Systematic review and social research to further understanding of current practice in the context of using antimicrobials in livestock farming and to inform appropriate interventions to reduce antimicrobial resistance within the livestock sector

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EXECUTIVE SUMMARY

OBJECTIVES

The purpose of this research, funded by Defra and undertaken by a research team from the universities of Exeter (social science) and Bristol (veterinary science) between January and March 2015, is:

1. to provide evidence-based analysis of how and why AMs are prescribed and used in contemporary livestock systems,
2. to explore the extent to which farmers, veterinarians and key actors are aware of the issue of AMR
3. to identify how awareness becomes embedded in and through social positions and social practice,
4. to inform future AM interventions in the livestock sector.

The research eschews traditional individualist attitude and behavior studies to investigate current AM uses in livestock through an approach grounded in social practice theory. As a starting premise, the study assumes that it is vital to understand the context of AM use, including the drivers and relationships within the industry, before further action can be countenanced. The study focuses upon the interfaces between farming, food production, veterinary and advisory practices as a basis for understanding how changes to these practices might be achieved.

METHODOLOGY

The research has been conducted using a combination of three different yet inter-linked methodological approaches.

1. A Rapid Evidence Assessment (REA) was undertaken, drawing upon an initial database search of over 4500 published and unpublished works from the UK, from other EU states and from the US, and narrowed down to 31 papers from which a detailed comparative assessment was generated. This also served to contextualize the subsequent empirical research.

2. A Q-sort and analysis was developed as a means to interrogate view points and value positions with respect to AM use and related issues (such as animal welfare, public health and governance).

3. Qualitative, semi-structured interviews with selected farmers, veterinarians and key actors across the three livestock sectors (poultry, pig and dairy) were undertaken. For each of the three sectors, five farmers (at least one of which in each sector was organic) and three vets were interviewed (on-farm or in-practice). Additionally, interviews were held with a number of key actors from the professional bodies, the food sector and assurance/certification bodies. In total, 32 individual interviews were undertaken. The transcribed
interviews were subsequently analysed for common and contradictory themes, for specific examples of practice, for relevant statements that would support identified common positions and for an understanding of the range of practices within which the use and prescription of AMs constituted a regular (or irregular) component.

The results of the REA, Q-sort and qualitative research are drawn together in a series of key concluding points from the analysis which are then used to draw up a series of specific policy-informing messages.

RESULTS

Four main categories of comparative evidence emerge from the REA: on the volumes/dosage and application of AMs in farming systems; on veterinary prescription practice in different countries, on farmer attitudes towards AM use and on questions of data and recording of AM use.

In sum, existing research suggests:

- There is prevalent use of AMs in different livestock systems and these are regarded as a critical component of contemporary livestock production.
- There are significant differences in AM use across different countries and different systems.
- There is relatively little work on the scope for reduced or more appropriate use of AMs within current systems.
- There are differing levels of farmer and veterinary awareness of the issue of AMR in both human and animal medicine.
- Finally, there is relative paucity of genuine social science research on and analysis of the use of AMs in livestock farming, with a particular lack of work that takes social and industrially embedded practices seriously.

The Q-sort exercise suggested that there were both significant shared values as well as differences across the livestock sectors and across personnel and professions. Shared positions included a relative disdain for the risks posed by farming to AMR in the wider environment and a tendency to underplay the importance of the livestock sector’s contribution to AMR as a human health issue. The Q analysis revealed three broad positions that veterinarians and farmers tended to take:

1. The *Modern Business* approach - antibiotics are already being phased out through modern farming methods which prioritise hygiene, health planning and herd management. AM use is already appropriate and under control. Any further changes may be unnecessary or at best incremental.

2. The *Interventionist* - changes in AM use can be brought about through better farmer education and a veterinary-led understanding of the issue. This position is most amenable to making changes in AM use in livestock.
3. The Autonomist - there is a fear that over-zealous regulation or outside influence will lead to inappropriate restrictions and further erode the viability of farming.

The Q analysis therefore suggests there are areas within the livestock sector that are more amenable to change than others, with some degree of blasé attitude as well as a general resistance to outside regulation. This might suggest that the best hope for developing better and more appropriate use would be to work with farmers and vets rather than regulate in a top-down fashion.

The qualitative research, by focusing on key actors and allowing them to drive the discussion, enabled deeper insight into these positions. The analysis of the farmer, veterinarian and key actor interviews is presented under three key headline themes: awareness, practice and responsibility.

**Awareness.** The participant veterinarians and farmers were certainly aware of the broad issue of AMR in human medicine and recognized the need to act responsibly in the use and prescription of AMs in livestock farming. However, the perceived lack of robust data linking livestock use to human pathogen resistance coupled with a seeming reluctance to recognize resistance as such amongst farm animals as a growing concern suggests a potential barrier to more integrated human health/animal health approaches.

While awareness seemed to be high, and was linked to various sources (veterinary information, assurance schemes, etc.), it is simplistic to assume that this awareness inevitably leads to behavior change. The amount of change is often constrained by infrastructure, economies and so on, but it is also framed, or made sense of, within existing practices and norms. In other words, the message doesn't simply pass from a to b, but rather its meaning and implication change as the message is translated into practice.

**Practice.** The research identifies three overlapping forms of farming practice with respect to the ways in which farmer/veterinarian awareness of the issues surrounding AM use becomes embedded into livestock farming: i. changing AM practice (where change is understood less in terms of reduction in use but more as a need for different and more strategic ways of using AMs) ii. legitimating AM practice (where current use practices are regarded as appropriate and legitimate for reasons of productivity and animal health and welfare) and iii. risk managing practice (where a variety of on-farm health and hygiene practices are adopted to reduce the need for AMs).

**Responsibility.** Responsibility doesn’t fall squarely on the shoulders of one actor or sector component. In terms of current practice and AM use, the relationship between veterinarians and farmers is key. Trust between veterinarians and farmers is critical particularly when repeat prescriptions are used or when individual farmers will administer AMs from their on-farm reserves. Responsibility for AM use is thereby shared. However, amongst veterinarians, there is a sense of concern that
information and data on the actual application and use of medicines by farmers is often largely absent. In this sense the relationship between prescription and use needs to be more transparent.

In terms of changing AM use, veterinarians within individual practices and as part of larger corporate food/processing groups are critical actors in the promotion of ‘responsible’ use through prescription practice and advice. Retailers, sector organisations, assurance schemes and certification bodies play an important role in pushing specific actions through independent market-led regulatory means and through the role of assurance scheme assessors and advisors. These actors are arguably most effective when they work with veterinary practices and combine both enforcement and educative actions with respect to farm practices.

The distributed or shared nature of responsibility for the use of AMs offers possibilities for sector-wide initiatives. Given the findings of this report, however, it will always be important to understand both the potential and possible limitations of client style relations in affecting genuine change. This is not to suggest complicity or untoward behaviours, but rather that established norms and practices can be difficult to break.

**Concluding Points and Implications for Policy**

There are many reasons why animals and herds are given AMs on farms: to reduce suffering, to maintain productivity, to avoid the necessity (and costs) of culling and disposal, to reduce mortality rates, to insure against future health issues, and because it is sometimes more straightforward to medicate an entire herd/flock/group than identify and separate specific individual animals. Addressing each of these requires a range of arguments and approaches that go beyond the simple call for ‘reduction’. While AMs are seen as a necessary tool in maintaining the health and welfare of farm animals, for farmers and veterinarians alike, the key issue is the inappropriate use of AMs. This translates into five principal areas of concern:

- prophylactic and metaphylactic use that may not be wholly necessary for the health and welfare of the individual animals
- inappropriate use of AMs to treat animal health issues that are not caused by sensitive microorganisms
- unnecessary use of later generation AMs that are also used in human medicine when other older ones would be as effective
- over-dependence on medicalization as a replacement for improved farm environment and livestock health management, and
- incorrect dosage and application on-farm
Targeting these areas of concern is a priority, though we would highlight the following lessons that are drawn from this research:

1. Achieving change in the livestock sector requires more than awareness of the issues

Participants in this research were both aware of the AMR issue, as well as its likely importance for livestock farming and were largely cognizant of the fact that change to AM use was likely. The question of how much change, and how this would be implemented (from within the sector, or installed from outside) were however key areas of uncertainty and possible tension. “Appropriate use” and other terms, designed to abrogate the use of blanket reduction, tended to calm fears of escalating costs in terms of production or animal welfare. However, defining terms is not simple, and there is no single ‘one-size-fits-all’ understanding of ‘sensible’ and ‘appropriate’.

A key issue here may be to firm up a distinction between AM use for treatment and for productivity. Currently there are grey areas between prophylactic, metaphylactic and treatment uses, and there may be a need within some sectors to expressly target the use of blanket herd/flock level treatments that are implemented without clearly defined clinical need.

2. Changes can be both facilitated and to some extent constrained by existing social and practical relationships

Farmer-vet and industry-wide relations are key to the shared responsibility for AM use. Attempts at significant change in use will need to work with these relationships and must aim to build and/or maintain trust. However, the customer-client relation may well generate a short-term, problem-fixing and business-as-usual approach to the issue. It may therefore be useful to develop alternative fora for farming and veterinary professions to explore possibilities for change outside the day-to-day practice of farming. Enhanced farmer and veterinary training needs to be encouraged. Likewise, adjustments to the client relationship through benchmarking exercises and incentive schemes for medicine conservation may help to focus efforts. Furthermore, joined up thinking across the food chain may help to reduce prophylactic use or unnecessary treatment at what are currently key pinch points in the system.

3. Governance of AMs will require a mixture of regulation and responsibilisation of the industry

Retailers, food companies and assurance schemes are taking a greater role in promoting certain actions and practices to achieve more sensible and appropriate use of AMs. These can achieve wide-scale and effective changes to practice ‘over-night’. However, it is clear that achieving sustainable change that avoids the unintended consequences in terms of reduced animal welfare, increased mortality and even a shift in medicine use patterns, will require
greater buy-in from farmers and veterinarians in order that such schemes do not become mere tick-box assurance style exercises.

4. The need for sector specific knowledge and data

In order to improve understanding and inform subsequent action, detailed social science research is clearly needed on the processes of diagnosis, prescription, AM use, the application of treatments besides AMs and the processes of data generation. This would help to identify sub-optimal use, identify high users and food chain pinch points, and so inform future interventions.

While there is a growing amount of data on the prescription and supply of AMs in livestock farming, there is a general paucity of data on on-farm application and use of AMs. More formalised methods and tools for recording on-farm medicine use such as paper spreadsheets and computerized entry, as required by some assurance schemes, may be of little practical use to farmers in the health management of their animals/birds or to veterinarians in providing an accurate picture of how prescribed medicines are actually used. While they serve the function of demonstrating ‘conformity’ to prescribed rules under legislation or assurance certification, even then, many of these methods are of little value as a genuine indication of use. Better on-farm recording systems of medicine use are required. Moreover, any improvement in data capture should ensure that important trust relationships are not severed and that all parties understand the utility of more informed practices.

Finally, we note that the role of AM medication surely should be to reduce the suffering of individual animals and restore health and welfare. Although the UK, along with other EU countries, has banned the use of AMs as growth promoters, the rationale of using medicines as a mechanism for maintaining high levels of productivity remains prevalent in contemporary farming systems. Addressing this productivity-based incentive is a key area for future cross-disciplinary work.
1. Project Context

Antimicrobials (AMs) have become a critical component of modern intensive livestock systems. It has been estimated that globally around 70% of antibiotic use is in agriculture. In the UK, around 30% of antibiotics are believed to be used in veterinary medicine, 87% of which are used in the livestock sector. It is often asserted that a number of production systems would not be able to maintain current production levels without use of AMs to combat and prevent animal disease and maintain herd and flock health. However, recent years have seen increasing concern amongst policy-makers, legislators, food companies, veterinarians, farmers and producers, scientists and consumers that current use of AMs for the treatment and prevention of animal disease is contributing to growing resistance amongst certain bacteria (for example *Salmonella, Campylobacter, Staphylococcus* and *Escherichia coli*; EFSA, 2013). Concern also exists that the production and transfer of AM resistant (AMR) genes to the environment will result in far-reaching implications for the treatment of both human and animal disease as well as public trust and confidence in modern husbandry and food sources.

The upshot of this is that there have been growing calls for a reduction in the use of AMs in agriculture. The UK’s 5 Year Strategy (DoH/Defra, 2013) explicitly calls for improvements in veterinary disease prevention and prescribing practice, better farm management and animal welfare improvement to reduce disease occurrence (and thus the need for AM treatments), a raising of general awareness of the issue, the development of new active molecules and the establishment of responsive governance strategies and mechanisms amongst food chain actors.

Significantly, the issue of AMR in livestock has not emerged as the result of a breakdown of mechanisms or failures of procedures and controls. Indeed, the development and use of AMs in maintaining human as well as animal health has been heralded as one of the great triumphs of modern beneficial pharmacological interventionism. Yet today, the issue of AMR - particularly within livestock farming - is arguably all the more insidious and far-reaching in its implications for these very reasons. This is an issue of definition, practice and governance, knowledge and information flow, responsibility, behavior and action throughout the food chain, from the sites, bodies, ecologies, practices and infrastructures of farm animal health and welfare through the actions of government, regulators, food companies and retailers to consumer choice, preference and awareness.

Government deregulation in sectors of health and welfare policy coincides with the growth in assurance and certification schemes. These are increasingly required as a pre-requisite for market access and, as such, have been a major feature of the shifting governance landscape of UK farm animal welfare. Market-led mechanisms, whether responding to consumer concerns through ‘corporate social responsibility’ actions or to strategic product segmentation strategies on the part of retailers and

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food supply sector actors, have become increasingly employed to regulate food supply chains and the processes and quality controls that operate within them. The potential leverage that such schemes and business relations can offer in terms of ‘governing’ AM use within livestock systems is, as yet, relatively unexplored.

These issues raise a range of questions: How can AM use on farms be made more responsible and, where appropriate, reduced? What levels of prescription and use might be considered appropriate and sustainable? How might such levels be defined, and by whom? What supplementary practices should be encouraged to reduce the need for AMs on farms, and how might these be identified and achieved? What measures and practices might be required to reduce the risk and flow of AM-rich effluent or waste within the farm (and wider) environment?

While there is an increasing amount of quantitative research and official data on the sale, prescription and application of AMs in farming\(^2\), as well as an ever-expanding number of regulatory initiatives taken by retailers, certification and assurance bodies and others to restrict the use of certain AMs, there remains little qualitative information and understanding of how and why AMs are used and prescribed within the wider context of veterinary and farming practice.

The aims and objectives of the research reported here have thus been defined by Defra in the following way:

- To inform further intervention-based research to reduce the use of AMs\(^3\) within the livestock sector
- To inform where and what forms of interventions are likely to be necessary (and effective) if there is a need to encourage more responsible use of antibiotics
- To generate situated accounts of how and why AMRs are used in a variety of livestock contexts
- To scope the extent to which key actors can envision significant change in the future
- To use these accounts to identify key social positions on the use of and reduction in the use of AMs in livestock

\(^2\) Though, there are also concerns about the accuracy of these data as being truly indicative of antibiotic consumption (VMD, 2014).

\(^3\) Defined here as antibiotics and antivirals but not anthelmintics
2. **Approach**

The research reported here has intentionally sought to explicitly move away from traditional individualist attitude and behavior studies to investigate how current AM uses in livestock are generated, reproduced and sustained within existing farming, veterinarian and advisory practices as a basis for understanding how changes to these practices might be addressed. Following earlier research and commentary (Escobar and Buller, 2014; ESRC, 2014; Hinchliffe et al., 2013), this research has drawn specifically upon a range of social science conceptual and investigative approaches and methodologies (including science and technology studies, veterinary sociology, social practice theory, neoliberal governance studies, human/animal studies, biopolitics and Q methodology) as well as being strongly informed by the veterinary science and veterinary policy work in the field of AM use undertaken at University of Bristol’s School of Veterinary Sciences (Barrett, 2014; Dufour et al., 2012), to explicitly go beyond behavioural approaches to individual action and decision-making.

In this approach, we have drawn specifically upon social practice theory and its emphasis on the time-deepened construction and reinforcement of routine actions and procedures to shape behavior (Berkhout et al., 2004) through system design, material arrangements, social relations, sector rules and knowledge flows. Taking Shove’s point that policy interventions do not take place “outside the processes they seek to shape” (2010, p. 1278), this has been employed to specifically de-centre individual behavior from the focus of analysis (Hargreaves, 2011). Hence, we argue that what is required is more situated understanding of the interaction of, and relationship between, different on- and off-farm drivers and barriers that operate within livestock systems and practices.

Thus, from the outset, the following assumptions have underlain the research approach:

- Questions of AM stewardship cannot be reduced solely to issues of individual farmer or vet behavior or to the investigation and evaluation of mechanisms to change individual behaviour in the prescription and use of AMs.
- Effective solutions require situated understanding of the multitude of on- and off-farm drivers and barriers that operate within livestock systems.
- Any simple reduction in the prescription and use of AMs in livestock systems cannot be seen in isolation to accompanying strategies and actions in farm biosecurity management and herd/flock health management.
- Consideration of sustainable responses to these issues critically needs to range beyond mere regulatory or interdictory action to include different forms of intervention, governance, collective and individual practice and incentive.
- Any changes in the prescription and use of AMs in livestock systems cannot be seen in isolation to the productive, environmental and health management practices and objectives of the farm and the veterinary practice.
Any notion of ‘inappropriate’ or ‘irresponsible’ use of AMs cannot be disassociated from an understanding of how appropriate and responsible uses are defined and enacted by farmers and veterinarians.

3. Methodologies

The research has been conducted using a combination of three different methodological approaches. Although each methodological approach constituted a distinct element in the project, all three were interlinked in the progression of the research. The specific steps taken for each of these are described in detail in the subsequent sections of this report. A Rapid Evidence Assessment was undertaken, drawing upon an initial database search of over 4500 published and unpublished works, ultimately being narrowed down to 31 papers for which a detailed comparative assessment is presented below.

Second, Q methodology (Watts and Stenner, 2012) was employed in order to understand how the approach to AM use in livestock is related to other issues (such as animal welfare, public health concerns and governance). The analysis of Q sorts allows us to draw out from our respondents a series of generic configurations of what is meaningful and significant to them with respect to the current and future use of AMs in different livestock systems.

Third, the research team carried out a qualitative research programme which entailed, first, face-to-face and telephone interviews with selected farmers across the three principal antibiotic intensive sectors (poultry, pig and dairy), veterinarians and ‘key actors’ and, second, the systematic analysis of the resulting interview transcripts.

The three linked methodologies enabled the triangulation and comparison of both methods and results, leading to a coherent and comprehensive understanding. The Rapid Evidence Assessment informed the setting up of the qualitative research programme that was itself informed by the results of the Q sort analysis. Further detail on each is provided below.
4. **THE RAPID EVIDENCE ASSESSMENT**

4.1. **Method**

In their recent consideration of the use of evidence in animal health and welfare policy, the Farm Animal Welfare Committee (2014) emphasise the key role that a systematic review (SR) of literature plays in supporting evidence-based policy making. Acknowledging that a full systematic review was inappropriate for the time-scale of the current project, this research has included a Rapid Evidence Assessment exercise, drawing upon the published examples and review procedures such as that employed by the European Food Safety Authority (EFSA 2010), that detailed in the Cochrane Handbook (Higgins and Green, 2009), as well as that developed by the Government Social Research Service in its ‘Rapid Evidence Assessment Toolkit’ (Civil Service, undated). We have drawn upon other examples of review techniques in both veterinary science (Reyher et al., 2013; Sargeant et al., 2006) and studies of farmer behaviour (Escobar and Buller, 2014).

In order to capture a true account of the depth and range of published research in this area in the limited time available, we adopted a two-method search strategy. The first method was a rigorous, structured search of databases using pre-defined search terms and drawing upon the PRISMA guidelines. The second was a more iterative approach whereby articles were sourced from the reference lists of previously obtained articles, through alerts on keyword searches and from search engines such as Google Scholar. Using these two approaches in tandem was considered optimal for ensuring the most accurate representation of the information available.

The assessment of published literature sought to identify:

- understanding of the role, place and extent of AM use, prescription and recording within the materials, sites, procedures, systems and (infra)structures associated with the practices of herd and flock health planning and maintenance.

- the attitudes, information and knowledge systems that farmers, veterinarians and relevant decision-makers draw upon in their understanding and use of AMs and the issue of AMR.

- actions employed to reduce AM use on farm and in veterinary practice as well as their effectiveness (including their limitations) and impact.

Initial searches were conducted using the search terms alone to identify what quantity of material was available. Filter criteria (published between 2000-present; English language only) were added later.
Method 1: Structured Database Search

Three databases were searched using combinations of key words judged appropriate to the databases. The keyword ‘antimicrobial’ was common to all searches but alternative words to capture the use of antimicrobials on farm and across different production systems were employed to secure a wide range of responses across different databases

1: MEDLINE - journal citations and abstracts for biomedical literature from around the world. Search started: 29/01/2015

Search terms and results: N=1877 articles
- Poultry AND Antimicrobial: Returned 258 articles. After filter\(^4\) 208 articles
- Dairy AND Cattle AND Antimicrobial: Returned 453 articles. After filter: 401 articles
- Swine AND Antimicrobial: Returned 1653 articles. After filter: 1268 articles

2: CAB Abstracts - over 7.7 million records from 1973 onwards, with over 360,000 abstracts added each year covering the applied life sciences including agriculture, environment, veterinary sciences, applied economics, food science and nutrition. CAB Abstracts covers 90.2% of the veterinary literature, against 36.5 covered by Medline and only 69.8% covered by any other combinations of databases are used (Grindlay et al., 2012). The search started: 29/01/2015

Search terms and results: N=2137 articles
- Antimicrobial or Antibacterial AND Livestock: 1371 articles
- Antimicrobial or Antibacterial AND attitudes: 176 articles. After filter: 160 articles
- Antimicrobial or Antibacterial or Antibiotics AND attitudes AND Livestock: After filter: 5 articles
- Antimicrobial or Antibacterial AND Farmers or farmers attitudes AND + livestock: After filter: 26 articles
- Antimicrobial or Antibacterial or Antibiotics AND Farmers or farmers’ attitudes: 179 articles. After filter: 141 articles
- Antimicrobial or Antibacterial or Antibiotics AND Prophylaxis AND livestock: 37 articles. After filter: 15 articles
- Antimicrobial or Antibacterial AND Surveillance AND Livestock: 34 articles. After filter: 31 articles
- Antimicrobial or Antibacterial or Antibiotics AND Vets: 470 articles. After filter: 339 articles
- Antimicrobial or Antibacterial or Antibiotics AND Vets AND Livestock: After filter 49 articles

The 4014 articles identified through Medline (1877) and CAB Abstracts (2137) were entered into Endnote Web where duplicates were removed, leaving 2034 articles.

\(^4\) Filter: English language, published in last 15 years
Additional search terms and results: N=102 articles
Antimicrobial AND Farm: Returned 65 articles
Antibacterial AND Farm: Returned 12 articles
Antimicrobial AND Farmer AND Use: Returned 25 articles

Method 2: Iterative search

In addition to the structured database searches, articles were sourced through searches on Google Scholar, from the reference lists of key articles and from alerts set up with various journals and search engines.

It also became apparent that two journals, The Veterinary Record and Preventive Veterinary Medicine, published a large proportion of the articles identified for the REA. Consequently article searches were specifically conducted in each of these journals:

Veterinary Record Search terms and results: N=93 articles
Antimicrobial: Returned 1308 articles. After filter*: 1168 articles
Antimicrobial AND farm: After filter*: 93 articles

Preventive Veterinary Medicine Search terms and results: N=316 articles
Antimicrobial: 360 – After filter*: 316 articles

Finally, a number of relevant unpublished research reports and other ‘grey literature’ were taken into consideration in the review. These were identified through research team knowledge, through Defra and other contacts and through references in published works.

The combined search strategy identified 2575 papers. Once duplicates and irrelevant articles (e.g. those that were entirely based on laboratory work or on human health) were removed, 134 articles were left from which a ‘long list’ of 114 articles were selected for further consideration according to their relevance to the research question.

Using a series of criteria of assessment (empirical survey of farmer/vet practice, geographical location of study/ social science approach / robust methodology and survey technique / peer-reviewed publication), the ‘long list’ of 114 papers was subsequently narrowed down to 7 papers that met the criteria of being within the context of UK farming, 14 papers drawing upon research in Europe and 10 papers that were drawn from research in the US and other countries; a total of 31 papers.

4.2. Results

The following Tables (Tables 1-3) summarise the papers examined under the Rapid Evidence Assessment. They are divided into three groups: selected papers dealing
with the UK; papers drawing upon empirical evidence and surveys in the EU and; finally, papers based on research in the US and elsewhere in the world.

It should be noted that these tables summarise and, in places, reproduce the findings from the reviewed research exactly in the manner that the authors of the papers reviewed have presented them. Although, for example, the use of percentages to describe low number data sets might be questionable, the authors, have nonetheless retained the authors’ own preferred presentational style.
**Table 1. UK research review**

<table>
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<th>WHO</th>
<th>OBJECTIVE</th>
<th>SURVEY</th>
<th>KEY FINDINGS</th>
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<td>Brunton et al (2012)</td>
<td>A survey of antimicrobial usage on dairy farms and waste milk feeding practices in England and Wales. <em>Veterinary Record</em>. [Principal Discipline of authors: Veterinary Health and Medicine]</td>
<td>Antimicrobial use and waste milk feeding practices investigated in 557 dairy farms (28% response rate) in 2010/2011 that responded to a randomised stratified postal questionnaire survey (financial incentives to respond).</td>
<td>Cefquinome is the first-choice treatment for mastitis on nearly a third of responding dairy farms. 83% of respondents fed waste milk to calves, primarily for economic reasons. 93% use AMs to treat mastitis, 96% of those prophylactically. Halting this feeding practice because of AM load would be economically damaging to dairy farmers.</td>
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<tr>
<td>Coyne et al (2014)</td>
<td>Understanding antimicrobial use and prescribing behaviours by pig veterinary surgeons and farmers: a qualitative study. <em>Veterinary Record</em>. [Principal discipline of authors: Epidemiology and Veterinary Science]</td>
<td>Focus groups (purposeful sampling) drawn from pig vets and farmers (2 vet groups and 4 farmer groups) from areas of low, medium and high intensity pig production.</td>
<td>Study identifies a number of themes (common to both vet and farmer groups) relating to AM use practice: ‘Agricultural Factors’, ‘External Pressures’, ‘Vet–Client Relationship’, ‘Drug-related Factors’, ‘Disease Epidemiology and Outcomes’, ‘Responsibility’, ‘Economic Factors’ and ‘Knowledge Base’. ‘External pressures’ (clients, public, legislation) were an important factor in vet decision-making – revealing heightened awareness of issues. Farmer concerns are driven by production system and management criteria. Farmers consider responsibility for AM use lies with vets. Overall, vets and farmers felt there was insufficient evidence to prove a decisive link between antimicrobial use in food-producing animals and the development of resistance in human beings.</td>
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<td>De Briyne et al (2013)</td>
<td>Factors influencing antibiotic prescribing habits and use of sensitivity testing amongst veterinarians in Europe. <em>Veterinary Record</em>. [Principal</td>
<td>Electronic survey questionnaire to veterinarians in different EU states – 3004 responses from 25 countries (290 responses from UK vets – 1.5% of UK vets).</td>
<td>Responses indicated no single information source is universally considered critical, though training, published literature and experience were the most important. Factors recorded which most strongly influenced prescribing behaviour were sensitivity tests, own experience, the risk for antibiotic resistance developing and ease of administration.</td>
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<td>WHO</td>
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<td>Gibbons et al (2013)</td>
<td>Influences on antimicrobial prescribing behaviour of veterinary practitioners in cattle practice in Ireland.</td>
<td>Questionnaire survey (based on similar survey undertaken amongst medical practitioners) of cattle veterinarians distributed at veterinary clinical society meetings in 6 locations (2007-2008). 118 returns (66% response).</td>
<td>Antimicrobial prescription strongly influenced by: ‘the farmer wants antimicrobials’ (57.5 per cent more likely to prescribe), ‘you will be blamed if antimicrobials later prove necessary’ (55.8 per cent), ‘the farmer expects antimicrobials’ (50 per cent), ‘if the animal doesn’t improve, you will be called again’ (49.5 per cent), and ‘you are not confident in your diagnosis’ (40.2 per cent). Findings reveal the extent to which prescription decisions are strongly influenced by multifactorial non-clinical influences (farmer pressure, cost of drug).</td>
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<td>Stevens et al (2007)</td>
<td>Characteristics of commercial pig farms in GB and their use of antimicrobials.</td>
<td>Postal survey of 1889 pig farmers in GB (farms &gt;100 sows or &gt;1000 pigs) – 482 returned (25.5% response). Variety of different production systems surveyed.</td>
<td>AMs most commonly used in feed. 60-70% of farms used AMs in weaners (partly as growth promoters) and 30-62% in growers. Injections used in 59%. Different use practices demonstrably associated with different production system factors, (e.g. age of animals and scale of production), membership of assurance scheme, vaccination and other farm management criteria (purchase policy, farm biosecurity, veterinary expenses also considered). Overall strong support amongst farmers for AM use in disease prevention (but less support for growth promotion).</td>
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<td>Higgins et al. (2012)</td>
<td>A Bayesian elicitation of veterinary beliefs regarding systemic dry cow therapy.</td>
<td>To conduct probabilistic elucidation to assess variation in vet beliefs regarding antibiotic efficiency of dry-cow therapy.</td>
<td>Major variations in vet beliefs and strength of belief regarding efficacy of systemic antibiotics for dry-cow therapy – likely to result in ‘very different decisions being taken on farm’ and ‘considerable discrepancies in treatment’. Raises concern of the consistency and appropriateness of antibiotic prescription. Explanation for variation likely to be result of availability/ cost of products and their marketing by pharmaceutical companies, differences in how veterinarians source and critically appraise information, the lack of robust</td>
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<td>Pinchbeck et al. (2012) Antibiotic use in food-producing animals in the UK Research report to Defra [Principal discipline of authors: Epidemiology and Veterinary Science]</td>
<td>To determine the criteria used by veterinary surgeons for the selection of antibacterials for the treatment of cattle. To collect objective data on the prescribing patterns of antibacterials in cattle practice.</td>
<td>Postal questionnaire survey of UK cattle vets – 255 usable returned questionnaires against 1438 sent out (18% return). 37 Antibiotic prescribing logs returned and analysed. 5 practices supplied pharmacy data for all drugs sold over 1 year period.</td>
<td>Antibiotics (ABs) dispensed at vet’s discretion but few practices have written AB prescription policy. Decision to use specific ABs based principally on clinical signs. Infection site, AB sensitivity – few vets test AB sensitivity. Information sources – varied as expected. 90% of vets used fluoroquinolones and cephalosporins in last year, over half ‘regularly’ or ‘often’. These and macrolides emerge as most common used. The most common class sold as a proportion of total weight was the tetracyclines (25.2%), followed by the penicillins (including potentiated) (22.8%) and the macrolides (14.1%), with the 3rd/4th generation cephalosporins (1.9%) and fluoroquinolones (2.2%) accounting for a small proportion of the total weight sold. Concern that 4th generation cephalosporins are being prescribed for mastitis sometimes without examining the animal, with less than half of animals recorded in the logs being examined for prescribing of these antibiotics. States that further investigation of drivers and behaviours is warranted, including understanding the relationship between clinicians and farmers, and motivations for prescribing of antibiotics.</td>
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### Table 2.

**European Non-UK research output review**

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<td><strong>Busani et al (2004)</strong> Survey of knowledge, attitudes and practice of Italian beef and dairy cattle veterinarians concerning the use of antibiotics. <em>Veterinary Record</em> [Principal discipline of authors: Animal Health]</td>
<td>To determine how Italian veterinarians prescribed antimicrobials in the Italian beef sector and to ascertain their attitudes to the broader issue of AM use.</td>
<td>Telephone survey in June 2002 of private large animal veterinarians associated with two large national veterinary associations. 106 randomly selected vets interviewed by telephone.</td>
<td>67% used lab support for susceptibility testing ‘always’ or ‘often’ for mastitis, less for scour and respiratory disease. 20% used antimicrobials ‘often’ or ‘sometimes’ before the onset of the clinical signs of calf scours; 28% used antibiotics ‘often’ or ‘sometimes’ before the onset of signs of respiratory diseases. The prophylactic use of antibiotics against mastitis at drying off was more common; 62% used always/often. For mastitis, cephalosporins (30%), third/fourth-generation cephalosporins (6%). For respiratory diseases, fluoroquinolones (21%), macrolides (20%) and phenicols (12%). 54% referred to the use of fluoroquinolones as a first-choice drug for calf scours, and 38 per cent as a second choice. Common experience of failure with AMs. General conformity to guidelines. Widespread prophylactic use of AMs (all dairy cows treated at ‘drying off’). 28% use AMs en masse for enteric disease and 20% for respiratory. Suggests vets are under pressure to provide solutions and use newer AMs.</td>
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<td><strong>Charvin et al. (2002)</strong> Survey of group-level antibiotic prescriptions in French pig production. <em>Preventative Veterinary Medicine</em>. [Principal discipline of authors: Animal Health, Veterinary Medicine and Food Safety]</td>
<td>To determine nature and range of prescription of AMs for group-level treatment by pig vets in France.</td>
<td>Postal questionnaire survey of pig veterinarians undertaken in 2000 to establish type of animals, presumptive clinical diagnosis and drug prescription. 303 responses to questionnaire, 159 prescriptions analysed.</td>
<td>Of 159 prescriptions: 69 weaners, 63 fattening pigs, 27 breeding sows. Oral administration (148), feed (94), water (54). [Detailed table of prescriptions to diseases]. Analysis of drugs used and intended duration. No real surprises. Most prescriptions were for clinical syndromes (respiratory disease and diarrhoea) rather than defined pathology. Many AMs used for same purpose. Doses comply with recommendations but high variations in treatment length and dosage – little consistency across farms.</td>
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**OBJECTIVE**
To investigate farm-level economic and technical factors associated with the use of ABs on Dutch pig farms With a view to increasing knowledge and advising policy over reductions in AB use.

**SURVEY**
LEI-FADN data and associated on-farm medication data from 2004-2007 was used (69 farms and 151 farm-year records for fattening and 63/155 for sow farms).

**KEY FINDINGS**
Daily dose rates calculated and presented – highly variable and concentrated 10% of farms being responsible for 30% of AB dosage. Few factors correlated with AB levels: farm system, population density of region, average number of fattening pigs present on the farm, starting BW piglets, slaughtered BW pigs, feed conversion, concentrate price, percentage lean meat, mortality, net farm result, bedding material costs, number of man-years, and heating costs. Growth in AB over time until impact of growth promotion ban. Ban on promoters led to temporary growth in therapeutic use. Major variation in daily does rates with some farms having no AB use others having AB treatment every day of pig life on ‘heavy AB use’ farms. AB use both on sow and fattening pig farms, mainly influenced by farm system and number of pigs present on the farm, and for sow farms only, antibiotic use was also affected by the population density in the region of the farm. The greater number of pigs present on the farm may result in a greater probability of infection, which can explain the increased antibiotic treatments on large farms. Suggestion that workers on large farms spend less time inspecting individual animals and use antibiotics in a more preventive manner as compared with the workers on small farms. Antibiotic use on sow farms is thus influenced both by the number of animals within a farm as well as by the number of farms within a specified region.

Laanen et al (2013) Relationship between biosecurity and production/antimicrobial treatment characteristics in pig herds. Veterinary Journal [Principal discipline of authors: Veterinary]

**OBJECTIVE**
To investigate the relationship between the implementation of biosecurity in pig herds in Belgium, and various production parameters and the prophylactic use of antimicrobials.

**SURVEY**
Risk based analysis of biosecurity status of 95 breeder-finisher pig herds.

**KEY FINDINGS**
On average, 17% of animals were being treated daily with AMs for prophylactic group treatment. Study demonstrates and quantifies a clear link between biosecurity and both production- and antimicrobial treatment-related criteria in pig herds. Disease management (hospital pens, handling of diseased animals and farrowing/suckling (washing of piglets and cross-fostering) most negatively associated with AM use intensity. Suggest that fewer prophylactic treatments with...
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<td>epidemiology</td>
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<td>AMs are given to herds with higher biosecurity. Effective management of diseased animals can reduce need for AMs, especially in the early part of the production cycle. Belgian producers only required to record AM use for 2 months prior to slaughter.</td>
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<td>Menendez Gonzalez (2010) Antimicrobial use in Swiss dairy farms: Quantification and evaluation of data quality. Preventative Veterinary Medicine [Principal discipline of authors: Federal Veterinary Office]</td>
<td>To quantify antimicrobial use in Swiss dairy farms; to evaluate data quality of farm records on antimicrobial use, and; to compare data quality of different recording systems.</td>
<td>Data on AM use over a 12 month period collected from 97 average Swiss dairy farms in 2005.</td>
<td>Dry cow therapy (36%), udder disease (35%) and reproductive disorders (18%) most common reasons for cows. AM use in heifers very low. In calves, AM use half that of cows. Insights into the measurements of AMs. High potency AMs used in low doses so amount of active substance does not reflect treatment intensity and risk for development of AM resistance. A measurement that refers to the number of treated animals and body weight is preferable, such as daily and course doses. Under and over-dosing frequently observed. Under-dosing a particular problem and implications for AMR. Significant variations in use and dose across different farms. Vets record more dosage regimens than farmers but neither are complete. Farmer errors in recording common. Call for measurement units in AM data recording to be standardised and reflect course doses.</td>
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<td>Merle et al (2012) Monitoring of antibiotic consumption in livestock: A German feasibility study. Preventative Veterinary Medicine [Principal discipline of authors: Biometry, Veterinary medicine]</td>
<td>To identify the technical preconditions and develop a concept for a regular monitoring system of AB consumption across different livestock sectors within Germany.</td>
<td>Data base from AB prescription and use records across 12 month period (2006-2007) from 24 vet practices and 65 farms (total 95,584 records).</td>
<td>In pigs and cattle, tetracyclines were the most frequently used substances, followed by beta-lactames, and in cattle by the trimethoprim/sulfonamide group. 92% of applications to pigs were oral against 75% in cattle. The high percentages of parenterally and locally applied antibiotics in cattle compared to those of pigs reflect that individual therapy takes place only in cattle while pigs are treated mainly herd-wise. However, all EU states have different reporting criteria for AM use.</td>
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<td>Moreno (2012) Survey of quantitative antimicrobial consumption in two different</td>
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<td>Comparative data presented on F-F and F farm use of AMs and delivery method, by animal age, Almost all farms recorded AM use – mainly orally administered with high levels of animals</td>
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<td>pig finishing systems. Veterinary Record. [Principal discipline of authors: Biometry, Animal Health, Veterinary medicine]</td>
<td>fattener pigs; to compare AM use in different Spanish pig management systems</td>
<td>delivery over 6 months during 2010. 108 sample size for each, leading to total of 67 F and 49 F-F analysed.</td>
<td>treated (often &gt;90%), the use of integration as the management organisation was associated with higher AMU. Farm size, both qualitative( eg, official farm-size group) and quantitative (eg, sow and finisher numbers) not statistically significant association to AM use. The most critically important AMs, especially fluoroquinolones and third-generation cephalosporins, were almost always used per injection. Farm management structure was related with higher uses of some AMs on finisher farms; farms raising Iberian pigs had lower use of some AMs.</td>
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<td>Moreno (2014) Opinions of Spanish pig producers on the role, the level and the risk to public health of antimicrobial use in pigs. Research in Veterinary Science. [Principal discipline of authors: Biometry, Animal Health, Veterinary medicine]</td>
<td>To collect and analyse the opinions of Spanish pig farmers on the role, the level and the risk to public health of on-farm antimicrobial use.</td>
<td>Interview based study using two sets of questionnaire based face-to-face interviews with 48 farrow-finish Spanish pig farms and 62 finisher farms.</td>
<td>Results show strong sense of dependence amongst farmers on AMs to sustain production, improve farm performance and maintain health status of pig farms. AMs regarded as profitable, some disagreement about high cost of AMs. Little support for notion that livestock AMs reduce ability of human treatments. Lack of concern identified amongst pig producers about the harmful effects of antimicrobial use on their own health and that of the public at large as a result of a reduction in the curative ability of antimicrobials and the selection of AMR bacteria.</td>
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| Ortman and Svensson (2004) Use of antimicrobial drugs in Swedish dairy calves and replacement heifers. Veterinary Record. [Principal discipline of authors: Animal and Environmental Health] | As part of a larger project on the relationship of length of rearing period to animal productivity amongst Swedish dairy cattle, this particular paper seeks to estimate the use of antimicrobial drugs in calves and replacement heifers. | Survey involving 122 dairy farms, tracking diseases and medicine application records of 3081 heifer calves from birth to either first calving or removal. Regular clinical testing accompanied the survey. | Study identified 1268 cases of infectious disease, 26.4% of which were treated with antimicrobial drugs. Over 70% of cases occurred between 0 and 201 days with respiratory disease and diarrhoea being main ones for AM treatment. In total 355 treatments (90% of which administered in first 210 days). In 61.4%, treatment given without vet consultation. 22.6% with vet consultation, 13.6% vet examination of animal. Because most AM use in dairy is to treat mastitis, the use in calves is small in comparison. Farmers more likely to contact vet in older animals (larger so needs more drugs, more valuable, diseases require larger doses). Yet the moderate use of these drugs in dairy calves and heifers probably contributes to the
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<td><strong>Stege et al (2003)</strong>&lt;br&gt;VETSTAT – The Danish system for surveillance of the veterinary use of drugs for production animals. Preventative Veterinary Medicine [Principal discipline of authors: Veterinary Science]</td>
<td>Assesses the operation of the Danish VETSTAT system for recording AM use.</td>
<td>Uses VETSTAT data coming from pharmacies (legally obliged to record sale of all veterinary medicines), from veterinarians (obliged to record all treatments) and feed mills, obliged to record all sales of medicated feed. Data used for this survey from 2001.</td>
<td>low levels of antibiotic resistance in cattle in Sweden.</td>
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<td><strong>Swinkels et al (2015)</strong>&lt;br&gt;Social influences on the duration of antibiotic treatment of clinical mastitis in dairy cows. Journal of Dairy Science. [Principal discipline of authors: Animal health, Social science, Veterinary medicine].</td>
<td>To explore the social factors influencing farmers’ decision-making on the duration of antibiotic treatment of clinical mastitis of dairy cows in the Netherlands and in Germany.</td>
<td>17 dairy farms from the Netherlands and 21 farms from Germany were interviewed for this study.</td>
<td>82% of AMs sold by pharmacies were direct to individuals on prescription with specifications for use, age groups and target species. 78% of AMs sold by pharmacies used for pigs, 20% for cattle. Pharmacy data more reliable than that from vets or mills. Lacking any data on the number (and type/age/weight) of animals treated. Only AM recording an increase in use were cephalosporines. Apart from these and quinolones, overall usage was stable across year. Data from feed mills (who purchase direct from manufacturers) was poor.</td>
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79% of farmers reported routine and 18% occasional extended antibiotic treatment. The interviewed farmers were sensitive toward social norms of other farmers and recognition for good stockmanship. Extended treatment is perceived as part of the social norm of “being a good farmer.” The participants’ perception was that mastitis is not treated “thoroughly” if clinical symptoms were still visible at the time of cessation of treatment, because it may persist or recur. As a result, treatment was frequently extended by repeating the initial label treatment. Farmers, specifically the more “cow-oriented” farmers, expressed insecurity on how to treat mastitis effectively. It appears that prudent antibiotic use is hindered by perceived subjective norms on optimal treatment duration.
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| **Timmerman et al (2006)**  
Quantification and evaluation of antimicrobial drug use in group treatments for fattening pigs in Belgium.  
Preventative Veterinary Medicine.  
*Principal discipline of authors:* Veterinary Epidemiology, Veterinary medicine. | To investigate the antimicrobial drug consumption in pigs, using the treatment incidence based on the animal daily dose pig , the treatment incidence based on the used daily dose pig, and the ratio of the above.  
Study based on retrospective farmer records for 50 randomly selected closed or semi-closed pig herds in Belgium obtained through face-to-face interviews. | Group treatments predominate, principally for prophylactic reasons. On only 12% of herds were animals not treated in groups. Group treatments (injected and oral) for 52% of herds. Large differences in drug use across structurally comparable herds – some with little or no group treatments other (more than 25% of herds) had at least 80 standard doses per 1000 pigs at risk per day. Older drugs still frequently used. Ratio of Used Daily Dose (UDD) per pig to Animal Daily Dose (ADD) per pig appears to be a potential tool for more accurate data on dosing and application. Study shows that most AMs are not administered to correct dose. |
| **Trauffler et al (2014)**  
Antimicrobial drug use in Austrian pig farms: plausibility check of electronic on-farm records and estimation of consumption.  
Veterinary Record  
*Principal discipline of authors:* Veterinary public health. | To determine the plausibility of statutory drug application data and to estimate the total amount of antimicrobial consumption in Austrian pig production using different units of measurement.  
Using official records of drug prescription combined with a meat production company’s own private quality assurance scheme data, data set of 75 conventional pig farms and 19 supervising veterinarians analysed from January 2008 to December 2011. | Different forms of measurement assessed: weight of active substance, used daily dose per kg of biomass, animal daily does per kg of biomass, product-related daily dose for 1 kg biomass. Measurements undertaken in total, per farm-type, per farm. Evidence of significant inaccuracies. 22% under-dosage revealed, 10% over-dosage (when held against prescription). Breeding farms used most ABs and most farms (90% of Fattening and breeding farms used group treatments. CIA use only 12%. AM use showed correlation with farm size. Accordance between prescription and actual application was low (57%). Paper advocates expression of AM consumption in number of daily doses. Under-dosage is a concern. Clear need for better on-farm use data. |
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<td>Vaarst et al. (2003) Organic dairy farmers’ decision making in the first 2 years after conversion in relation to mastitis treatments. Livestock Production Science.</td>
<td>To examine how AM treatment patterns could be influenced during conversion to organic farming.</td>
<td>Study (using semi-structured qualitative research interviews) of 20 Danish dairy herds undergoing conversion, from conversion to 20-24 months after (period 1999-2000).</td>
<td>Mastitis the dominant disease treated with AB – regarded as best treatment by most. Few respondents concerned by AMR transfer. Concern for individual health and welfare but also a herd perspective (concern for welfare of herd). Preferred cows would be more likely to receive AM treatment. Treatment decision also based on need to maintain herd structure. Only one respondent suggested relationship with vet had improved. Vet costs seen as prohibitive to greater collaboration. Conversion to organic not a major factor in changes to practices re AM (other factors such as changing herd size more important). None of respondents thought issue of AMR to be of importance and had no impact on their own disease management choices. Falling meat and dairy process much more significant. Being organic not seen as changing attitudes and practices re AMR. Organic dairy faces major challenges in extending the ideas of organic farming to udder health practices.</td>
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Table 3.

US and other States - research output review

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<td>Cattaneo et al (2009)</td>
<td>Bovine veterinarians’ knowledge, beliefs, and practices regarding antibiotic resistance on Ohio dairy farms. <em>Journal of Dairy Science</em>. [Principal discipline of authors: Food Animal Health].</td>
<td>In-depth interviews of 10 bovine veterinarians in Ohio, the results of which were used to inform the development of a survey distributed by post and online to 174 Ohio bovine veterinarians (26% response rate, n=43).</td>
<td>Veterinarians believed that specific antibiotics (e.g. gentamicin) are used by farmers to treat animals without veterinary consultation. While over 75% of veterinarians considered one-to-one meetings and handouts detailing good management practices, diagnosis descriptions and appropriate dosages for antibiotics would be effective methods of educating farmers, less than a quarter stated they actually provide treatment protocols for antibiotic use. The authors conclude that improving information flow from veterinarians to farmers may be the most effective means of promoting prudent use of antibiotics on dairy farms rather than producing materials to educate the veterinarians themselves.</td>
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<td>Dean et al (2011)** The Role of Trust and Moral Obligation in Beef Cattle Feed-lot Veterinarians’ Contingent Adoption of Antibiotic Metaphylaxis Recommendations. <em>The International Journal of Sociology of Agriculture and Food</em>. [Principal discipline of authors: Health Science, Veterinary epidemiology].</td>
<td>To examine the willingness of beef-cattle feed-lot veterinarians to forgo the recommendation of antibiotic mass treatment (metaphylaxis) to their beef-feed-lot clients as a contingency based on the demonstration of a definite harm to human health.</td>
<td>Postal survey of 325 <em>cattle feedlot veterinarians</em> from 37 US states (42% response rate, n=103). The survey development was informed by interviews with 32 key actors associated with feedlot medicine.</td>
<td>The analysis examined how some veterinarians contend with potentially conflicting values as they evaluate antibiotic treatment options. Factors that predict willingness to forgo metaphylactic treatment for their feedlot clients are primarily psycho-social, including social influence, moral duty, and trust or distrust, characterized as competency. Several items were associated negatively with the likelihood that feed-lot veterinarians would decrease their metaphylactic treatments. These items included: the strength of the economic pressure to recommend metaphylaxis; the strength of the moral obligation to recommend metaphylaxis regardless of negative consequences to human health; the strength of the expectations of other veterinarians, pharmaceutical companies and professional organizations to recommend</td>
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<td><strong>Friedman et al (2007)</strong> Importance of Prudent Antibiotic Use on Dairy Farms in South Carolina: A Pilot Project on Farmers’ Knowledge, Attitudes and Practices. Zoonoses and Public Health. [Principal discipline of authors: Public Health].</td>
<td>To determine South Carolina dairy farmers’ information sources and knowledge about antibiotic resistance in dairy herds and to explore with dairy farmers appropriate methods for communicating information to them about prudent use of antibiotics on the farms.</td>
<td>Face-to-face interviews were conducted with 20 South Carolina dairy farmers and a further 22 farmers took part in one of four focus groups. A survey was also completed by participants with the questions asked orally by project staff.</td>
<td>40% of farmers stated that they were familiar with antibiotic resistance and were confident in their use of antibiotics. Most farmers (86%) were not concerned that overuse of antibiotics in animals could lead to resistance amongst farm workers. 32% of farms had written protocols for diagnosing and treating common medical conditions in the dairy herd. Three themes were identified from the focus groups, these were current knowledge, information sources and information-seeking barriers. The main barriers to seeking out antibiotic protocols were a lack of finances and a lack of time. Responses indicate that personal experience of farmers and advice from other local farmers were often more important than scientific evidence in their decision-making about antibiotic use.</td>
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<td><strong>Green et al (2010)</strong> Producer attitudes and practices related to antimicrobial use in beef cattle in Tennessee. Journal of the American Veterinary Medical Association. [Principal discipline of authors: Health Science, Veterinary Medicine].</td>
<td>To evaluate knowledge, attitudes, and management practices involving antimicrobial use among Tennessee beef producers so that continued educational efforts focusing on judicious antimicrobial use might be appropriately designed.</td>
<td>Postal questionnaire of 3000 beef producers in Tennessee administered in 2007 with a second mail out in 2008 to nonresponders (final response rate 35%, n=1042 of these only 850 still had cattle).</td>
<td>Operations were categorised as multiple operation type (MOT) or calf-only. A higher proportion of MOT than calf-only operations agreed that antimicrobials worked less effectively than in the past. Approximately a third of all producers (34%) reported using bacterial culture to determine the cause of disease, and approximately a third (32%) reported using results of susceptibility testing to choose the appropriate antimicrobial. Use of antimicrobial-related record keeping was reported by 39% of producers. 77% of producers reported purchasing antimicrobials from a cooperative; just over half (51%) of producers reported purchasing antimicrobials from a veterinarian. The</td>
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<td>antimicrobials most commonly administered, by mouth or by injection, during the year prior to survey response were tetracyclines (38%), (\alpha)-lactam antimicrobials (33%), sulphonamides (9%), macrolides (9%), and florfenicol (13%). Use of ceftiofur, fluoroquinolones, aminoglycosides, aminocyclitols, and lincomycin was reported by &lt; 5% of producers.</td>
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**Jan et al (2010)** The effects of moral obligations to others and others’ influence on veterinarians’ attitudes toward and recommendations to utilize antibiotics in feedlot cattle. *Journal of Rural Social Sciences*. [Principal discipline of authors: Sociology, Health Science].

To determine the influence of moral obligations and behavioural expectations on attitudes toward antibiotic use and recommendations to use antibiotics in feedlot cattle.

A 18 page questionnaire was sent to 325 **cattle feedlot veterinarians**, the content of which was informed by interviews with 35 feedlot operators and other key actors (response rate 42%, n=103).

Subjective norms and a sense of moral obligation affect both the attitudes toward, and the recommendations for, the use of antibiotics in feedlot cattle. Several significant interactions among subjective norms and moral obligations were found, which suggests that perceived moral obligations to peers, clients, and the regulatory norm-setting sector associated with the feedlot industry increase the impact of social pressures from those sectors on the recommendation to use antibiotics in acutely sick, chronically sick, and high-risk feedlot cattle.


To compare across four differing circumstances the relationships among moral beliefs and instrumental beliefs regarding antimicrobial use in the U.S. cattle feedlot industry, and influences that subjective norms, importance of the sources of those norms (referent others) and background factors have on these moral beliefs.

Postal survey of 325 **cattle feedlot veterinarians** from 37 US states (42% response rate, n=103). The survey development was informed by interviews with 32 key actors associated with feedlot medicine.

The results indicate the effects of moral beliefs on behavioural beliefs are somewhat contingent on the condition; that is the level of risk associated with treating cattle with antimicrobials, the level of risk of not doing so, and the effectiveness of the antimicrobial in situations such as acute illness or being at-risk of illness. While veterinarians differ in their moral beliefs across situations, moral beliefs appeared to increase the belief that treating sick cattle with antimicrobials was efficacious; those who saw a moral imperative for such treatment were more likely to perceive that antimicrobial use improved cattle health, profitability and well-being regardless of whether the cattle
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<td>Redding et al (2014)</td>
<td>Comparison of two methods for collecting antibiotic use data on small dairy farms.</td>
<td>20 dairy farmers in Peru, participated in the study. Farmers placed discarded antibiotic packaging in bins for six months. At the end of this period, farmers were interviewed and asked to recall the antibiotic usage that occurred on their farm over the past month and past six months. These self-reported data were quantitatively and qualitatively compared to the bin contents collected in the last month and previous six months.</td>
<td>85% of farmers kept to the study protocol and placed their packaging in the bins as discussed. The agreement between bins and self-report used to collect data on antibiotic use on farms was relatively poor. The bins appeared to perform better than self-report for longer periods of time and self-report appeared to perform better for more commonly used drugs on a short-term basis and for intra-mammary infusions. The results of this study may provide guidance for investigators undertaking similar studies in similar environments.</td>
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<td>Sawant et al (2005)</td>
<td>A Survey on Antibiotic Usage in Dairy Herds in Pennsylvania.</td>
<td>248 dairy farms were invited to participate in the antibiotic usage survey. Of these 113 who were interested and met the criteria actually participated. The author administered the first part of the survey to all 113 farmers and the second part to the 33 farmers who kept records on health and medication usage.</td>
<td>50% of dairy farms kept antibiotic treatment records. 21% of dairy producers had written plans for treating sick animals. 32% of dairy producers sought veterinarian advice before administering antibiotics. On 93% of farms, antibiotics were administered by the owner/manager or designated herdsman. 24% of the dairy producers said they always completed the course of antibiotic treatment. Any extralabel use of antibiotics was administered only on the guidelines of a veterinarian on majority of the farms. Records from 33 dairy farms indicated that antibiotic usage was largest for calves with enteritis (36%) followed by pneumonia in calves (25%) and foot rot in cattle (16%). Twenty-four antibiotics including beta-lactams, spectinomycin, florfenicol, and tetracyclines were used on these farms. Beta-lactam antibiotics were used mostly for</td>
</tr>
</tbody>
</table>


To define the type and specific use of antimicrobial agents that are associated with on-farm management Practices in dairy herds in Pennsylvania.

248 dairy farms were invited to participate in the antibiotic usage survey. Of these 113 who were interested and met the criteria actually participated. The author administered the first part of the survey to all 113 farmers and the second part to the 33 farmers who kept records on health and medication usage.

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<table>
<thead>
<tr>
<th>WHO</th>
<th>OBJECTIVE</th>
<th>SURVEY</th>
<th>KEY FINDINGS</th>
</tr>
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<tbody>
<tr>
<td></td>
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<td>dry cow therapy, clinical mastitis, and on some farms for pneumonia and metritis. On 18% of the dairy herds surveyed, ceftiofur was used in an extra-label manner to treat mastitis in lactating cattle. On 70% of farms, calves were fed medicated milk replacers containing oxytetracycline and neomycin.</td>
</tr>
</tbody>
</table>
| **Zwald et al (2004)**  | To compare reported antimicrobial usage between conventional and organic dairy farms.  
To contrast selected management characteristics of conventional and organic dairy herds. | A questionnaire was administered on site to selected *dairy farmers* located in Michigan, Minnesota, New York, and Wisconsin. 131 farms participated (32 organic herds and 99 conventional herds). | Conventional dairy producers were more likely to use advice from veterinarians for recommendations of treatment, and organic dairy producers were more likely to rely on advice from other farmers. Based on recall of antibiotic usage in the previous 60 d, 5.1, 84.9, 9.1, and 0.9% of farmers with conventional herds reported treatment of none, 1 to 10%, 11 to 25%, and >25% of milk cows, respectively. 90.6% of organic farmers reported no antibiotic treatments of milk cows, whereas 9.4% reported treating 1 to 10% of milk cows. Ceftiofur was the most commonly reported antibiotic for both farm types. Milk replacer containing antibiotics was reportedly used on 49.5% of conventional herds but only on one organic herd (3.1%). Antibiotics were used in heifer calves on 74.7% of conventional herds versus 21.9% of organic herds. Antibiotics to treat mastitis were used on 79.8% of conventional herds but on none of the organic herds. |

** These studies draw on the same dataset


Moreno MA (2012) Survey of quantitative antimicrobial consumption in two different pig finishing systems. Veterinary Record 171: 325-331 doi: 10.1136/vr.100818


Pinchbeck et al. (2012) Antibiotic use in food-producing animals in the UK. Research report to Defra (Defra Project code VM02211)


4.3. Key Points from the Rapid Evidence Assessment

The REA served two principal functions. First, it framed the subsequent qualitative research and the lines of interrogation for the farmer and veterinary interviews. Second, it provided a series of insights in its own right. Individual papers provide detailed empirical evidence on:

- The use (volumes/dosage/application) of antimicrobials in contemporary farming systems (for the UK: Brunton et al., 2012; Stevens et al., 2007; Pinchbeck et al., 2012, from Europe: Busani et al., 2004; Charvin et al., 2002; Menendez-Gonzalez, 2010; Merle et al., 2012; Moreno, 2012; Ortman and Svensson 2004; Timmerman et al., 2006; Trauffler et al., 2014 and, for the US and elsewhere: Sawant et al., 2005; Zwald et al., 2004)

- Veterinary prescription practice, decision-making and attitudes (for the UK: Coyne et al., 2014; De Briyne et al., 2013; Gibbons et al., 2013; Higgins et al., 2012, for Europe: Busani et al., 2004 and the US: Cattaneo et al., 2009, Dean et al., 2011; Jan et al., 2010; McIntosh et al., 2009)

- Farmer attitudes towards medicine use (for the UK: Coyne et al., 2014; for Europe, Moreno 2014; Swinkels et al., 2015; Vaarst et al., 2003 and for the US, Friedman et al., 2007; Green et al., 2010)

- Data requirement and recording issues relating to AM use (a particular theme in the reviewed papers drawing upon European empirical research: Menendez-Gonzalez 2010; Merle et al., 2012; Stege et al., 2003; Timmerman et al., 2006; Trauffler et al., 2014, and for the US, Redding et al., 2014)

Few reviewed studies seek to compare AM usage across different farm-level variables, preferring broader production system comparisons (though see Van der Fels-Klerx et al., 2011 which demonstrates significant variations in AM use within similar production systems, Laanen et al., 2013 and Moreno, 2012 which reveal the importance of on-farm management in reducing levels of AM usage and Moreno 2012). Fewer still directly compared farmer and veterinary attitudes (though see Coyne et al., 2014) and only one specifically relates to the use of AMs with biosecurity measures (Laanen et al., 2013). All the reviewed studies concerned either dairy or pig production systems. The original literature search identified very few empirically informed research papers on AM use in poultry systems. One possible explanation for this is that while research on AM use in poultry systems is taking place, it is likely to be commercially sensitive and therefore remains largely unpublished.

Overall, the studies assessed show no clear and consistent cross-sectoral messages other than:

- First, the ready and prevalent use of AMs in livestock systems, which is both expected by farmers and widely understood as a central component of modern
animal health management. All studies point to what are reported as being high and consistent levels of prophylactic and metaphylactic use of AMs in all systems (except organic). Links between system type and AM use are not always consistent though pig systems emerge as higher users than dairy systems (little or no information available on poultry systems). High degrees of variability in dosages and AM uses across different farms and systems (not so much country or production sector specific but farm specific). Few of the reviewed papers identify opportunities for reduced or more appropriate use within existing production system rationales.

- Second, a broad awareness of the issue of AMR as a contemporary issue within modern society though major variations in the strength of belief that AM use within livestock systems is directly contributing to this. From the reported research, there would appear to be a high level of farmer/veterinary awareness in UK but less (from these studies) in other EU and, in particular, the US where a lack of specific concern was more commonly reported.

- Third, the review shows considerable variation in patterns of use and prescription both between and within production systems with some evidence of farmers directly influencing prescription practice (Gibbons et al., 2013; Higgins et al., 2012)).

There are some variations in the broad tone and focus of the three sets of papers. Recent UK-based research characterised a shift in focus on farmer/veterinarian behavioural and attitudinal factors in AM use and prescription. European research more dominated by prescription/use data (medicine type, dosage, frequency of use - often against simple farm/animal characteristics) and by interest in measurement and accounting techniques. Papers drawing on the US, where AMs are still permitted as growth promoters, reveal greater emphasis on veterinary roles and on attitudinal research amongst farmers and vets.

Many of the reviewed papers refer to two significant gaps in the existing knowledge of the issue:

- Understanding of farmer and veterinary prescription and use practice (over and above the recording of prescribed or applied doses)

- The need for comparable data on prescription and use. While certain countries, notably Denmark, provide detailed prescription data on, many of the reviewed papers refer to the paucity of detailed use data both within and across production systems. Different methodologies for assessing volumes and rates of use are discussed in several papers though no consistent recommendations emerge for a directly comparative and systematic evidence base.

Finally, it is clear from the assessment that almost all of the reviewed research into farmer and veterinary beliefs, behaviors and actions is undertaken by natural/animal scientists, with a relative paucity of social-science led research into AM use. This has
led to clear gaps in knowledge and understanding about, on the one hand, how beliefs and attitudes are translated and reinforced (or challenged) by practice and, on the other hand, how an understanding of complex social processes and how practices of decision-making and action relate to the structures and contexts of social action.

The results of the Rapid Evidence Assessment have nevertheless provided essential and informed input into the subsequent Qualitative Research by revealing research and evidential gaps in the following areas of understanding:

- how farmers and vets contextualise and give relative meaning and value to the issue of AMR both in their prescription and use of AMs and in their broader social and professional contexts;

- how farmers and vets actively seek to respond to calls for more sensible AM uses through their prescription and animal practices;

- the potential contribution of innovative social science methodologies to understanding to the issue of AM use and practice
5. Q SORT COMPONENT

5.1. SUMMARY

The project set out to understand current practices relating to antibiotic use in livestock in the UK. Using Q method along with a series of semi-structured interviews we aimed to generate accounts of those practices. AMR is a complex social issue, in that potential threats to public and animal health can emerge from efforts to minimise health risks. In this and other ways, the problem is not straightforward and is bound up with all manner of concerns including animal welfare, food security and production costs. Our methods for this study were selected in order to retain rather than artificially reduce this multivalent quality of the issue.

Q method was chosen for the following reasons. First, we wanted to elicit shared viewpoints across sectors and professions involved in the issue. Q methodology is particularly suited to providing an analytical and statistically robust process that can summarise subject positions. It can also allow analysts to take a more objective approach to qualitative data analysis, and allow surprises to emerge from the data. For example, we didn’t want to assume beforehand that the shared viewpoints would map neatly on to specific sectors, systems or professions (or other by-variable categories). Second, as subjects rank a range of relevant statements in a Q methodology there is a possibility to access the full complexity of an issue. If shared understandings emerge they will be related to a suite of issues that will allow analysts to understand the interrelation of those issues. For example, if there is a consensus that responsible use of antibiotics is a good thing, but if there is resistance to greater regulation of that use, then Q methodology would not only allow for those divergent positions to emerge, but also offer routes to thinking about how possibly contradictory statements could occur together. It is a methodology that enables researchers to explore and possibly clarify a maelstrom of sometimes conflicting views. It can therefore give insights into current understanding and practices and provide a sense of the landscape in which policy is to be formulated.

Twenty-six separate sorts, performed by farmers and vets, were reduced to three shared viewpoints through an analysis of their degree of shared properties. Each shared viewpoint included both vets and farmers, suggesting that alliances are strong across, as well as within, professions. The shared viewpoints are:

Antibiotics are already being phased out through modern farming methods which prioritises hygiene, health planning and herd management (to minimise mixing of stock). These improvements can be achieved without too much pain or cost, and can occur even in the absence of a strong link between use of AMs in livestock and public health concerns.

A more interventionist and deficit view suggests that further changes can be brought about through better farmer education. There is in this view a stronger sense that
there is a potential human health problem with current antibiotic use and the solution is a better, veterinary led, understanding of the issue.

A final viewpoint is characterised by strong resistance to imposition of new regulation or market-led changes. This view is reluctant to cede control of livestock treatment to outside bodies. Externally sanctioned blanket limits may not be what is best for the industry.

These views are not necessarily oppositional. Indeed, there are certain commonalities between them including a shared belief in responsible usage, an overall sense of the cost-effectiveness of changes and the need for good working relationships between vets and farmers. Nevertheless, they do describe some clear mindsets through which the issue is filtered and engaged by farmers and vets.

The implications for policy relate to implementation. There is a strong sense that AM use can be managed though some disagreement on how this might be done. For one viewpoint there is a need for greater science-led regulation and intervention, for others there is a sense in which outside interference might miss the nuances involved in using ABS responsibly. These nuances are picked up in more detail in the analysis of farmer and vet semi structured interviews.

5.2. Method and Analysis

Q methodology is designed to reveal shared positions on a topic or issue. It does so through an exercise that involves research subjects ranking a set of statements. These rankings are then inter-correlated and subjected to factor analysis in order to reveal statistically significant shared viewpoints (or patterned subjectivities). These factors or groupings are then interpreted, qualitatively, and by means of the loading of particular statements on to a factor, in order to describe realistic and shared understandings. Comparison of factors can give insight into how an issue, like antibiotic use, AMR and livestock, is viewed by distinctive groupings.

5.2.1. Overview of Method

Concourse: A final concourse of 40 statements was generated drawing on the assembled expertise of the multi-disciplinary team and preliminary reviews of literature, policy reports and workshop reports. Statements were included if they fell under one or more of the project themes and an effort was made to cover a wide opinion domain on farm-based antibiotic use and AMR. Statements were excluded and / or reworded if they included more than one qualifier (e.g. ‘Antibiotics are used regularly because they are cost effective’), were expressed negatively or were oppositional to already accepted statements. The final Q set of 40 statements (a lower limit for Q method but one that was thought to be manageable in the field and in the time frame) is included in table 1.
Grid: A 40 square grid with a shallow distribution was chosen in anticipation that many of the participants would have expert and direct experience of the issue. Deeper grids are used in situations where there is likely to be greater ambivalence or uncertainty. On reflection, a deeper grid may have been more appropriate given that some participants found being forced into a fine-grained discriminations between statements to be off-putting. See table 2.

The sort: 26 people, 10 veterinarians and 16 farmers (7 dairy, 3 pig, 5 poultry and 1 mixed), participated in the sort – either face-to-face, with an interviewer using cards, or on-line (without interviewer present). The number is acceptable for Q method, as greater numbers do not alter the significant factor loading (a figure dependent on the size of the Q set) and will not necessarily greatly alter the emergence of significant viewpoints or factors. Nor would greater numbers allow us to identify a dominant view. Indeed, the point of Q-sort method is to identify valid subject positions and understand the ways in which these are constructed. It does not give an indication of their popularity. All we can say here is that the positions we identify are significant in the shared discourse and understanding of the issue. In general, the method works best when the P set (the people who complete the sort) is numerically less than the Q set (the concourse of statements). The majority of sorts were carried out face-to-face. In each case, a randomly ordered set of statements was given to the participant who was then asked to sort each statement into piles of ‘agree’, ‘disagree’ or ‘not sure’. These pre-sorted piles were further sorted, in turn, on the grid, with participants encouraged to shuffle items or re-order as they progressed. When they were happy with the final distribution, participants could save the sort or have it recorded by the interviewer.

Correlation, factor extraction and rotation: A correlation matrix between sorts was generated and used to identify and extract factors using centroid factor analysis. The analysis was repeated until a satisfactory number of factors had been extracted. The selected factors were then rotated to maximise their alignment with real sorts (see table 3 for more detail). The resulting rotated factors accounted for 41% of the data set’s variance, and together accounted for 20 out of 26 sorts with 3 sorts confounded (where they were significant on more than one factor). Correlations between factor scores were tested and all demonstrated insignificant levels.

Factor interpretation: The total weighted scores for each statement relative to a factor were standardised in order to allow for the different number of Q sorts in each factor. The standardised Z scores were then used to generate factor arrays – or a grid of rankings that would be expected if this factor viewpoint were to sort the statements. The resulting factor arrays were then used to interpret the viewpoint, with cross-reference to any demographic, interview or other available information.

5.2.2. Results and interpretations

After rotation, Factors 2 and 4 offer the most explanatory power, so we take these first before looking at Factor 1. Factor 3 did not satisfy the selection criteria (for
more detail on selection see table 4 and accompanying text). The standard notation is used whereby a statement and its Q Sort value for the relevant factor array is denoted as the statement number (in bold) followed by a score ranging from -6 to +6 (see grid in table 2). The numbered statements are listed in table 1.

*Factor 2: THE MODERN BUSINESS - Farming works (The AMR issue may be overstated. Modern, high-health livestock systems are already working well)*

Explains 15% of the variance, has an Eigenvalue of 3.9, and includes 6 farmers and 3 vets as defining sorts. All the farmers operate intensive, indoor systems and farm pigs or poultry. The vets each specialised in different sectors (dairy, pig and poultry).

For this shared viewpoint, farmers and vets are responsible actors (15 +5) (25 -5) and are able to limit antibiotic use by maintaining high levels of biosecurity (12 +4), low inter-mixing of stock (11 +5) and a good working relationship with their vet (27 +6). There is little sense of a major issue or problem with antibiotic use or resistance (1 -1), and vehement rejection of the notion that current use of antibiotics in livestock is a risk to human health (30 -5) (or a contribution to environmental AMR (39 -4)). This viewpoint regards current livestock practices as working, and disagrees, for instance, that antibiotics are used without proper veterinary diagnosis (17 -3). This viewpoint does seem to accept that there are trade-offs between antibiotic treatment and animal welfare (4 +2). Current guidelines are clear (16 +3) and improved herd health planning is the way to reduce unnecessary use (10 +4).

*Factor 4: THE INTERVENTIONIST - The veterinary extensionist (Reductions in antibiotic use are both justified and achievable and require regulation and veterinary-led farmer education)*

Explains 16% of the variance, has an Eigenvalue of 4.2, and includes 4 defining sorts (3 vets, spread across sectors and 1 organic, outdoor pig farmer).

In contrast to Factor 2, this viewpoint starts from strong support for the statement that reducing antibiotic use is worthwhile even if the benefits for human health are uncertain (2 +5). There is also keen agreement that restricting critically important antibiotics is justified (34 +6) and that the key is to develop good working relationships between farmers and vets (27 +5). Antibiotics are not cost effective as prophylaxis (29 -5), and they are eminently replaceable without a reduction in animal welfare or a threat to current farming revenue (4 -4, 6 -4). There is support for greater regulation and enforcement (37 +3) and no sense in which restrictions are currently leading to inappropriate use (24 -5). Educating farmers (who are likely in this view to hold stocks of antibiotics on the farm) and improved herd health planning are key to reduction in use (5 +3, 22 +4, 10 +4). All of this is achievable without a hike in on-farm costs or indeed a requirement for radical change in practices. Good scientific sense needs to prevail. The regular use of antibiotics was more likely in this view to be an issue for indoor and intensive systems (28 +2), and therefore the solution to AMR may differ to that of Factor 3. It involved not simply
better (or more secure) livestock farming, but a greater presence of veterinary knowledge on the farm.

**Factor 1: THE AUTONOMIST: There may be an issue, but it can be sorted in-house.**

Explains 10% of the variance, has an Eigenvalue of 2.6, and includes 4 defining or significant sorts. (3 farmers and 1 vet).

AMR is a possible problem (2 0, 1 +2), but responsibility for change is with vets and farmers (9 +6, 33 and 26 +5). This factor is most strongly defined by a rejection of the notion that there is a need for or utility in retailers, assurance schemes, or other market or regulatory players taking the lead in changing use (32 -6, 31 -5, 36 -4). This is an anti-intervention position and one that regards itself as independent to the other market actors (in this sense it is like Factor 2, but less sanguine about outside interference)5. There is a rejection of the notion that indoor systems are likely to be the main culprits in antibiotic use (28 -5), and no strong feeling either way on the injunction to act in order to safeguard human health (2 0). There is however measured agreement that resistance in livestock may be a problem (1 +2). Again this articulation of the key concern (animal production and health rather than human health) suggests a position that an in-house solution is both reasonable and is all that is justified. This viewpoint regards improvement in veterinary practices as key. A replacement of antibiotics through greater use of vaccines, improving veterinary practice standards and the provision of better diagnostics in order to target AB use are all favoured, though there is concern that currently vets rely on sales of antibiotics too greatly (18 +4).

It is worth noting that while factor 4 is the most veterinary-led position, all three factors include both vets and farmers as significant sorts, suggesting that there are common views held across these professions.

Taking the three factors together, one possible interpretation involves plotting them within a conceptual space defined by the severity or certainty over the AMR issue against the degree to which management of the issue could be achieved within the current regulatory or operational system. We would plot it as follows:

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5 This runs against the grain of a growing consensus in regulatory practice that retail and/or consumer-led changes are the most appropriate and the least costs means of achieving positive outcomes. Given the current bind that many in farming face regarding the downward pressures on price exerted by processors and retailers, it may be less surprising that retailer and or wholesaler-led action is regarded with some suspicion. This may also represent a need to maintain some control over use and application as responsible use does not equate to absolute reduction or bans.
5.2.3. COMMONALITIES BETWEEN AND OUTSIDE FACTORS:

It is worth noting that seven statements were non-significant for each of the extracted and rotated factors (3, 6, 8, 14, 19 39, 40. All were non-significant at P>.01). This suggests that, in terms of the relative ranking, there was some degree of consensus across the factors. So, all factors were non-committed when it came to farmers controlling the use of antibiotics on the farm. We can only assume that this was a ‘sometimes/ sometimes not’ response. All factors agree that cost effective means of reduction in ABs already exist (though we have hinted that the actual means may differ – from livestock systems in Factor 2 to vaccines and veterinary planning in factors 1 and 4). All of the factors agree strongly that data collection on AM use is a priority (though we might deduce that this is in the hope that the extent of the problem is revealed, either as a minor issue (Factor 2), or a major concern (Factor 4)). Meanwhile, and of general interest, is that the sense that antibiotic use was contributing to an environmental AMR issue through residues or farm waste disposal was rejected by all factor positions.

There are dangers in reifying these views, and it is necessary to remember that nine sorts were either confounded (3) or did not load significantly onto the extracted factors (6). This may have been a function of the design (the kurtosis of the grid, or
the rather rapid generation of the concourse). That said, these kinds of figures are not unusual for Q method.

5.3. Conclusions

Despite the range of different actors involved in the sorts - the vets; the pig, poultry and dairy farmers; the indoor and more extensive systems; the conventional as well as organic production systems, which we assume to have some quite different pressures and issues - we have teased out a broader and applicable typology or set of key tensions that relate to current antibiotic use and practice. The conceptual space diagram is one possible presentation of some key tensions that the Q method has suggested. We have maintained a sense of the multivalent nature of the issue while at the same time identifying several key tensions or issues.

The implications might be as follows:

Responsible use is broadly accepted as an aim across these sectors. This is the case even though there is acknowledged uncertainty with respect to animal and public health risks.

In all cases the agency for change lay within the livestock sectors, either through modernisation of farm practices, better integration of veterinary knowledge or through the safeguarding of on farm control and discretion.

These could be read as defensive positions taken with an industry already perceived to be under siege. Or they may mark an experienced assessment of the practices that are necessary to reduce AB usage through responsible use.

Again, the implication that awareness itself is insufficient, and that its translation into specific actions is formatted through practices, through livelihood, social and human-nonhuman relations, is a key finding that is elaborated upon in the more expansive interview material that follows.
Table 1: Final Q Set

<table>
<thead>
<tr>
<th>No.</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Livestock pathogens are building up resistance to antimicrobial treatments.</td>
</tr>
<tr>
<td>2.</td>
<td>Reducing antibiotic use in food animals is worthwhile even if the benefits for human health are currently uncertain.</td>
</tr>
<tr>
<td>3.</td>
<td>Farmers control the use of antibiotics on the farm.</td>
</tr>
<tr>
<td>4.</td>
<td>Reduction of antibiotic use in livestock will increase animal welfare problems.</td>
</tr>
<tr>
<td>5.</td>
<td>Reducing antibiotic use on farms is largely about educating farmers.</td>
</tr>
<tr>
<td>7.</td>
<td>Improving farm animal welfare would reduce levels of antibiotic use.</td>
</tr>
<tr>
<td>8.</td>
<td>Cost-effective means of reducing antibiotic use already exist.</td>
</tr>
<tr>
<td>9.</td>
<td>More vaccines would reduce reliance on antibiotics.</td>
</tr>
<tr>
<td>10.</td>
<td>Herd health planning helps to reduce reliance on antibiotics.</td>
</tr>
<tr>
<td>11.</td>
<td>Antibiotic use is likely to be higher in systems that mix animals from different sources.</td>
</tr>
<tr>
<td>12.</td>
<td>Better biosecurity reduces the need for antibiotic use.</td>
</tr>
<tr>
<td>13.</td>
<td>Reducing antibiotic use would require major investment in new farm buildings and equipment.</td>
</tr>
<tr>
<td>14.</td>
<td>Reducing antibiotic use would involve radical changes in farming practices.</td>
</tr>
<tr>
<td>15.</td>
<td>The vast majority of farmers use antibiotics responsibly.</td>
</tr>
<tr>
<td>16.</td>
<td>Guidance for vets and farmers on which antibiotic to use is clear.</td>
</tr>
<tr>
<td>17.</td>
<td>Antibiotics are used instead of proper veterinary diagnosis.</td>
</tr>
<tr>
<td>18.</td>
<td>Vets are reliant on sales of antibiotics as a source of income.</td>
</tr>
<tr>
<td>19.</td>
<td>Vets are under pressure from farmers to prescribe antibiotics.</td>
</tr>
<tr>
<td>20.</td>
<td>Newer antibiotic medicines should be used in animals as they are more effective.</td>
</tr>
<tr>
<td>21.</td>
<td>Older antibiotics should be used in the first instance before any newer products.</td>
</tr>
<tr>
<td>22.</td>
<td>Keeping a stock of antibiotics on the farm is common practice.</td>
</tr>
<tr>
<td>23.</td>
<td>Without antimicrobials farmers would not be able to produce at the level they do.</td>
</tr>
<tr>
<td>24.</td>
<td>The restricted range of available products to treat animals means that less suited antibiotic medicines are being used too often.</td>
</tr>
<tr>
<td>25.</td>
<td>Some vets prescribe antimicrobials irresponsibly.</td>
</tr>
<tr>
<td>26.</td>
<td>Proper diagnostic testing should occur before any antibiotics are used.</td>
</tr>
<tr>
<td>27.</td>
<td>A good working relationship between a farmer and vet is critical to changing antibiotic use.</td>
</tr>
<tr>
<td>28.</td>
<td>Antimicrobials are more likely to be used as a matter of course in indoor and intensive systems.</td>
</tr>
<tr>
<td>29.</td>
<td>Antibiotics are the most cost-effective way of preventing disease.</td>
</tr>
<tr>
<td>30.</td>
<td>Current use of antibiotics in food animals poses a risk to human health.</td>
</tr>
<tr>
<td>31.</td>
<td>Assurance schemes are key to changing practices in antibiotics use.</td>
</tr>
<tr>
<td>32.</td>
<td>Retailers are a key influence on farm use of antibiotics.</td>
</tr>
<tr>
<td>33.</td>
<td>Improving veterinary ‘Practice Standards’ would help to reduce antibiotic use.</td>
</tr>
<tr>
<td>34.</td>
<td>Reducing the veterinary availability of antimicrobials deemed critically important in human health is justified.</td>
</tr>
<tr>
<td>35.</td>
<td>Withdrawal times should be standardised to discourage antibiotic use.</td>
</tr>
<tr>
<td>36.</td>
<td>Market intermediaries like processors or integrators are key to reducing antibiotic use.</td>
</tr>
<tr>
<td>37.</td>
<td>There should be greater regulation and enforcement of antibiotic use on farms.</td>
</tr>
<tr>
<td>38.</td>
<td>Farmers tend to ‘treat now call the vet tomorrow’.</td>
</tr>
<tr>
<td>39.</td>
<td>Residues from farm waste contribute to antimicrobial resistance in the environment.</td>
</tr>
<tr>
<td>40.</td>
<td>Data collection on antimicrobial use is an important priority.</td>
</tr>
</tbody>
</table>
Table 2: The sorting grid

<table>
<thead>
<tr>
<th>-6</th>
<th>-5</th>
<th>-4</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>+4</th>
<th>+5</th>
<th>+6</th>
</tr>
</thead>
</table>

MOST DISAGREEMENT  MOST AGREEMENT
Factors were judged on their explanatory variance, Eigenvalues, whether or not they contained two or more significant factor loadings, and whether the cross product of the two highest loadings on the factor exceeded twice the standard error. In this case four factors were extracted and three factors were selected. Factor 3 was not taken further as it failed all the relevant tests listed in table 4 (its Eigenvalue was less than 1, failed to produce two or more significant loadings and was almost a factor of 10 times of Humphrey’s Rule).

**Table 3: Factor selection criteria for AMR Q sort**

<table>
<thead>
<tr>
<th></th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Expl. Variance</td>
<td>24</td>
<td>8</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Eigenvalues</td>
<td>6.3</td>
<td>2.2</td>
<td>0.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Two or more significant loadings (Sig factor loading score is 0.408)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Humprey’s rule (product of 2 highest factor loadings &gt; 2 x SE = 0.316)</td>
<td>0.547</td>
<td>0.346</td>
<td>0.035</td>
<td>0.352</td>
</tr>
</tbody>
</table>

Factors 1, 2 and 4 satisfied all the selection criteria. Pre-rotation, they accounted for a reasonable 40% of the variance.

Factor rotation was then used to maximise the alignment of selected factors with as many sorts as possible, without generating correlations between factors. An automated Varimax solution was employed, resulting in adjustments to the factor explanatory variance to 10%, 15% and 16% for factors 1, 2 and 4 (EVs of 2.6, 3.9 and 4.2). Defining sorts were then flagged in each of the selected factors (i.e. any sort that had a loading on a factor of greater than 0.41, the significant factor loading, was flagged in order to highlight its alignment with that sort). Confounded sorts (where sorters were significantly loaded on more than one factor) and those that were non-significant across all factors were also noted. For more information on the methods adopted, on extraction, selection and rotation see Watts and Stenner 2012.
6. Qualitative Interview Research

6.1. Context

As specified above (Section 2), the approach adopted for the qualitative research has been guided by the concept of ‘social practice’. That is to say how individual and collective awareness and actions intertwine, and how social and economic relations (and the institutions, technologies, rules and knowledges that sustain them) create (transferable or not-transferable) patterns of practice. Social practice also addresses the many ways in which these actions and patterns of practice might be disturbed and re-configured to further impact upon awareness and understanding. In this approach, the current research seeks to go beyond the more traditional behavioural and attitudinal research approaches that have so far characterized the bulk of investigations into the use and prescription of AMs by farmers and veterinarians. In doing so, the current research has sought:

- To understand how, and the extent to which, the (systematic and specific) use of AMs is integrated into different systems and practices of livestock farming through the materials, sites, rhythms, tools, shared ideas and practices of animal health care,

- To identify how individual and collective farmer and veterinarian attitudes, priorities and understandings towards the reduced or sustainable use of AMs might be differentially embedded in those practices and the information systems and flows that derive from practice, and

- To explore how social practices might be perceived as encouraging or leading to changes in individual prioritization and response.

The qualitative research thereby follows from the Q sort as the ‘second step’ in understanding how on-farm practices respond to and re-frame awareness.

6.2. Method

Empirically, the focus for the qualitative research has been the practices of farmers and veterinarians. To undertake the research within the limited time frame of the project (January to March 2015), a convenience sample of interviewees was constructed using established contacts and the team’s knowledge of – and contacts with - the various production sectors and veterinary practices.

A sample of farmers and veterinarians was constructed for each of the production sectors. Interviewees were selected, where possible, to reflect geographical variation (within England), relevant variation in farm/flock/herd size, size of the veterinary practice (for veterinary surgeons) and location. Although the selection of the
interviewees cannot be said to be categorically representative of each sector, care was taken to ensure that interviewees generally conformed to expected variables of production. For example, farm enterprises with herd/flock sizes well under the general averages for the sector were not considered.

Following the parameters laid out in the original bid, five farmers were interviewed from each of the three major sectors. The final farmer/vet interviewee list is shown in Table 5.

Table 5: Selected interviewees

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Indoor/Outdoor</th>
<th>Conventional/Organic</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig farmer 1</td>
<td>Outdoor</td>
<td>Conventional</td>
<td>Somerset</td>
</tr>
<tr>
<td>Pig farmer 2</td>
<td>Indoor</td>
<td>Conventional</td>
<td>Somerset</td>
</tr>
<tr>
<td>Pig farmer 3</td>
<td>Indoor</td>
<td>Conventional</td>
<td>Yorkshire</td>
</tr>
<tr>
<td>Pig farmer 4</td>
<td>Indoor</td>
<td>Conventional</td>
<td>Bedfordshire</td>
</tr>
<tr>
<td>Pig farmer 5</td>
<td>Outdoor</td>
<td>Organic</td>
<td>Gloucestershire</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Broiler/Layer</th>
<th>Conventional/Organic</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry farmer 1</td>
<td>broiler</td>
<td>Conventional</td>
<td>Somerset</td>
</tr>
<tr>
<td>Poultry farmer 2</td>
<td>broiler</td>
<td>Organic</td>
<td>Pembrokeshire</td>
</tr>
<tr>
<td>Poultry farmer 3</td>
<td>Caged layers</td>
<td>Conventional</td>
<td>Cheshire</td>
</tr>
<tr>
<td>Poultry farmer 4</td>
<td>layers</td>
<td>Organic</td>
<td>Devon</td>
</tr>
<tr>
<td>Poultry farmer 5</td>
<td>Free range layers</td>
<td>Conventional</td>
<td>Oxfordshire</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Indoor/Outdoor</th>
<th>Conventional/Organic</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy farmer 1</td>
<td>Large indoor</td>
<td>Conventional</td>
<td>Cheshire</td>
</tr>
<tr>
<td>Dairy farmer 2</td>
<td>Indoor/outdoor</td>
<td>Organic</td>
<td>Gloucestershire</td>
</tr>
<tr>
<td>Dairy farmer 3</td>
<td>Indoor/outdoor</td>
<td>Conventional</td>
<td>Somerset</td>
</tr>
<tr>
<td>Dairy farmer 4</td>
<td>Indoor/outdoor</td>
<td>Conventional</td>
<td>Somerset</td>
</tr>
<tr>
<td>Dairy farmer 5</td>
<td>Indoor/outdoor</td>
<td>Conventional</td>
<td>Shropshire</td>
</tr>
</tbody>
</table>

Scheduled interviews were also held with a number of veterinarians, all from different veterinary practices across the country. Three specialist vet interviews were carried out from each sector (Table 6).

Finally, eight interviews were held with identified key actors drawn from the food sector, assurance schemes and certification and regulatory authorities. These interviews have provided both context and specific viewpoints in the subsequent analysis. In total, 32 interviews were completed.
The interviews were recorded with the full permission of the interviewee. Codes of practice were followed to secure fully informed consent for all relevant aspects of the research. The majority of the interviews were face-to-face. On average the interviews lasted around one hour, the longest stretching to nearly four hours. All interviews were carried out in February and March 2015.

Table 6: Interviews with veterinarians

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Location of practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy vet 1</td>
<td>South West</td>
</tr>
<tr>
<td>Dairy vet 2</td>
<td>South West</td>
</tr>
<tr>
<td>Dairy vet 3</td>
<td>Midlands</td>
</tr>
<tr>
<td>Pig vet 1</td>
<td>Yorkshire</td>
</tr>
<tr>
<td>Pig vet 2</td>
<td>Wiltshire</td>
</tr>
<tr>
<td>Pig vet 3</td>
<td>Herefordshire</td>
</tr>
<tr>
<td>Poultry vet 1</td>
<td>Yorkshire</td>
</tr>
<tr>
<td>Poultry vet 2</td>
<td>South West</td>
</tr>
<tr>
<td>Poultry vet 3</td>
<td>South West</td>
</tr>
</tbody>
</table>

The interviews were semi-structured, employing a pre-developed list of questions and areas for discussion and debate. They took the form of (often lengthy) free-flowing debate allowing, where appropriate, for the drilling down of the enquiry into areas of specific detail and practice. On a number of occasions, the interviewers were invited to visit the farm and to look at medicine books and on-farm medicine storage facilities.

While the research team aimed to achieve sample balance across and within sectors, the participants are in no way expected to reflect a numerically robust sample. Nevertheless, the interviews often lasted for a long period of time, and a rapport was often established with the participants such that they spoke frankly and in a way that allowed them to tell us, in no uncertain terms, which issues were of most importance. In this, the interviews should be thought of as representative not in terms of the breadth of the sample, but in terms of the depth of engagement and exploration of issues. Critically the research method employed sought from the outset to reveal and explore - through a dialogue with the interviewees - the complexity, messiness and multiplicity of the social practices (Law 2004) that operate in the farm and in the veterinary practice, through which the prescription and use of AMs occurs.

The transcribed interviews were subsequently analysed for common and contradictory themes, for specific examples of practice, for relevant statements that would support identified common positions and for an understanding of the range of practices within which the use and prescription of AMs constituted a regular (or irregular) component.
6.3. Results

This section draws out the principal comparative (and in places, contrasting) themes from the analysis of the interviews before presenting the key messages from this research. The results are presented under three key headings: awareness, practice and responsibility.

6.3.1 Awareness

The Rapid Evidence Assessment suggested that, within the UK, farmers and veterinarians are aware of the wider AMR issue and of the general expectation to practice responsible AM use. As a starting point, the research carried out here shows that within the livestock sectors under study, there is certainly an awareness of the broader issue of AMR in human medicine and an understanding amongst both vets and farmers that the use of AMs in farming is part of that broader debate.

We have found neither unequivocal resistance to the notion that this is a legitimate area of concern nor a sense that this is solely an issue for human medicinal prescription and use.

“The excessive use of antibiotics to keep animals that intensively is going to have a side effect on human health if it’s going to mean that antibiotics are less effective for them.” (Dairy farmer)

Farmers and vets tended to talk about the broad aims of sensible use in approving terms:

“We’re being told that antibiotic resistance is increasing in the human population which means that it is in some of the food we eat [...] I entirely understand why there is pressure to stop giving drugs to chickens.” (Poultry farmer)

That being said, the lack of clear evidence linking AM use in livestock production to the development of resistance in human pathogens introduces a sense of doubt over the extent of farming’s role in this issue:

“Someone has done some research I’m told that shows that, of the resistance in humans, only 5% is coming from animal use of antibiotics and 95% from doctors. So, [...] we don’t feel quite so bad about it, and most probably the people who are at danger are the people who are working with animals - myself and the farm workers.” (Poultry vet)

AM use is therefore an acknowledged issue, but the broader contribution of farming to the growth of resistance in human pathogens and the particular impact of sector-wide and individual farm animal health management practices is contested by farmers and some veterinarians. In the absence of a validated chain of evidence, this has implications for how terms like ‘sensible’ or ‘responsible’ use become justified in warranting changes to existing practices.
Respondent farmers are by no means universally convinced that their existing practices in AM use are, given current circumstances, excessive, irresponsible or indiscriminate. Some would go further in expressing a concern that livestock farming is being indiscriminately identified as a contributory element to the development of AMR amongst human pathogens, particularly when they themselves follow what they see as attentive practices in their own use of AMs. In a number of instances, farming was seen as being a ‘scapegoat’ with little concrete ‘evidence’ to support the call for drastic actions.

One might suggest that a possible contributor to a more informed awareness of the issue and of the place of farming within the wider debate might come from direct experience of resistance amongst animal pathogens on the farm and subsequently prolonged illness or aggravated mortality levels amongst livestock. In this sample, however, farmers and veterinarians differed significantly in their acceptance that this was a real issue. While some veterinarians certainly acknowledged the growing concern, others – often within the same production sector – dismissed it as unfounded. Nonetheless, in the absence of research data on resistance amongst animal pathogens, farmers and veterinarians did provide first-hand accounts, rather than clinical evidence, of probable or potential cases of on-farm resistance and of their own strategies of response. Certain antibiotics were perceived to be getting less and less potent, with farmers feeling that they had to use them more frequently than before to achieve similar results. One consequence of this was that farmers (and in this, the respondent poultry farmers stand out) seek regular changes to the medicines prescribed in order to avoid the perceived build-up of resistance amongst their stock, even though they often do not explain the phenomenon in these terms.

“You just don’t start with a product and use it nonstop, you’ll vary it ... you don’t use the same load of chemicals all the time because it builds resistance up." (Poultry farmer)

“You will get a farmer ring up and say ‘I put my birds on this last time, and I’m not convinced it works. I want to try something different,’ and so that kind of translates as maybe resistance.” (Poultry vet)

“It isn’t any good spending money medicating them, and they are dying, and so we had some testing done and the bugs were resistant to that antibiotic, so we changed antibiotics, and it’s cured up.” (Pig farmer)

“The fewer you use, the better they work when you do actually use the things.” (Poultry vet)

Interviewed farmers and vets do recognize an occasional lack of efficacy in the medicines being used, or treatment failure, that may point to resistance on the farm (as one of a number of possible causes). They respond to this through managed medicine change while at the same time challenging what they perceive as an ill-informed accusation that the use of AMs in livestock farming is contributing towards resistance. This suggests a dissonance in the perception of these two issues as being unconnected. This has implications for how the broader discourse of ‘better’ AM use might be framed, with an emphasis on improving understanding of the links between medicine use and disease/resistance development.
In summary, respondent vets and farmers are certainly aware of the broad issue of AMR in human medicine and recognize the need to act responsibly in the use and prescription of AMs in livestock farming. However, the perceived lack of robust data linking livestock use to human pathogen resistance coupled with a seeming reluctance to recognize resistance as such amongst farm animals as a growing concern, suggests a potential barrier to more holistic human health/animal health approaches (e.g. Craddock and Hinchliffe, 2015).

Awareness is mediated to farmers in a number of ways: veterinary advice, assurance scheme and certification policy and, to a lesser extent, herd health planning. It is also mediated through a more general awareness of the broader issue (via the farming press, continuing education events, and so on). However, awareness by itself implies no necessary compulsion or obligation to act (cf: the growing literature on environmental awareness and subsequent inaction; Blake, 1990; Kolmus and Agyeman, 2002). The assumption that awareness inevitably leads to behavior change has been shown to be overly simplistic. The research presented here has sought to throw light on how awareness of the broader AM issue articulates with embedded farming and veterinary practice, if indeed it does. We also seek to expand on how the embedded practices of livestock farming allow or contribute to a re-framing of awareness (an issue that was raised through the Q sort analysis above).

At one level, the research suggests that little has changed in terms of on-farm medicine use. Interviewed farmers did not register significant reductions in their levels of AM use over the last five years; medicine use was described as relatively stable through that period. The veterinarians interviewed confirmed this picture, identifying no real reduction in AM use over the last half-decade. Those farmers that did record a substantive reduction largely explained it as a consequence of conversion to organic production. For one organic dairy farmer, the impact of reduced antibiotic use following organic conversion was described as ‘a bit restricting’ having led to an increase in the culling of sick animals. He went on to describe the effect on yields and performance in the following way:

“It’s always a bit and miss as well, especially the mastitis, it’s quite difficult at the moment. We’ve got a lot of cows calving inside and you know, we used to use that dry cow therapy where you put [...] a long-acting antibiotic when you dry them off and we try and steer clear of any of that now, but if you go too far you end up calving cows with mastitis and then you’ve got a job to get rid of it. [...] We don’t use anything we just dry them off and that’s it, we stop milking them. But we only milk once a day, so they dry off quite quick, quite well you know. [...] We’ve upped the cow numbers because we’ve gone over to once a day milking, so we’ve had to increase the herd in order to keep the yield up because obviously you get a reduction in yield when you go to once a day milking” (Organic dairy farmer).

At another level, however, we noted a variety of responses in farming practice that incorporated, either directly or indirectly, acknowledgement of the issue of (inappropriate) AM use. These might be re-grouped into three distinctive forms of practice that cut across the different production sectors. We have entitled these:

- Changing antimicrobial practice
- Legitimating antimicrobial practice
• Risk managing antimicrobial practice

6.3.2. Practice

6.3.2.1. Changing antimicrobial practice

Where changing practices of AM use have taken place on respondent farms, they cannot always be expressed as a simple reduction in the use of AMs. Rather, that change was expressed, by both farmers and veterinarians:

i. in the balance of medicines used (reduced use of more expensive, newer AMs; greater reliance on cheaper, older AMs (some of which may require higher doses and longer withdrawal periods than newer medicines); using the more contentious higher efficacy medicines as ‘last resorts’);

“We have migrated towards what we would describe as the older products [...] and less of the newer products over the last probably three or four years. We’ve actually found that they’ve mostly worked fine in the sort of conditions that we’re using them. So there hasn’t been any loss of efficacy, it’s been cheaper for the farmer. The only people who have probably lost out have been the pharmaceutical companies where the mark up is tiny.” (Dairy vet)

ii. in a reduction in the tendency to see AM use as ‘crutch’ or ‘insurance’ for the livestock industry – coupled with an acknowledgement of the need to shift towards less prophylactic and metaphylactic use in favour of more therapeutic use;

iii. in the use of targeted (therapeutic) treatments within some systems;

iv. in an increasing reliance on vaccinations (in some sectors);

v. in recognition of a shift in technologies for the application of medicines or preventative treatments (e.g. teat sealants), and

vi. in a move away from certain ‘blanket’ treatments, increasingly seen by veterinarians as ‘inappropriate’.

“I think within the dairy sector it is inevitable that we will go towards reducing antimicrobial usage when it comes to dry cow therapy which, as I said earlier, is the biggest area of use of antimicrobials in dairy cows, and I think that there is the flexibility to be able to do that, and if vets provide the structure for the farmers of which animals it should be using antimicrobial dry cow therapy on and which animals they don’t need to use antimicrobial dry cow therapy on, then they can use just teat sealants instead, then I think we can educate farmers going forwards, and that will work with some of our farmers.” (Dairy vet)

The individual reasons for these changes in current AM practice on farms are nevertheless complex and are not generally expressed as responses to either individual or collective concern over pathogen resistance. The drivers include:
• Differential costs of AMs

“If we’re a bit more careful and a bit more analytical in the use, we could reduce and save the money as well.” (Dairy farmer)

“It could improve the profitability if we stopped treating healthy animals. It’s a waste of time and money.” (Dairy farmer)

• Consumer pressure (transited through assurance schemes)

“People are having a greater, the public having a greater awareness of it. I think it’s a big thing, and you know when the customer starts saying to the supermarket ‘What are you doing about it?’, then they put the pressure on the farmers, and there we are.” (Poultry vet)

“There’s not so much pressure on the small animal industry whereas poultry there is definitely, from companies like [a major retailer] and things like that.” (Poultry vet)

• Sense of professionalism and of ‘good farming’

“If you’ve got to keep animals and you can only keep them with medicated feeds and stuff like that, then like I said before, you’re doing it... you’re not doing it right.” (Dairy farmer)

• Certification requirements

“When you have your organic inspection, they have a fit because you have used too much antibiotic.” (Organic dairy farmer)

• Veterinary advice

“All we can do is go by our vet. I really think the onus is on the vet to be responsible and just advise the farmer on dosage rates and everything else. And really it’s up to the veterinary profession isn’t it... that’s their job not the farmer’s.” (Pig farmer)

Within this particular set of practices, farmers and vets across the sectors maintained that there was flexibility in production systems to allow for changes towards more sensible antibiotic use, though this may well entail additional tasks:

“So I believe the flexibility is there, it does rely on the farmer’s milk recording which means recording on a regular basis the cell counts and levels of mastitis within their cows, so that might affect farm business management.” (Dairy vet)

... and some risk.

“If we had to stop giving drugs, I could see production probably falling away but hopefully by no more than about 2-3%.” (Poultry farmer)

“I think it can probably work, I think one day. It worries me a little bit but not too much. I know quite a few farmers who are already drug free, so it can be done.” (Poultry farmer)

“I would be quite happy to accept 5% mortality across the board.” (Pig farmer)
“I believe the flexibility is there [...] so I don’t think margins would be affected significantly.”
(Dairy vet)

“With group medication in feed, if you don’t stop using it, you will never know the consequences on not using it. It becomes a habit. I took everything out [prophylactic AM treatment] and didn’t see any consequences.” (Pig farmer)

For certified organic farmers, reduction in the use of AMs brings added challenges

“We don’t use anything at all apart from the odd antibiotic on an individual animal. But in the last couple of years we’ve had to use a wormer and we’ve introduced a vaccination program very recently because we had a pig at the slaughterhouse identified with Erysipelas. So, but as far as the Soil Association is concerned, vaccinations are okay. But anything, apart from treatment of an individual animal with the vet’s permission, we need to apply for a derogation for. If we did have something really nasty break out in the herd and the only course of action would be a blanket treatment for the whole herd, we would have to get special permission. And possibly that might mean the loss of those animal’s organic status. So it is quite tight, the regulation”. (Organic pig farmer)

Reducing dependence on medicines is, according to one farmer, ‘easier when food prices are high’. Yet in this sample, we uncovered no sense that producers in modern intensive systems are any less likely to be willing to act in achieving more sensible use of AMs than those operating more extensive or smaller scale enterprises.

6.3.2.2. LEGITIMATING PRACTICE

A second set of practices we identified from the qualitative research centred around the legitimation of current levels of AM use. Here, medicines are seen as a vital and necessary tool in protecting the health and welfare of farm animals, particularly at certain set periods in their life or production cycle. Levels of use are considered appropriate, sensible and legitimate within the context both of contemporary production requirements and the broader debate over AM use in both animal and human medicine, and are defended as such. The arguments put forward in support of this set of practices include:

- A consistent and cross-sectorial concern for maintaining high levels of animal health and welfare, and the belief that not using AMs would compromise this.

“It’s part of the toolbox; you have to be able to do something because ultimately if they are ill, you’ve got to look after them. You can’t just not.” (Pig farmer)

“You’ve got animal welfare issues. You know there is a requirement to keep the animals healthy; you can’t just let them cough and wheeze just because I don’t want to use antibiotics.” (Pig farmer)

“Animal health would be affected [...] you know, that has to be taken into account.” (Poultry farmer)

“Purely from a welfare point of view, I wouldn’t be happy to farm without them. You could. If we didn’t have AMs, we would cull animals more/sooner - if something is not responding to treatment. I am not sure the level of production would be the same; we would lose a few animals but not that many, I wouldn’t say. I don’t think it would make an awful lot of
difference to us. It would make a difference to me personally, having to decide that there is no course of treatment other than dispatch.” (Pig farmer)

• A belief that current levels of use were ‘sensible’ and ‘appropriate’ to intensive production systems. Here farmers regarded their own, largely therapeutic, use of AMs as wholly justified, partly because the medicines, as currently used, were seen to be doing a valuable job in maintaining both farm productivity and animal health, and partly because the farmers followed veterinary advice. Major changes in the way AMs could be used would necessitate some redefinition of the goals of productivity and acceptable levels of animal welfare/health. In most cases, farmers felt that they had achieved a satisfactory balance between, on the one hand, animal health and productivity and, on the other, meeting concerns over AM usage.

“You wouldn’t use them if you didn’t need them.” (Dairy farmer)

“We can’t just stop, if its going to lead to a falling off in chicken health and also obviously in the business margins.” (Poultry farmer)

- “They are producing on a knife-edge and you know working really hard metabolically, and therefore they are more susceptible to infection whether its bacterial or viral or mycotoxins or anything like that.” (Poultry vet)

• The assertion that current levels of use have full veterinary approval. Farmers here stressed the importance of diagnostic and sensitivity testing as legitimation for their use of AMs.

“It isn’t up to me to say what the dose is, that’s the vet’s responsibility. So he just tells me on his prescription to the feed firm, how much to put in, you see. So it’s out of my hands basically.”(Pig farmer)

“As to which drugs we can use, I must admit I just totally rely on the advice of my vet [...] I certainly haven’t got the freedom myself. It is very much determined on the production cycle and the vet’s word on it.” (Poultry farmer)

• Concern to maintain current production levels. Across the different sectors, there is an awareness of the need to achieve a viable balance between costs, productivity and the acceptability of possibly higher levels of mortality and animal suffering if AM use it to be reduced or constrained. As one vet put it, would it be socially or professionally acceptable to raise birds without any AMs, yet with 25% mortality? One organic poultry farmer, who no longer administers AMs prophylactically to his entire flock, maintains that a certain threshold of mortality, if reached, would lead him to reconsider. Another farmer argues:

“There’s no doubt we couldn’t do without it. No, we couldn’t do without them. I mean we could, but you know the place wouldn’t be profitable at all really.” (Pig farmer)

Within these legitimising practices, certain aspects of current medicine use appear as lines that cannot be crossed under existing farming systems, for example the generalised use of dry cow therapy in dairy or the blanket treatment of weaner pigs.
This suggests that such practices, if seen as increasingly unsustainable within the context of concern over AMR, will be amongst the most difficult to change.

“I do think it would be nice to have some convincing, really convincing data that we could drop blanket dry cow therapy and that we have enough information from monthly cell counts to do that, ‘cos farmers are not convinced, and I am not totally convinced.” (Dairy vet)

In the legitimising mindset, AMs play a critical supporting role in contemporary livestock farming. Repeat prescriptions are the norm (amongst the respondent farmers and veterinarians concerned), along with blanket treatments and the lack of systematic analysis/testing to differentiate which animals need treatment from those who do not. Herd health planning, though undertaken (often as a necessary component of assurance), was not considered a driver of change.

6.3.2.3. Risk managing practice

“If you’ve got good management systems, then I think you’ve got more scope for reducing your reliance on quite a few inputs – not just antimicrobials.” (Dairy farmer)

A third set of more heterogeneous activities and strategies group around what we have termed the risk management of AM practice. Common husbandry actions are emerging that facilitate more appropriate use of AMs as elements of broader strategies for improvements in animal management, hygiene and the reduction of infection risk. As one vet put it, using an AM is usually recognition that something on-farm has ‘gone wrong’. Hence, although the reduction of AM use is neither the sole nor the central driver for these various management actions, it is nonetheless seen as a component – or a desired outcome - of the broader on-farm improvement.

The practices observed in this area include:

- Restocking and improved practices for sourcing animals from breeders and from other farms with comparable animal health profiles to ensure better herd health

  “If the health of the pigs got to the point where we were using excessive amounts, then we’d destock and, you know, restock with fresh blood.” (Pig farmer)

  “In the end, everything was slaughtered, the place was cleaned; that lasted 18 months - he’s not had an antibiotic. It hasn't done my business any good, but he’s a lot happier, but it was the right advice.” (Poultry vet)

- Improved management of animal housing and hygiene to reduce conditions for infection and disease.

  “Hopefully if we get the management correct, we haven’t got to use the medication, because the medication costs money.” (Pig farmer)

  “If you get the ventilation right, you don’t get pneumonia.” (Pig farmer)
“If there is a disease, you need to be able to medicate it or, you know, as a short sharp thing to get them better, and then they have to look at your production systems of making sure that it doesn’t come back again.” (Pig farmer)

“If you can get the buildings clean and keep the pigs clean, you don’t need it [antimicrobials].” (Pig farmer)

“I’ve reduced the risk by having an all in/all out system.” (Pig farmer)

Others include: reducing animal stress, improved feeding conditions, better on-farm biocontainment and avoiding where possible the mixing of different age groups of animals in a single housing unit. Yet, as one veterinarian pointed out, the ability to make long-term investment decisions to reduce the risk of infection can be dependent upon economic circumstance:

“There are some very good farmers who will always be very good farmers, but there are some average farmers who will be better farmers when the milk price is high and when the beef price is high or the lamb price is high ‘cos they’ll make those investments in short term things like straw and cleaning out and labour, but they will also make those long-term investments in housing and tracks and things like that which will improve things.” (Dairy vet)

### 6.3.3 Responsibility

#### 6.3.3.1 The Farmer-Vet Relationship

Often seen as critical to the development of effective strategies of response to animal health issues (see the Rapid Evidence Assessment above and also Fisher, 2013; Enticott 2011; Escobar and Buller, 2014), the relationship between vets and farmers emerges from the qualitative research as a key factor in the way in which AMs are not only embedded in practice but in which their use can also be either contested or legitimated. There are three points here.

First, while the prescription process itself is generally regarded as robust and effective by respondent vets in all three sectors, there is a strong sense of concern that information and data on the actual application and use of medicines by farmers is largely opaque and/or absent. Although prescription data is largely recorded in a systematic manner, vets have little data on actual usage.

Hence, a crucial element of trust needs to exist between veterinarian and farmer, particularly in the (frequent) use of repeat prescriptions and in those abundant cases when individual farmers will administer AMs from their on-farm reserves.

“Yes I do make repeat prescriptions but the way it works is the farmers ring up, and if they have an animal that is that they feel that they have made their diagnosis on the animal before that they feel that they know what the condition is, then they will request the antibiotic from us; ok, and if we’re happy that the farmer has made that decision, then we will allow them to come and collect the antibiotic and not see the animal.” (Dairy vet)
"You know, a lot of our farmers do have a stock of antimicrobials. I would think that it is not a large spectrum, I would think it would be the most commonly used antimicrobials: so specifically penicillin and oxytetracycline and maybe the occasional bottle for treating calves for pneumonia." (Dairy vet)

Respondent vets and farmers across all sectors agreed that, in the main, AMs are administered to farm animals not by veterinarians, but by farmers. The implication of this transfer of responsibility from prescription to administration was that vets have no means of confirming that farmers follow correct doses and application periods once prescriptions have been made and medicines acquired.

Yet, for some veterinarians, there was a strong sense that client farmers were skilled and experienced and used the prescribed medicines properly and responsibly.

“I do think the majority of farmers [...] are getting much better at giving the correct dosage, and there’s not many farmers that don’t give it for the correct duration; most will, you know, know now to give a course, not just a single shot of antibiotic; you know they know to give the course [...] the majority of our farmers I would think are using antimicrobials in a good enough way or an acceptable way.” (Dairy vet)

For the farmers, veterinary instructions over dosage and application should be sufficient.

“It isn’t up to me to say what the dose is, that’s the vet’s responsibility. So he just tells me on his prescription to the feed firm, how much to put in you see. So it’s out of my hands basically.” (Pig farmer)

“If you’re given a course of antibiotics, then it’s your responsibility to carry on that course until it’s finished, otherwise you’re going to knacker it all up [...] you’re going to do it by the book.” (Dairy farmer)

However, other veterinarians interviewed were less adamant in their belief that their clients were administering medicines in the proper manner or in the proper dosage. Although the predominant assumption and evidence from this study is that the ‘sensible’ use of AMs implies an overall reduction in their use, a counterview was also expressed. Any potential build-up of resistance in pathogens might indeed be the result of under-dosing of AMs, either through the under-estimation of body weight or through inaccurate on-farm mixing of medicines into feed. Some farmers, vets held, may cease treatment before the recommended stop date, either in order to save money or because, in their judgment, the animal appears to be ‘better’ or ‘cured’. As one dairy vet put it, ‘We cannot be sure the farmer is getting it right’.

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7 In a recent report, the EU Commission, citing a field study in Germany, estimates that under-dosing occurred in over 70% of studied cases on on-farm mixing of medication into animal feed. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014SC0271
Second, although herd health plans were widely used amongst respondents, their value as a mechanism for seeking more sensible use of AMs was seen as limited; in reality, these herd health plans were seen as a checklist for compliance rather than a strategy for adaptive change:

“Every farm has a permitted medicine list, so you can’t phone up and say ‘I want this or that’, and they can’t even try and trick the system and order something exotic and hope our dispensers will dispense it because they won’t. So if it’s not on their checklist, they don’t get it.” (Pig vet)

In alignment with other recent research (Escobar 2015), respondent farmers did not regard on-farm medicinal record-keeping as a useful procedure for the management of medicine usage. Rather it was seen as part of a set of procedures used primarily by external agencies to monitor on-farm use, either for reasons of legal or assurance scheme conformity. From the farmer experiences, it becomes clear that medicinal and animal health record-keeping exists in two parallel forms: that which is required periodically by legislation and certification and that which is actually used on a day-to-day basis by the farmers for their animal health management practices; to a large degree, these are two separate endeavours.

Veterinarians were nonetheless clear in their insistence that the use of medicines on farm animals should always be a veterinary decision.

“I like to think that my prescribing practices take the form of what is most likely to make the animal better or improve its health, and that is my main justification for choosing an antimicrobial not pressure from the farmer or pressure from the industry, and so I base my decisions on research and on experience and on the experience of individual clients, and that makes and forms the basis irrespective of whether it’s a new medicine or a tried and tested medicine.” (Dairy vet)

Third, vets interviewed increasingly sought – or acknowledged that they should seek – to reduce the prescription of later generation cephalosporins and fluoroquinolones, particularly for prophylactic use, in preference for the ‘older antibiotics’, retaining the more recent medicines for more exceptional circumstances. Many regularly review their own veterinary practice guidelines over the use of AMs, and all felt that this should be encouraged in other veterinary practices. Finally, a number of veterinarians expressed a certain frustration with the limited range of AM products available to them (notably in the poultry sector) and the flexibility of the Cascade system, arguing that the narrow usage specifications of some permitted medicines prevented cross-species use, or use for infections other than those specifically identified, thereby ‘forcing’ them to initiate the Cascade and employ AMs they would prefer not to have to use.

6.3.3.2 RESPONSIBILITY, POLICY AND GOVERNANCE

While respondent farmers and veterinarians across the sectors recognise government and, though to a lesser extent, ‘Europe’ as proselytisers of broad political concern over the development and consequences of AMR as a public health
issue, this sits alongside, first, a clear sense that veterinarians - both within individual practices and as part of larger corporate food/processing groups - were the critical drivers in the promotion of ‘responsible’ use through prescription practice and advice and, second, that retailers, sector organisations, assurance schemes and certification bodies played important roles in pushing specific actions through independent market-led regulatory means or through assessors and advisors.

“I think it's firstly from the vets' responsibility; ultimately you are the one giving, signing the prescription. I think you need to make sure that clinically it's the right thing to do and according to sensitivity results. I think it's the farmers' responsibility to make sure that everything else on the farm – so, how clean the environment is when the chicks are placed, what the ventilation is like, what the litter is like, what the water quality is like - I think they need to try and make sure that everything else is as good as possible to try and prevent the bacterial infection.” (Poultry vet)

“I think we’re probably seen as leading it as much as anybody. You know, we’ll put things in newsletters, we’ll have discussions on farms, we’ll get involved that way, so, I mean, there has been a suggestion that we were going to do something through [named supplier] on antimicrobial resistance.” (Dairy vet)

On occasion, the two work in tandem:

“For the stubborn farmers that just want certain antibiotics, I think it’s good for supermarkets and integrators and/or whoever they supply their chicken to put pressure on them in that way. I think some is [given name of processor]; I think they have a blanket ‘no enrofloxacin use’, so that makes our lives easier because, you know, I can say, ‘Well, ok, you might want Baytril, but if I put your birds on Baytril you're not going to be able to sell them to [given name of processor], and you won’t get any money for them. So that makes it easier as well. So yeah I think it’s a group response.” (Poultry vet)

Veterinarians thus play a central role in defining (and legitimating) ‘best practice’, even within the increasingly regulated environment of private assurance. As one major milk buyer and dairy processing company put it: ‘It is not for us to say what ‘best practice’ is. But we must facilitate it’. To facilitate it, food companies may set rules regarding the use of certain medicines amongst their suppliers, but vets are the ones who ‘make it happen’.

Respondent farmers and veterinarians point to food company rules as well as private assurance and certification schemes as having a growing impact on medicine use within livestock practice through rule-making, monitoring and data gathering and, on occasion, through encouragement. Increasing integration across the production sectors included in this study would permit potentially large-scale shifts, particularly where a single company could specify required changes in on-farm medicine usage. While farmers acknowledge the advantages of such schemes both in articulating consumer and societal demands and in providing access to markets, there are also concerns relating to the broader efficacy of some of the mechanisms they employ (compliance documentation, ‘tick-box’ conformity and so on), as well as to their tendency to impose conditions on an already pressurized system for reasons that are not always apparent to the farmers themselves.
7. Key Concluding Points

This research has contributed to an in-depth and informed understanding of the practices of AM use on farms, and to how those practices are affected by and, in their turn affect, farmer awareness of the issue of AMR. The report argues that such an understanding should not be limited to, or framed within, simplistic notions of behaviour or of ‘attitude-action’, but rather should be drawn from an appreciation of how the issue of AMR becomes differentially embedded into the multitude of actions, structures, relations and priorities that collectively make up the practice of farming.

The research has employed and combined three different methodological approaches to the investigation of AM use: a rapid evidence review, drawing in research literature from the UK, Europe and the US; an innovative Q Sort analysis of farmer and veterinarian positions regarding AM use; and a qualitative research programme based on semi-structured interviews with farmers, vets and food industry actors.

Participants in this research were both aware of the AMR issue, as well as its likely importance for livestock farming and were largely cognizant of the fact that change to AM use was likely. The question of how much change, and how this would be implemented (from within the sector, or installed from outside) were however key areas of uncertainty and possible tension. “Appropriate use” and other terms, designed to abrogate the use of blanket reduction, tended to calm fears of escalating costs in terms of production or animal welfare. However, defining terms is not simple, and there is no single ‘one-size-fits-all’ understanding of ‘sensible’ and ‘appropriate’.

Veterinarians play a key role not only in advising farmers over appropriate AM use and changes to use practice, but also in legitimating existing use practices. Veterinarians thereby emerge as critical actors in the negotiation of what is, or should be, ‘sensible’ and ‘appropriate’ within the context of each individual farm.

Although there are significant differences in the use of AMs between the different production sectors under study, the research revealed no major differences in awareness of the issues or in the farmer/vet relationship in the management of AM use across the different sectors under study.

The research identifies a number of practices through which awareness of AMR becomes embedded into farming systems. Three in particular are taken forward in the analysis: changing practices, where farmers and their vets are enacting changes to farming practice in response to concerns about AMs; legitimating practices, where farmers legitimate existing practices and patterns of use as being ‘sensible’ and ‘appropriate’; and risk management practices, where farmers seek to reduce the risk of dependence or use of AMs as part of a strategy for adopting innovative on-farm management responses to animal health and hygiene.
The research shows how farmers and veterinarians interpret the discourse of ‘reduction’ in AM as having possibly negative implications for the welfare of farm animals and as a possible challenge to their duty of care.

Although the prescription of medicines is the role of the veterinarian, routine diagnostics of animal disease (in the absence of testing), the decision whether to involve the vet, the administration of medicines and, in some cases, the mixing and dosing of medicines, is often undertaken by farmers. Farmers emerge as the primary care-givers in this context. Whilst some respondent vets were skeptical both of farmer knowledge and skills in these areas and in their correct use of medicines on farm, others placed their trust in experienced farmers to carry out these tasks well. More appropriate use of AMs will rely on farmers as knowledgeable and responsive practitioners. Regulatory approaches would therefore need to encourage farmer discretion and skill as well as providing incentives to manage usage more effectively. Any scheme that imposes reductions without factoring in this care-giving role of farmers and their vets would risk producing unintended consequences in terms of animal welfare and could perturb the balanced skill sets of farmers and vets. It may be timely to review training needs for farmers in conjunction with organizations such as, for example, the Responsible Use of Medicines in Agriculture Alliance (RUMA).

While AMs are seen as a necessary tool in maintaining the health and welfare of farm animals, for farmers and veterinarians alike, the key issue is their inappropriate use. This translates into five principal areas of concern:

- prophylactic and metaphylactic use that may not be wholly necessary for the health and welfare of the individual animals
- inappropriate use of AMs to treat animal health issues that are not caused by sensitive microorganisms
- unnecessary use of later generation AMs that are also used in human medicine, when other older ones would be as effective
- over-dependence on medicalization as a replacement for improved farm environment and livestock health management, and
- incorrect dosage and application on-farm.

While there is a growing amount of data on the prescription of AMs in livestock farming, there is a general paucity of data on on-farm application and use of data. Simply not enough is known on how AMs are used on a daily basis within farm practice. Research is clearly needed into understanding how medicines are used on farms and how decisions are taken by farmers on a day-to-day basis regarding the diagnosis of disease or infection and the selection and application of appropriate treatment as well as on improved methods for on-farm data entry and collection.

Current methods and tools for recording on-farm medicine use are regarded as inappropriate and of little practical use to farmers in the health management of their animals/birds or to vets in providing an accurate picture of how prescribed medicines
are actually used. They serve the function of demonstrating ‘conformity’ to prescribed rules under legislation or assurance certification and, even then, are regarded as being largely inaccurate and of little use as a genuine indication of use.

There is a crucial balance to be achieved between regulation (whether statutory or through certification/assurance) and responsibilisation (facilitating farmers and vets to work together to find local responses to the need to use AMs responsibly).

Retailers, food companies and assurance schemes are taking a greater role in promoting certain actions and practices to achieve more sensible and appropriate use of AMs. However, as long as such rule-making relies principally upon on-farm auditing, record keeping and periodic inspection, it will offer little long-term shift in medicine use unless it is accompanied by the active engagement of the farmer/veterinarian relationship to help embed those changes into practice and by mechanisms for record-making that are relevant to actual farming practice.

There is a need for medicine auditing tools that provide useful data to farmers and vets, thus encouraging both accurate recording and reflection on on-farm medicine use. These tools could then be used to provide anonymized data to regulatory bodies. The key to accurate on-farm recording though is that the farmer sees a real benefit in recording and analyzing these data.
8. INFORMING POLICY

Regulatory approaches to the practices of AM use on farms is focused around three key, yet distinct, areas:

- Assessing veterinary and farmer compliance to statutory or assurance rules and guidelines in medicine use
- Monitoring the presence of AM residues in animal products
- Reducing resistance in animal pathogens

Different means are employed by different actors (or combinations of actors) to achieve these various objectives, and different regulatory actors (from scheme assessors to processors) are involved, with varying degrees of enforcement capacity. There is an opportunity, and arguably a need, to achieve a better coherence and integration across actors and sectors in achieving these goals, with veterinarians playing a central role.

The national focus on data collection has so far concentrated principally upon sales data and, we note, in other EU countries, the increasing use of such mandatory data to inform policies on AM use. This research suggests that ‘post-prescription’ data is urgently needed to inform understanding of how AMs are actually used on-farm, both as a means of identifying and, where appropriate, benchmarking sensible and appropriate uses, as well as as a means of identifying inappropriate practices. In-depth, on-farm ethnographic and social science research is needed to effectively ‘follow the medicine’, from prescription to farmer to animal.

Innovative technologies for relevant on-farm recording on medicine use which is of value to farmers and animal keepers needs to be explored and developed.

This research has identified a number of concerns over the rules governing the use of particular medicines and the consequences of these rules for prescription practice. Certain older products, still considered by many to be effective in animal treatment yet no longer licensed cannot be used in favour of more recent medicines. Changes to the Cascade system to allow the responsible use of these products may well help reduce the use of those newer AMs considered as problematic.

It is clear from the qualitative and Q Sort research that farmers accept that responses are needed to the issue of AMR but often lack the means or the information to make informed decisions over the nature and longer-term implications of those changes. Vets, and increasingly food companies, are playing an important role, here but research is needed into the detailed financial and other gains to be made from more sensible and appropriate AM usage. While some food companies and processors are experimenting with incentivizing farmers to reduce AM use (through ‘points systems’ and other means), information on the cost implications of reduction for individual farmers may be required to break the path dependencies of established practices on some farms.
Farmers are, in practice, the principal care-givers with respect to farm animals. This research has demonstrated the importance of farmers and animal keepers in identifying, diagnosing and responding to animal illness and disease and the potential threat of illness and disease, particularly in the relative infrequency of regular diagnostic or post-mortem testing by veterinarians. We reiterate the above call for more research into how these decisions are made, how they are informed and how farmer expertise and inventiveness become critical resources in responsible animal care and on-farm hygiene management.

There are many reasons why individual animals are medicated on farms: to reduce suffering, to maintain productivity, to avoid the necessity (and costs) of culling and disposal, to reduce mortality rates, to insure against future health issues, and because it is sometimes more straightforward to medicate an entire herd/flock than identify and separate specific individual animals. Addressing each of these reasons requires a range of arguments and approaches that go beyond the simple call for ‘reduction’.

A greater emphasis needs to be placed upon managing the risks of infection and disease through improved housing and farm environment management, through improved animal sourcing and through improved on-farm hygiene. Building repair, design and, in places, replacement are critical elements in maintaining the health and welfare of farm animals, and data from the interviews suggests that these can be particularly effective in supporting reductions in AM use.

The assurance schemes, professional bodies, food processors, retailers and other corporate actors are responding to the challenge of more appropriate AM use through a variety of regulatory, collaborative and incentivizing methods. It is important that statutory regulatory bodies and government work in tandem with these organisations. However, though currently at the forefront of developing practical initiatives, such market-led and private governance approaches are not necessarily the universal panacea to the issue of AM use in livestock farming and cannot thereby act alone. Not all farms are included in these private and market-led schemes, leading to a potential polarization and differential levels of monitoring and response. Private and market-led rules are subject to market pressures and do not have the force, permanence or universality of statutory requirements. They rely (as do many statutory requirements) on what are sometimes simplistic forms of data collection and assessment that, in the case of AM use, has been shown by the current research and elsewhere to be often irrelevant to actual on-farm practice. Finally, such schemes cannot hope to help change long-term practices by enforcement alone. They need to work in collaboration with education, benchmarking and information exchange as well as through recognition and upscaling of on-farm innovation.

The discourse of ‘sensible’ and ‘appropriate’ use also needs to be made relevant to on-farm and veterinary practice. There is no single definition of ‘sensible’ or ‘appropriate’ use, and policy-makers, as well as private assurance scheme managers, need to work with veterinarians and farmers, as well as with the professional bodies.
in both sectors, in establishing the relevant criteria for what is considered ‘sensible’ and ‘appropriate’, as well as in defining the conditions under which those criteria might change.

Our attention has been drawn to a number of specific practical concerns such as the packaging of AMs (in volumes that often necessitate the opening, partial use and subsequent storage of medicines, with the attendant risks of farmer contamination, poor storage and environmental leakage), the on-farm storage and disposal of unused medicines and the consistent use of glass for some medicine packaging. Monitoring this is, we suggest, a future research priority.

Our attention has also been drawn to the specific issue of the constitution of herds from diverse sources, notably veal calves from different dairy farms as an assurance scheme condition or the sourcing of piglets from different breeders. This, it is argued, may well prompt the use of metaphylactic or prophylactic AM treatments as a matter of course, where unprofitable male calves have probably received less colostrum than the female calves on the source farms. It has similarly been reported that AMs are often used in a blanket fashion when new poultry flocks are assembled, as breeders have little confidence that chicks are entirely without disease or are from young parents with less immunity. Both examples suggest that an area of possible focus, for research or policy initiative, lies in improved animal/bird health profile matching and control.

Improving the relationship of vets and farmers, through initiatives such as demonstration events, ‘medicine days’, continuing education events and programmes that allow for closer vet and farmer interaction such as benchmarking, perhaps with subsidised costs, all appear as important mechanisms for achieving appropriate use of AMs in livestock systems. Support for these events, through the possible use of Rural Development Programme money should be explored.

A number of interviewees drew our attention to the less regulated sector of hobby farming as a growing area of AM use. As in other fields of livestock policy implementation, this is a sector that is not only expanding but for which enforcement and poor usage practice is often a particular challenge.

The role of AM use should be to reduce the suffering of individual animals and restore health and welfare. Although the UK, along with other EU countries, has banned the use of AMs as growth promoters, the rationale of using medicines as a mechanism for maintaining high levels of productivity remains prevalent in contemporary farming systems. More needs to be done to address health and welfare problems in the livestock sector, and to enable farmers and vets to make informed decisions aimed at improving health and welfare with minimal reliance on the use of AMs.

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