction: governing life in a time of Climate Change. *Antipode* 53 (4): 1161–1185. https://doi.org/10.1111/anti.12714.

Okello, E., D. R. Williams, W. R. El Ashmawy, J. Adams, R. V. Pereira, T. W. Lehenbauer, and S. S. Aly. 2021. Survey on Antimicrobial Drug Use Practices in California Preweaned dairy calves. Frontiers in Veterinary Science 8.

Oliver, S. P., S. E. Murinda, and B. M. Jayarao. 2011. Impact of antibiotic use in adult dairy cows on antimicrobial resistance of veterinary and human pathogens: a comprehensive review. *Foodborne Pathogens and Disease* 8: 337–355. https://doi.org/10.1089/fpd.2010.0730.

Padda, H., M. Wemette, A. Greiner Safi, W. Beauvais, M. A. Shapiro, P. Moroni, and R. Ivanek. 2021. New York State dairy veterinarians' perceptions of antibiotic use and resistance: a qualitative interview study. *Preventive Veterinary Medicine* 194: 105428. https://doi.org/10.1016/j.prevetmed.2021.105428.

Poultry, Health Today. 2018. Rennier: NAE programs represented 40% of US broiler feeds in 2017. April 30, 2018. Available at: https://poultryhealthtoday.com/rennier-nae-programs-represented-40-of-us-broiler-feeds-in-2017/. Accessed April 2, 2019.

Renkenberger, J., H. Montas, P. T. Leisnham, V. Chanse, A. Shirmohammadi, A. Sadeghi, K. Brubaker, A. Rockler, T. Hutson, and D. Lansing. 2016. Climate change impact on critical source area identification in a Maryland watershed. *Transactions of the ASABE* 59 (6): 1803–1819. https://doi.org/10.13031/trans.59.11677.

Robbins, P. 2006. The politics of barstool biology: environmental knowledge and power in greater Northern Yellowstone. *Geoforum* 37 (2): 185–199.

Sarewitz, D. 2004. How science makes environmental controversies worse. *Environmental Science & Policy* 7 (5): 385–403. https://doi.org/10.1016/j.envsci.2004.06.001.

Sawant, A. A., L. M. Sordillo, and B. M. Jayarao. 2005. A survey on antibiotic usage in dairy herds in Pennsylvania. *Journal of Dairy Science* 88: 2991–2999. https://doi.org/10.3168/jds.S0022-0302(05)72979-9.

Scandelius, C., and G. Cohen. 2016. Achieving collaboration with diverse stakeholders—the role of strategic ambiguity in CSR communication. *Journal of Business Research* 69 (9): 3487–3499. https://doi.org/10.1016/j.jbusres.2016.01.037.

Schall, D., D. Lansing, P. Leisnham, A. Shirmohammadi, H. Montas, and T. Hutson. 2018. Understanding stakeholder perspectives on agricultural best management practices and environmental change in the Chesapeake Bay: a Q methodology study. *Journal of Rural Studies* 60: 21–31. https://doi.org/10.1016/j.jrurstud.2018.03.003.

Shackley, S., and B. Wynne. 1996. Representing uncertainty in Global Climate Change Science and Policy: Boundary-Ordering Devices and Authority. *Science Technology & Human Values* 21 (3): 275–302. https://doi.org/10.1177/016224399602100302.

Singer, R. S., L. J. Porter, D. U. Thomson, M. Gage, A. Beaudoin, and J. K. Wishnie. 2019. Raising animals without antibiotics: U.S. producer and veterinarian experiences and opinions. *Frontiers in Veterinary Science* 6: 452. https://doi.org/10.3389/fvets.2019.00452.

Star, S. L., and J. R. Griesemer. 1989. Institutional Ecology, `Translations' and Boundary Objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science* 19 (3): 387–420. https://doi.org/10.1177/030631289019003001.

Tourangeau, W. 2017. GMO doublespeak: An analysis of power and discourse in Canadian debates over agricultural biotechnology. *Canadian Food Studies / La Revue canadienne des études sur l'alimentation* 4(1): 108–138. https://doi.org/10.15353/cfs-rcea.v4i1.208.

U.S Food and Drug Administration. 2021. *2020 Summary Report on Antimicrobials Sold or Distributed for Use in Food-Producing Animals*. 49p. Available at: https://www.fda.gov/media/154820/download. Accessed: July 14, 2022.

Veterinary Feed Directive. 2015. *Federal Register*. June 3. FederalRegister.gov. https://www.federalregister.gov/documents/2015/06/03/2015-13393/veterinary-feed-directive. Accessed Jan. 5, 2023.

Wallinga, D. 2020. *Better Burgers: Why It's High Time the U.S. Beef Industry Kicked Its Antibiotics Habit*. NRDC. Available at: https://www.nrdc.org/resources/better-burgers-why-its-high-time-us-beef-industry-kicked-its-antibiotics-habit. Accessed: 7 August 2022.

Wallinga, D., L. A. M. Smit, M. F. Davis, J. A. Casey, and K. E. Nachman. 2022. A review of the effectiveness of current US policies on Antimicrobial Use in Meat and Poultry Production. *Current Environmental Health Reports* 9: 339–354. https://doi.org/10.1007/s40572-022-00351-x.

Watts, S., and P. Stenner. 2012. *Doing q methodological research*. London: Sage.

Wells, S. J., S. L. Ott, and A. Hillberg Seitzinger. 1998. Key Health issues for dairy Cattle—New and Old. *Journal of Dairy Science* 81: 3029–3035. https://doi.org/10.3168/jds.S0022-0302(98)75867-9.

Wemette, M., A. Greiner Safi, W. Beauvais, K. Ceres, M. Shapiro, P. Moroni, F. L. Welcome, and R. Ivanek. 2020. New York State dairy farmers' perceptions of antibiotic use and resistance: a qualitative interview study. *PLOS ONE* 15 (5): e0232937. https://doi.org/10.1371/journal.pone.0232937.

David Lansing is an associate professor in the Geography and Environmental Systems Department at the University of Maryland Baltimore County. He holds a PhD in Geography from Ohio State University. His research interests are on the impact of technology and state policy on agrarian change.

Jaime Barrett is a PhD candidate in the same department. She holds a Master's degree in Geography from the University of Delaware. She is interested in the politics of farm health management. She is currently conducting dissertation research on mastitis treatment and prevention in the dairy industry.