Corporate Food Retailers, Meat Supply Chains, and the Responsibilities of Tackling Antimicrobial Resistance

STAKEHOLDER REPORT 2018

Dr Suzanne Hocknell, Professor Alex Hughes, Dr Emma Roe,
Professor Bill Keevil, Professor Neil Wrigley and Professor Michelle Lowe.

Newcastle University

University of Southampton

Food Standards Agency

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

"The rise of antimicrobial resistance is a global crisis, recognised as one of the greatest threats to health today … [T]his may even bring the end of modern medicine as we know it. We need to act now to make sure this does not happen… Resistant pathogens travel very well internationally in people, animals and food… We should not blame any single sector. We are all in this together. We need ways to monitor progress and make quick course corrections if we are moving in the wrong direction. Antimicrobial resistance, as I say again and again, is a slow-motion tsunami. It is a global crisis that must be managed with the utmost urgency."

Dr Margaret Chan, Director General of the WHO, 18 April 2016

Executive Summary

This report provides the key findings and recommendations of a study funded by the Economic and Social Research Council (ESRC) as part of a UK Research and Innovation (UKRI) Cross Council Initiative on 'Tackling Antimicrobial Resistance (AMR)'. Our project is a Pump Priming study funded as part of Theme 4: 'Tackling AMR beyond the Healthcare Setting'. The aim of the project is to address the responsibility of retailers in tackling the AMR challenge in the context of their chicken and pork supply chains, and to investigate this evolving role and how it might be shaped in the future, both in the UK and also extending to the global scale. This research is significant in light of the O'Neill (2016) report on *Tackling Drug-Resistant Infections Globally*, the *Government Response to the Review of Antimicrobial Resistance* (HM Government, 2016) and subsequent roles played by the Department for Environment, Food and Rural Affairs (DEFRA) and the Food Standards Agency (FSA) in taking forward their recommendations regarding the setting of targets for the reduction of antibiotic use, support for antimicrobial stewardship in the food system and the development of codes and standards for addressing AMR in the food system at both national and global levels. The O'Neill Report (2016: 29) calls for "producers, retailers and regulators to agree standards for 'responsible use'. These standards could then be developed and implemented as an internationally recognised label, or used by existing certification bodies."

In food supply systems, as in human health, the focus of AMR policy has been on the use and stewardship of antibiotics in general, and Critically Important Antimicrobials (CIAs) in particular. Stewardship is significantly more complex than a reduction in antibiotic use and attention has been paid to stewardship related to good animal husbandry. Indeed, within the food industry antibiotic drugs remain important tools to support farm animal health and welfare, and the safety of foodstuffs.

The research finds that AMR is being framed less as a food safety issue and more as a public health concern, cutting across multiple areas of policy and practice. Collaboration and pre-competitive agreements have been vital to the success of meeting antibiotic reduction targets in domestic production ahead of schedule. Next steps for food retailers and other actors in the food system include consideration of AMR beyond the sphere of domestic on-farm production of fresh food to tackle AMR as it presents in associated environmental reservoirs (water bodies, soils), in processed foods and through international food supply chains.

Key Findings:

- The greatest strides in the UK have been made in reducing antibiotic use in domestically produced, fresh meat. Meeting targets recommended by the O'Neill (2016) report, committed to by DEFRA and supported by the FSA, two years ahead of schedule without impacting on animal health, welfare or productivity is a significant achievement.
- Central to the success of antimicrobial stewardship programmes in the poultry and pork sectors to date has been the treatment of AMR as a pre-competitive issue. Moreover, the collection and analysis of large datasets concerning on-farm antibiotic use and the execution of antimicrobial stewardship programmes have been managed effectively through food

supply chain coordination, partnership and corporate responsibility, and via investment in training and infrastructure.

- Consumers have limited knowledge of AMR. Consumers are also already overwhelmed by the volume of conflicting information they are bombarded with around food and health.
- Whilst the monitoring and recording of antibiotic use in domestically-sourced fresh meat products to address the challenge of AMR is becoming more rigorous, robust and transparent, calculation by UK retailers and processors of AMR risk associated with imported and processed meat products is at a much earlier stage of development.
- Environmental reservoirs, human-food pathways through handling foodstuffs and food animals (alive/dead) barely featured in discussion with the retail sector.
- Combining publicly available trade and AMR risk data, the project demonstrates the potential use of maps in depicting AMR risk in international meat supply chains. The maps illustrate what might be achievable if granular data were available to industry practitioners.

Key Recommendations:

- Effective work has been conducted across food supply chains, including but not limited to Responsible Use of Medicines in Agriculture Alliance (RUMA), the British Poultry Council (BPC), the National Pig Association (NPA), Red Tractor and the Agriculture and Horticulture Development Board (AHDB), in rolling out platforms, guidance and training enabling data collection on antibiotic use. It would be useful going forward if the same platforms could be standardized to allow more research into any patterns that are emerging.
- Data collection on antibiotic use needs to be comprehensive, collaborative, standardized and shared, whilst remaining pre-competitive. Companies should be able to use such data for their own benchmarking, and data can be anonymized and not made publicly available.
- Dialogue is needed as the UK moves to a post-CAP (Common Agricultural Policy) landscape regarding priorities for farm investment in the context of AMR.
- AMR raises important questions about public health, local practices and global connectivity, animal welfare, and household budgeting. At school level, AMR is potentially a productive lens to cut across disciplines such as geography and biology, but also food technology and citizenship classes in order to address public awareness through education.
- Mapping AMR risk is likely to become particularly important, as the FSA highlights (Advisory Committee on the Microbiological Safety of Food, 2018), in the context of Brexit and should therefore be explored further.
- Routes of AMR transmission beyond the food itself represent important areas for future attention. Pathogens resistant to antimicrobials, resistance genes and antimicrobial residues can travel and persist in soil, in water, and through direct contact with people including farmers, farm labourers, and abattoir workers. These routes require further research to inform evolving codes and standards for antimicrobial stewardship in food systems.
- It is important for Codex Alimentarius Guidelines for Integrated Monitoring and Surveillance of Foodborne Antimicrobial Resistance, into which the FSA is crucially feeding, to address environmental reservoirs and internationally-sourced processed, as well as fresh, foods. These pathways are structured by the architectures of the global food system, coordinated in part by retailers and processors.
- Scientific research on AMR in food should be conducted in collaboration with social scientific study of the organizational geographies of food supply chains. These global supply chains cross borders of national and regional regulatory systems. For antimicrobial stewardship to be implemented effectively, it is vital to grasp how responsibility is, and can be, practiced through border-crossing commercial realms.

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"AMR clearly involves biological processes, but the context which determines the operation of these biological mechanisms is shaped by social, cultural, political, and economic processes. The most effective actions to reduce and control AMR will involve changes in social practices, including how farmers, vets, and regulatory systems manage livestock production for human consumption; how regulatory and fiscal frameworks incentivise or deter antimicrobial development, production and use; and how public and healthcare professionals behave in relation to infection and use antimicrobials. The most critical feature of AMR is that resistance to a new antimicrobial begins as soon as it is developed, and so development of new antimicrobials is not a panacea. Providing a mechanism for sustainable use of the valuable resource of antimicrobials will therefore necessitate considerable behavioural, cultural, political and economic change throughout the world, which needs a strategy to be developed in harmony with the scientific and professional agenda"

Anti-Microbial Resistance: Setting the Social Science Agenda
Report of an ESRC Working Group: July 2014: 1

1. Introduction

This ESRC-funded scoping research, 'Corporate food retailers, meat supply chains and the responsibilities of tackling antimicrobial resistance', began on 1st February 2017, with the research element running from June 2017 to June 2018. The project was jointly based in the School of Geography, Politics and Sociology at Newcastle University, and Geography and Environmental Sciences, Biological Sciences and the Business School of the University of Southampton. It was supported by the Veterinary Medicines Directorate and by the Food Standards Agency as Project Partner. The research built on the proceedings of a 2016 workshop[1] organized by the Universities of Southampton and Newcastle and the Food Standards Agency, and funded by the Network for Antimicrobial Resistance and Infection Prevention (NAMRIP), the Engineering and Physical Sciences Research Council (EPSRC), an ESRC Impact Acceleration Award and the Food Standards Agency.

As the name suggests, AMR describes resistance developed by a microbe to the actions of an antimicrobial drug. Resistance to veterinary antibiotics is now widely acknowledged as having potentially catastrophic global implications, not only for animal and human health and wellbeing, but also for industrial sectors such as livestock agriculture and the wider economy. In the last century we have come to rely on the effectiveness of antibiotics to manage and treat infection in people and in animals. It is commonly antibiotics that contain infectious diseases and enable the risks of routine surgery to be managed. In response to this threat there has been a raft of policy initiatives at international, national and food sector levels to drive forward initiatives to tackle AMR. Consequently, the stewardship of antimicrobials is complex; linear approaches are rarely, if ever, going to tackle it.

The UK government has a stated desire to drive global policy leadership on AMR, with the commissioning of the O'Neill report in 2014, and its influence on EU and UN policy, seen as important elements of this. The O'Neill report (2016) focused on the potential economic implications of AMR and as such pushed AMR up the political agenda. AMR is often and rightly described as a 'wicked problem'. Resistance is a dynamic process that appears to unfold differently in different situations. The UK 5-year AMR strategy engages a stewardship antibiosis model which focuses on knowledge and understanding of antibiotic resistance, with the stated aims of ensuring that existing treatments stay effective, and developing new treatments; responsibility for implementing its recommendations is spread across multiple Whitehall departments. Of most relevance to this project are the roles of the FSA and DEFRA, including the Veterinary Medicines Directorate (VMD).

[1] https://www.southampton.ac.uk/namrip/news/2016/12/joint-fsa-workshop.page (accessed 05/11/18)

At the time of writing, only two years have passed since the 2016 O'Neill report identified the reduction of "the extensive and unnecessary use of antibiotics in agriculture" as one of four key interventions needed to tackle AMR. To date, actors from across UK meat production, processing, assurance, retail and supply have been proactive in working together under the umbrella of RUMA to dramatically reduce the use of antibiotics generally, and Critically Important Antimicrobials (CIAs) specifically. Indeed, the Veterinary Antimicrobial Resistance and Sales Surveillance (VARSS) report published in October 2017 detailed a 27% reduction in antibiotic use in livestock and fish farmed for food to an average of 45mg/kg, exceeding the government target of 50mg/kg two years ahead of schedule.[2] This has been accomplished without compromising on animal health or welfare, or on the economic viability and competitiveness of the UK meat industry. This achievement should not be undersold.

Antimicrobial stewardship refers not only to the act of reducing the usage of antibiotics, but also to a broader suite of practices that address animal health and welfare, and biosecurity, for example through on-farm infrastructure and production system improvements, selecting healthier breeds or strains and improved diagnostic techniques. However, given the complexity of AMR, and the ubiquity of microbes, the potential reach of antimicrobial stewardship extends beyond the farm gate to include improved hygiene routines in the food processing and packaging industries, and in the transit of animals and foodstuffs, as well as attention to how foodstuffs are kept, prepared and cooked in private and commercial kitchens. Stewardship is also about recognizing that all the techniques and tactics available may still fail to stop the emergence of resistance genes. Antibiotic stewardship therefore must address not only the need to limit antimicrobial usage, but also to reduce the transmission of pathogens and of resistance, between microbes living in diverse environments. Perhaps too, stewardship involves adaptation to a world where recovery times without antibiotic dosage may prolong illnesses in humans and animals.

In order to deepen our understanding of the complex challenges outlined above, this scoping study explores the practices, concerns and responsibilities of retailers as they navigate international, national and trade body policies, the emerging science, and the on-the-ground practicalities of AMR. Pork and poultry supply chains were selected as they are examples of how organizations from across the industry have worked together to pioneer approaches to antimicrobial stewardship, through supply chains flowing through spaces of the global South as well as the UK and the global North. Retailers are a key bridge between procedures of production and processing, and practices of consumption, so by looking across supply chains to unpack the role played by retailers, and the expectations placed upon them, it is possible to explore how the multiple actors from farm to fork negotiate and communicate to enact change. To this end, although we are interested in antibiotic stewardship and animal welfare, we are also keen to understand how other factors such as consumer expectations, the demands of local, national and international organizations, agencies and policies influence and interact with possibilities for change.

[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/707974/_1274590-v2-VARSS_2016_for_GOV.pdf (accessed 05/11/18)

2. Research Design

2.1 Research purpose and background

This study has been conducted with an ESRC Pump Priming grant, involving broad and exploratory goals. The project was a response to the 2016 UKRI Cross Council call for AMR research to address "the influence of large private sector organizations (e.g. supermarkets) on both consumer perceptions and farm practices, and how these can be utilised to positively infuence behaviour"[3]. Through gaining a more comprehensive understanding of the scope and scale of the AMR challenge in meat supply networks, we aim to offer insights of benefit to academics, industry and government, in collectively shaping approaches to tackling the risks of AMR. We explore how in real and emerging situations, organizations make sense of the uncertainty of the science of AMR whilst putting stewardship policies into practice.

2.2 Research aims

- To explore the evolving responsibilities of UK corporate food retailers in tackling AMR in their meat supply networks.
- To facilitate increased dialogue and collaboration between food retailers and wider institutional policy and scientific networks in the UK in order to shape future strategy.

2.3 Research objectives

- To evaluate current and evolving corporate retail antibiotic stewardship strategies and standards in the UK.
- To appraise the implementation of antibiotic stewardship policies across pork and chicken supply networks.
- To unpack the influences of consumer expectations on approaches to tackling AMR.
- To map the current AMR risks within UK chicken and pork retail supply chains.

2.4 Project design and timeline

This study built on the proceedings of a workshop organized by the Universities of Southampton and Newcastle and the Food Standards Agency on 25th November 2016. Commencing in June 2017 the research combined desk-based research with in-depth interviews with a range of companies and organizations working within meat supply networks. The desk-based research included: i. a review of publicly available international, governmental and industry AMR policies and guidelines pertaining to pig and chicken meat supply networks; ii. a review of the social science AMR literature; iii. analysis of AMR coverage in the UK media; iv. experimental use of publicly available data to create dynamic maps within which UK retail purchases, UK supply networks, resistance figures for meat and carcasses in supplying countries (where available), and average antibiotic use in supply countries (where available) were plotted.

The empirical research was conducted across two phases. In Phase One, we met with persons charged with developing, implementing and monitoring AMR policies for the major UK retailers. This included: a. interviews with nine of the UK top ten supermarkets. Within this we talked to seventeen people working as agricultural managers, technical directors, microbiologists, product safety and quality assurance directors and managers, and corporate responsibility and sustainability management; b. four interviews with nine people from eight industry bodies, including those tasked with developing, communicating or monitoring AMR related policies in practice; and c. consultations with seven staff from three policy-making bodies. In Phase Two, we extended our research across food networks and met meat processors, manufacturer representatives, farmers, trade bodies and others to further unpack how AMR emerges, is encountered, and is responded to at different nodes

[3] https://esrc.ukri.org/files/funding/funding-opportunities/amr/amr-theme-4-call-specification/

in food networks. This included: d. thirteen interviews with farmers via the Farm Business Survey; e. three interviews with processors including representatives working across production, health and welfare, research and development, and technical; f. two telephone meetings with two of the trade bodies for manufacturers; and g. three other meetings, including with representatives of a consultancy firm working across meat supply chains, and a campaigning organization; h. five conferences attended at which we met and interacted with people working on AMR across human and animal health, in industry, in policy and in academia. The team has followed the ESRC's Framework for Research Ethics and Research Data Policy throughout the project and the discussion and findings are presented without identifying any individuals or organizations participating in the research.

2.5 Project academic team

Professor Alex Hughes (Principal Investigator, Newcastle University)
Dr Suzanne Hocknell (Post-Doctoral Research Associate, Newcastle University)
Dr Emma Roe (Co-Investigator, University of Southampton)
Professor Neil Wrigley (Co-Investigator, University of Southampton)
Professor Michelle Lowe (Co-Investigator, University of Southampton)
Professor Bill Keevil (Co-Investigator, University of Southampton)

2.6 Acknowledgement*s*

We are very grateful for the advice and guidance provided by our Project Partner and Project Advisory Board: Steve Wearne, Rick Mumford and Guy Poppy (Project Partners at the Food Standards Agency); Kitty Healey, Fraser Broadfoot and Ana Vidal (Project Advisers at the Veterinary Medicines Directorate); Professor Tim Leighton and NAMRIP (Project Adviser at the University of Southampton); and Professor Tom Reardon and Dr Carmen Hubbard (Project Advisers on food supply chains from Michigan State University and Newcastle University respectively)

We also thank the University of Southampton's Frances Clarke in NAMRIP and Julia Branson, Gemma Gubbins and Andrew Sutton in the GeoData Unit for workshop support in 2016 and production of maps respectively, and Newcastle University's Maddy Thompson, Adam O'Neill, Jane Tilbrook and Trudi Pemberton for 2018 workshop support. We are also greatly appreciative of the participation of all project interviewees in the research and of the contributions from speakers and delegates involved in the workshop on 19th November 2018.

3. Responsible Antimicrobial Stewardship: The Role of Collaboration

3.1 Celebrating stewardship success

There should be applause for the AMR stewardship approach that the UK food industry with support from the FSA has adopted in light of the *UK Five Year Antimicrobial Resistance Strategy* (DEFRA, 2013) and the O'Neill (2016) report. The AMR stewardship approach adopted by the livestock, food retail and veterinary sectors has enabled antibiotic reduction targets to be surpassed two years ahead of schedule. This has been achieved in the UK through vets, drug manufacturers, assurance schemes, producers, retailers, processors and government coming together under the umbrella of RUMA to respond to key areas for action identified in the UK 5-year AMR Strategy 2013-2018. These were: optimizing prescribing practices; improving professional engagement, training and public engagement; and better access to and use of surveillance data when specifically applied to food and farming.

Behind the headlines about reducing antibiotic usage there have been and continue to be ongoing activities to address more broadly the non-linear relation between the emergence and persistence of AMR. It is therefore particularly heartening to hear a UK trade body outline a more holistic, collaborative 'One Health' inspired stewardship plan:

> "Sector level responses have been very much qualitatively … thinking, 'Well, what can we do in our industry? For example, to promote increased use of vaccination where possible, [or] preventative health measures, biosecurity on farm.' So, it's been an awful lot of renewed talk about prevention, about herd health plans on farms and things like that. So, people in the industry are looking at it in a much broader context. Yes, we know that the target is 50 [mg/kg], but actually there's much more qualitatively important topics to tackle here. So, we're using that as an opportunity to have that renewed conversation … [T]he hard thing is to do on farms, to go back and rethink about, 'Do I need to change my housing? Do I need to think about where I buy my stock from? Am I using the right vaccination regimes?' And things like that".
> Trade body respondent

Effective antimicrobial stewardship is as much about co-creating the conditions for health, welfare and robustness under the 'One Health' agenda, as reducing total antimicrobial use.

3.2 Supply chain collaboration on AMR stewardship

In terms of effective implementation of antimicrobial stewardship, as the cornerstone of corporate strategy for tackling AMR, the structure and organization of meat supply chains are important. Project interviews reveal the critical role of supply chain collaboration and coordination in meeting targets within an antimicrobial stewardship model, and the experiences of this process as a non-competitive issue. The collaborative industry body RUMA's AMR strategy dovetails with the *UK's Five Year Antimicrobial Resistance Strategy* (Department for Health and DEFRA, 2013) on this matter, by working to inform and influence best practice in the use and reduction of antimicrobials. These intentions have been embedded into supply chain auditing practices through the Red Tractor, a farm and food safety assurance scheme with very high membership in the UK livestock sector, which has incorporated standards for responsible use of antimicrobials from industry specific bodies such as the NPA and BPC.

The top five retail firms—Tesco, Sainsbury's, Asda, Morrisons and Aldi—hold just over 75% of the UK grocery market share at the time of writing.[4] Likewise, in the case of the poultry processing sector,

[4] https://www.kantarworldpanel.com/en/grocery-market-share/great-britain (accessed 23/08/18)

only four companies, some of them multi-national, control around 90% of the UK market.[5] Key points emerging from interviews on the implementation of antimicrobial stewardship in pork and poultry supply chains are:

- **Large sets of data on antibiotic use** in both poultry and pork production for fresh and domestically-sourced product are increasingly held by supermarket chains and processors. In some cases, specialist consultancy firms are involved in this data collection and analysis. Some interviewees reflect on the potential of blockchain and radio-frequency identification (RFID) technologies to hold data pertaining to aspects of AMR.
- **The management and monitoring of antibiotic use** is effectively handled, for the most part, by a relatively small number of players across the consolidated grocery retail, poultry and pork sectors (pork to a lesser extent than poultry). This consolidation can generate economies of scale and efficiencies in data collection and handling, stewardship collaboration with fewer vet companies and less yet more valued communication channels between industry and policy-makers.
- **Effective antimicrobial stewardship is achieved** through stability in the supply chain in terms of the length of contracts retailers have with suppliers, along with the closeness of buyer-supplier relationships in some cases and supply chain integration in a minority of others. Longer term contracts with suppliers are suggested by some interviewees to be helpful in managing data collection concerning antibiotic use, in ensuring that best practice and standards of antimicrobial stewardship are developed and implemented, and also as potentially giving the financial security necessary to invest e.g. in housing. Some interviewees reflect that AMR collaboration is eased by histories of retailer-supplier relationships emphasizing cooperative, developmental processes rather than setting targets in more punitive terms.
- **Strong organizational structures of corporate responsibility** have aided the effective implementation of wider programmes of responsibility in agricultural production, including farm animal welfare, and health and safety, into which stewardship fits.
- **Investment in hard (new buildings, equipment) and soft (training and data collection) infrastructure** to support AMR stewardship plans has been easier for larger suppliers and farms who tended to be in a stronger position to invest. Funding constraints and insecurity of contract have implications for small and medium-sized farms and firms, which require further research.

3.3 The importance of pre-competitive agreements

Key to the success of stewardship is the agreement, reflected by our study's interviewees, that the issue of AMR is pre-competitive:

> "Poultry is a prime example of how it should be an industry driven approach. It's, 'This is what we are going to do. This is the advice. These are the reasons why we are going to do it'… It's very important that this becomes industry driven, not retailer driven".
> Retail respondent

Achievement in antimicrobial stewardship should not be undersold. It has required significant industry-wide collaboration. This was not a race to be first. Rather, the industry responded to the AMR challenge by collaborating through knowledge exchange and the sharing of best practice. This marked a broad and inclusive sign-up to the AMR stewardship agenda, something retailers feel could be at risk if the coordination of initiatives is moved towards encouraging market competition, rather than cross-industry collaboration.

[5] https://www.foodnavigator.com/Article/2017/09/26/Consolidation-in-UK-poultry-as-Cargill-Faccenda-form-JV (accessed 23/08/18)

The antimicrobial stewardship achievements from the UK food and farming industry and policy makers are unusual not only in terms of the speed, depth and method of precautionary collaboration, but that this has largely happened below the radar of consumers:

> "I am not aware we have had any direct contact on it [from consumers]. If a letter goes to our Chief Executive it will come to the relevant person in the business to deal with and I don't recall ever seeing a letter into [our company] about [antimicrobial] resistance".
> Retailer respondent

Retailers are deeply concerned that overly simplistic reporting of this complex issue may result in consumer demand for antibiotic-free labelling with attendant negative impacts on the existing pre-competitive collaboration. Successful antibiotic stewardship on farm involves the interplay of prescription practices, HACCP (Hazard Analysis and Critical Control Points) plans, biosecurity procedures, welfare standards, staff training and more, so such a two-tier system is unlikely to hold any overall benefits for antibiotic use if animal welfare is to be maintained.

The achievements of the pig and poultry sectors in reaching the recent antibiotic reduction targets point to the **opportunities available to avoid the prescription of antibiotics when the welfare of animals was not affected.** At a farm level, this collaboration has been underpinned, as outlined earlier, by industry bodies (such as Red Tractor, the BPC and the NPA) who have facilitated communication, data collection, auditing and training within and across the different sectors. Meeting the national targets without adversely impacting on animal health and welfare has included agreements on a reduction in the use of antibiotic antimicrobials aided by targeted increased use of vaccination and diagnostics, alongside herd health plans and ongoing improvements in knowledge and practices of hygiene, biosecurity measures, and welfare arrangements. Collaborative agreements are key to minimizing the cost and time burdens on farmers:

> "[Retailers] are harmonizing [the] on-farm practices [of their suppliers], so they're [creating] requirements for farmers as well. I think [it] is quite important that farmers are getting the same messages. Because at the end of the day there is a scientific way to address this. So for farmers to get that similar message, regardless of who they're selling their produce to, I think is really important as well, in terms of them understanding that. Yes, we all know what we're talking about and we all understand what responsible use looks like, and it should be the same language".
> Trade Body Respondent

On farm, the relatively few antibiotics registered for use in many species is an added complexity that serves to illustrate that ultimately stewardship success lies in the practices of livestock farming. Stewardship involves understanding the health and welfare needs of animals in the context of the reduction targets, and our interviewees highlighted the role of data collection and analysis here.

3.4 AMR as a public health issue

The targets for antibiotic use arguably arose from conceiving a relatively straightforward relationship between antibiotic use and the incidence of resistance. However, scientists increasingly understand that the pathways of microbial resistance are complex and non-linear. Science still holds that the more often an antibiotic is used the greater the risk of the emergence of antibiotic resistance in the future. However, it is becoming clear that point of use is not the only risk. As such, the precautionary antimicrobial stewardship policies and practices of the industry have to some extent been ahead of the scientific evidencing of the mechanisms involved in AMR emergence and transmission.

Antimicrobial resistance does not simply fall under the umbrella of a food safety issue. As outlined above, antimicrobial resistance is a 'wicked problem', multiple in location, encompassing the movements of wild, farmed and companion animals and humans, the organisms within soils or water bodies, plants and fungi. As one retail respondent put it:

> "This is not a linear food safety risk but a broader public health issue, the linkages of which are not very understood".
> Retailer respondent

Antimicrobial resistance is a direct concern for the food industry because it places at risk the effectiveness of the use of antibiotics on animals and may lead to changes in production costs and systems. Yet the food industry, as well as producing food, is entangled with the emerging public health crisis through local and global pathways that connect microbes. The handling of animals living or dead, and their excretions, may facilitate the transfer of microbes with resistance genes. Animal health, human health and the environment are connected in multiple ways including through the gut flora of stomachs, human and animal. The urge to harmonize data collection under the 'One Health' agenda across the food, animal health and human health industries potentially has a key role to play.

3.5 Consolidating data

Food industry players have traditionally held trade and supply chain production data close to their chest, preferring not to share something potentially commercially sensitive. Some parts of the industry are benchmarking the average total use of antibiotics of their supply chains alongside other data. Such benchmarking sits behind the publicly available data detailing achievements in meeting the average use antibiotic targets. In order to keep the management and response to AMR pre-competitive, the benchmarking continuum is only accessible to those within the system. A question arises here as to how collaboratively to use this data to better understand the challenges of different farming situations and so to share best practices across diagnosis, housing, feed, hygiene, genetics and more, as well as supporting scientific study into resistance:

> "The ideal would obviously be a health and welfare platform. The farmers can see all their data, all at once and analyze it and it can produce graphs and things. I think, as well, the hope is that CCIR[6] data, the carcass conditions at the slaughterhouse… all different health conditions that are spotted and recorded at the slaughterhouse, that data is supposed to be fed back to all the farms and it currently isn't [fed back to the farms] very well. It will be a really useful resource for farmers to use for overall health and welfare [management], but it's definitely something that's not going to happen overnight".
> Industry body respondent

Looking beyond the farm gate, questions are also circulating about how to maximize the utility of wider supply chain surveillance and due diligence practices to tackle and better understand AMR as a dynamic phenomenon. The commercial interests of the food industry stand in relation to international and national public body moves to govern the issue. Overcoming the AMR challenge cannot become an industry competitive issue and it cannot be something the UK, or Europe, does by itself. There needs to be continued acceptance across human and animal health, and the whole food system that microbes know no borders. The complex issue of AMR cannot be tackled by legislation alone. Collaboration across the board is key to meaningful stewardship.

[6] Collection and communication of inspection results. https://pork.ahdb.org.uk/processing/collection-and-communication-of-inspection-results-ccir/ (Accessed 05/11/18)

4. Complex Risks of AMR in the Food System and the Challenges of Consumer and Policy Engagement

4.1 Living with microbial Life

To understand the shape and form of UK and international policy on AMR, and to situate the aforementioned antimicrobial stewardship programmes, it is helpful to place policy in the context of how science and society has framed both microbes and AMR. This framing has implications for how communities grapple with the challenges of disease prevention and management and drug resistance, and gives context to the fresh challenges highlighted in the next sections of this report.

'Microbes' refers to a diverse group of organisms too small to be seen without a microscope, although many of them are visible to the naked eye when clustered together in communities. Typically, microbes reproduce through asexual reproduction.[7] Microbe evolution is therefore not a matter of two organisms mixing their genes by way of sexual reproduction. However, neither is it solely as a result of mutation. Microbes have access to the genetic 'data bank' known as the pangenome. Microbes can use a process called lateral gene transfer (LGT) to pick up and try on for size genes from other microbial organisms within the pangenome. If a gene that a microbe accesses and tries is more useful than detrimental, it can then spread rapidly through microbial reproduction. Here the local material contingencies shape the usefulness of the gene. The processes of LGT, even without selection for resistance to antimicrobial drugs, continue to drive individual *and* collective microbial evolution in the pangenome. Attention to singular microbes is therefore insufficient to grasp what microbes are, or what they can do.

Historically, the scientific study of microbes has involved isolating a microbial organism from wider communities. For philosopher of science Dupré, this goes some way to explaining why microbial life has often been understood as simple and behaviourally limited, whereas they are "in fact, the evolutionary sophisticates" (2012: page 171). Microbial life can be thought of as a collective. That collective is simultaneously a collective of individual organisms that in any given situation may be competing, collaborating or indifferent to each other, and the pangenome which includes the total collection of the genetic information of all those individuals. Microbial communities played key roles in the geochemical development of the planet and its atmosphere. Microbes make their homes in soil, in water, in and on other life forms, and they are an integral part of the bodies of multi-celled organisms, including humans. For Dupré, microbial organisms carry out "essential metabolic processes that we, in the narrow single-organism or single-genome sense, have never evolved for ourselves" (2012: page 165). Dupré goes on to suggest that relationships with microbes may be at least as important for health as for disease.

4.2 The emergence and persistence of antimicrobial resistance

Antimicrobial pharmaceuticals were first developed just over 100 years ago and work by upsetting structures or processes that exist in microbial, but not eukaryotic cells. What is significant here, though, is that they were developed from substances that are themselves produced by microbes. This suggests that the term antimicrobial is perhaps something of a misnomer. As explored above, what we call drug resistance was part of the evolutionary strategies of microbes long before the pharmaceutical industry became involved. However, what has changed is that the use of antimicrobial drugs has increased the rates of gene transfer in organisms of most concern to human and animal health, and relatedly, livestock productivity.

AMR is a product of lively interactions involving living organisms within dynamic ecologies. This suggests that so called antimicrobial drugs are not, and have never been, magic bullets on a singular trajectory to cleanly take out pathogenic microbes. Studies in Sweden suggest that decreasing

[7] 'On average, under ideal conditions, bacteria may double in number every 20 minutes.' In 7 hours one can become over 2 million. http://www.fao.org/3/a-i5896e.pdf (accessed 05/11/18).

antibiotic use does not necessarily lead to a reduction in AMR associated with a particular drug (at least in the short term) (Kahn, 2016: page 82). The ability of microbes to adapt to antimicrobial drugs means that neither better prescribing, nor the development of new drugs will be sufficient to stop the spread of AMR. Indeed, commensal (harmless) bacteria can host antimicrobial resistance genes from which pathogenic bacteria can draw, including genes that may be resistant to antimicrobials other than the one that the microbe has been exposed to. Antimicrobial drugs remain an important strategy to take out a direct disease threat in the now, but whenever they are used they add fuel to the fire of future resistance.

4.3 Consumers

One of the steps recommended by the O'Neill report was for: "Food producers and retailers to … improve transparency for consumers regarding the use of antibiotics in the meat that we eat, to enable better informed decision-making by customers." (2016: page 73). Project interviews confirm that public knowledge and understanding of AMR is very limited and is represented neither as a significant consumer concern in customer research, nor through customer correspondence. More specifically, for example, there is limited grasp on the part of consumers of antibiotic use in farm animal production and effects of antibiotic withdrawal periods. Retail interviewees reflect on customer research revealing care for issues of provenance and animal welfare, though with product quality and price unsurprisingly foregrounded. So, whilst retailers themselves may have an incomplete knowledge, their experience of food consumers in general is that their understanding of the topic is even more limited.

Consumer anxiety about antibiotic consumption through residues in food products is not really the AMR challenge that the industry faces. Nevertheless, this consumer concern has sparked the use of the only AMR related marketing slogan "Antibiotic Free". Our respondents felt that such labelling gives out unhelpful messages, adding to consumer misunderstandings about residues in meat, whilst threatening both animal welfare and pre-competitive commitments on AMR. They were also concerned that consumers do not fully understand the labelling that already exists, and were keen to stress that consumers are overwhelmed by information about food. In the light of this, our retail respondents saw it as their duty to do the right thing from the outset rather than wait for consumer concerns to emerge.

Whether responses to AMR *per se* (as opposed to antibiotic-free) can ever feature as a marketing quality is a different question. Some respondents spoke of the marketing point of difference for those with strong farmer relations where they could sell responsible antibiotic use as part and parcel both of high-welfare and of ensuring a good procurement system. Others realized that it is not appropriate to have a point of competitive difference if it is realized as a fundamental food safety issue. And ultimately without a more informed consumer, active marketing on the topic is ambitious. It is unknown how it may become a food scare that would drive changes in consumer buying habits; food retailers historically are differently affected by food scares related to their brand image.

4.4 Policy

The sector is commercially sensitive to negative public exposure about their brands, which has often been the stick used by regulatory bodies to drive faster improvements. Independently of consumer ignorance on the topic of AMR, negative brand publicity is unwanted by the sector, and where there have been easy wins through industry cooperation e.g. reducing campylobacter in poultry, the industry is keen to collaborate pre-competitively. Therefore, significant thought is warranted about how cooperation across the industry to address the topic of AMR as more complex than antibiotic stewardship can be driven forward.

Retailers reacted with some concern that they were being positioned as having great influence over AMR in the supply chain, when it is recognized that some reservoirs fall outside of the borders of the farm or the product:

> "I don't like AMR as a target, because I can't manage it … there might be a microbe evolving with antibiotic resistance in the canal as we speak. What I can be responsible for and influence is antibiotic use, which may indirectly lead to antibiotic resistance, but I have no control of antibiotic resistance."
> Retailer respondent

Antibiotic usage is where food sector policies on AMR are commonly positioned. This includes both total use and minimizing the use of Critically Important Antibiotics (CIAs), although in reality it was pointed out that what is on these lists is inconsistent nationally, internationally and by corporation, which is unhelpful.

Antibiotic use is still acceptable, indeed necessary, but it is part of a complex conversation with consumers around reducing usage, and how this relates to animal welfare across different production systems. A recent POST (2018) publication details the extensive work to address AMR by reducing antibiotic usage through a number of improvements to husbandry, breed selection on health, diagnostic testing, and more. This therefore begs the question of a conversation with consumers within the 'less but better meat' framework about the environmental, welfare and health costs of different methods of livestock production. That is not to suggest that AMR is a topic suitable to sit under the umbrella of 'ethical consumerism', nor is it a food safety concern. Rather, it is an environmental problem with potentially serious public health implications in future decades. Investment in tackling AMR will not be found through profit margins in a competitive market for 'healthier' foodstuff, as the pathways of the movement of resistance genes between the potential reservoirs are too entangled to delineate supply chains and products in this way.

The 'One Health' paradigm is very pertinent to explain and inform policy-making around AMR, yet to date the scientific and public health culture has limited the apprehension of the AMR challenge by not earlier recognizing the porosity of borders between human, animal and environment and its many and varied inhabitants. Where historically concern for livestock production practices has driven a market in 'higher animal welfare' or 'more extensive' farming systems, it is hard to see how AMR taps into what one can now be appreciated as a siloed approach to a singular, rather than ecological, challenge, across the supply chain. AMR is a risk in the environment, but as the retailer reflected above, environmental reservoirs of resistance genes may feel beyond their scope. Our research indicates that there is space to explore how one might innovate products and markets that directly tap into the ecological relations of the 'One Health' agenda and that might deliver consumer-facing messages on the topic.

5. New Horizons and the Mapping and Tackling of AMR Risk in Food Systems

5.1 The significance of maintaining inter-firm collaboration and support from stakeholders

Collaboration has been a crucial part of addressing the challenge of AMR and in the achievements so far. The O'Neill (2016) report has been welcomed, and the discursive space of RUMA has been found to be useful, as have the resources produced. There is occasional confusion regarding the complexity of different lists and policies concerning CIAs, as well as concern that to restrict more classes of antimicrobials could threaten pre-competitive agreements and animal welfare without necessarily impacting on stewardship in any meaningful way. AMR is generally viewed as a pre-competitive issue, and therefore organizations such as the British Retail Consortium (BRC) Antibiotic Working Group are important for supermarket chains to address ongoing challenges in collaborative ways, involving their agricultural managers, product technologists and corporate microbiologists.

Many companies, recognizing the complexity of the AMR challenge, express a need for more advice, clarity and direction when it comes to managing AMR risk in their supply chains most effectively. There is also broad acknowledgement that more research is needed to understand the persistence of AMR. Specialist consultancy firms have a continuing role to play in terms of services and training for antimicrobial stewardship and data collection. There is also scope for collaboration beyond the farm between different sectors of the food industry. As many of our project interviewees rightly point out, AMR is a challenge requiring coordinated policy response, data collection and surveillance across industries, from grocery retail and food processing sectors to the hospitality industry and public sector food production and provisioning across international supply chains.

5.2 The possibilities of mapping AMR risk in international supply chains

Whilst the monitoring and recording of antibiotic use in domestically-sourced fresh meat products to address the challenge of AMR is becoming more rigorous, robust and transparent, calculation by UK retailers and processors of AMR risk associated with imported and processed meat products is at a much earlier stage of development. And yet, the international supply, in particular of processed meats, is significant. Raising awareness and developing responses to address the incidence of AMR in domestic and international food chains has been slow, with public health officials only just starting to engage with this economically and politically charged arena (George, 2018). As in human clinical settings, across the food sector we see the replication of 'dealing with AMR' through reduction in point of prescription usage, as opposed to infection prevention through improved biosecurity across the complex geographies of reservoirs where resistance genes could flourish in the agri-food supply network. As the Food Standards Agency's Advisory Committee on the Microbiological Safety of Food (ACMSF) fixed-term task and finish group's report on antimicrobial resistance published in March 2018 highlights:

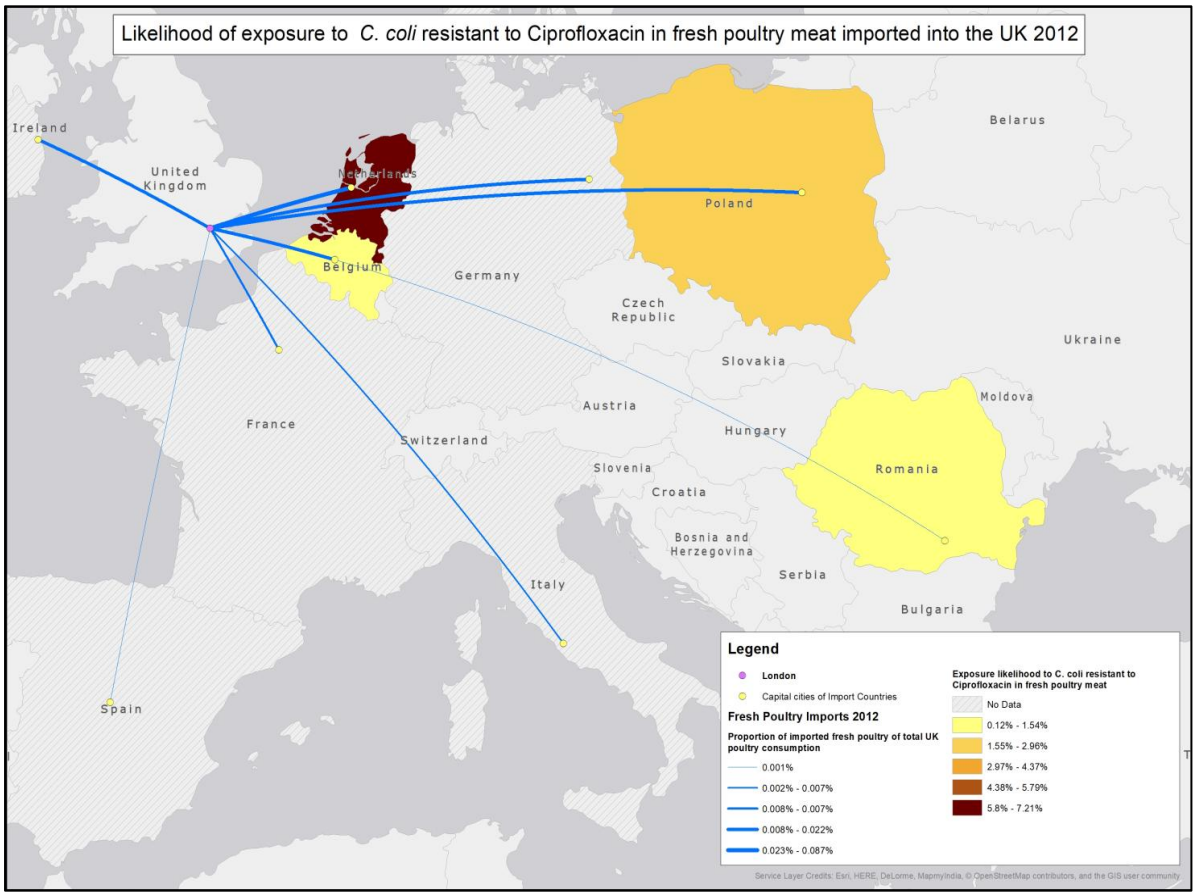
> "[T]here is significant and longstanding lack of antimicrobial and AMR data in relation to UK-produced, processed and/or imported food, in absolute and comparative terms … Apart from a small number of northern European countries… there is little or no data on AMR in foods imported into the UK. Brexit-related changes in the relative amounts of foods imported from non-EU countries are likely to change the qualitative and quantitative antimicrobial and AMR related challenges"
> ACMSF 2018: Pages 12-13

The project team combined trade data from the Agricultural & Horticultural Development Board with publicly available data on test results for the presence of antimicrobial factors, mainly from the European Food Safety Authority, in order to illustrate what retailers and other companies could do with their own and/or shared corporate data to support the management of AMR risk in their international as well as domestic supply chains. It is possible to visualize risks of AMR presence at different nodes in food supply chains through mapping exercises. The maps in Figures 1 and 2 are experimental in this respect and have been produced by the University of Southampton's Geodata

Institute.[8] They depict the risk of the presence of *Campylobacter coli* resistant to Ciprofloxacin, in fresh and processed poultry meat respectively, imported into the UK. Figure 2 is important in showing Thailand as a significant supplier of processed poultry meat to the UK; a supply chain important for its connection to UK retailers' store networks in South East Asia that can provide a boost to the agri-food exports of emerging markets. However, there is limited attention as yet paid to these international supply chains in terms of their role as global pathways of AMR. The publicly available data shows country of origin testing of carcasses and meat, not who and what such products (or the animals they were made from) come into contact with as they move through supply chains. A further limitation in producing these maps was the incompatibility of international datasets on antibiotic use in animals.

Although the data to which we had access have limitations and can mask particular trade complexities such as continental meats being labelled in their processing country, it demonstrates what kinds of mapping exercises for risk management could be conducted by retailers and other companies through sharing of more fine-grained data in the future. This is likely to become particularly important, as the FSA highlights, in the context of Brexit. In October 2018, the European Parliament voted in favour of tighter regulation concerning on-farm antibiotic use, extending to non-EU suppliers in several years' time.[9] There is a UN policy on a phased rolling out of AMR national plans, including support in doing this for the global South, but little of this has been conducted in the farming sector outside of Northern Europe (and even that data is sparse and incompatible).

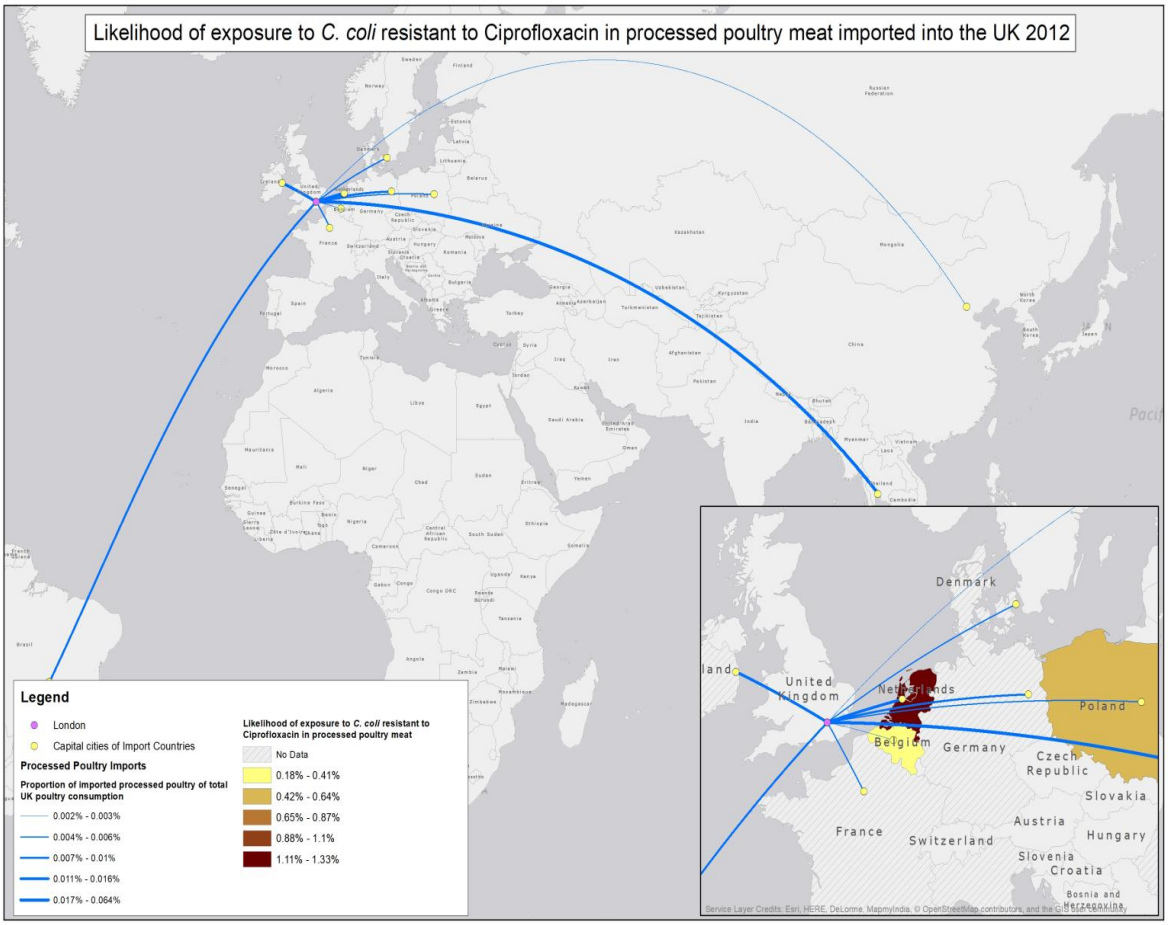
Figure 1



[8] 2012 was the year for which most complete trade and AMR risk data was available using these particular datasets

[9] http://www.europarl.europa.eu/news/en/headlines/society/20181018STO16580/veterinary-medicines-fighting-antibiotic-resistance (accessed 09/11/18).

Figure 2

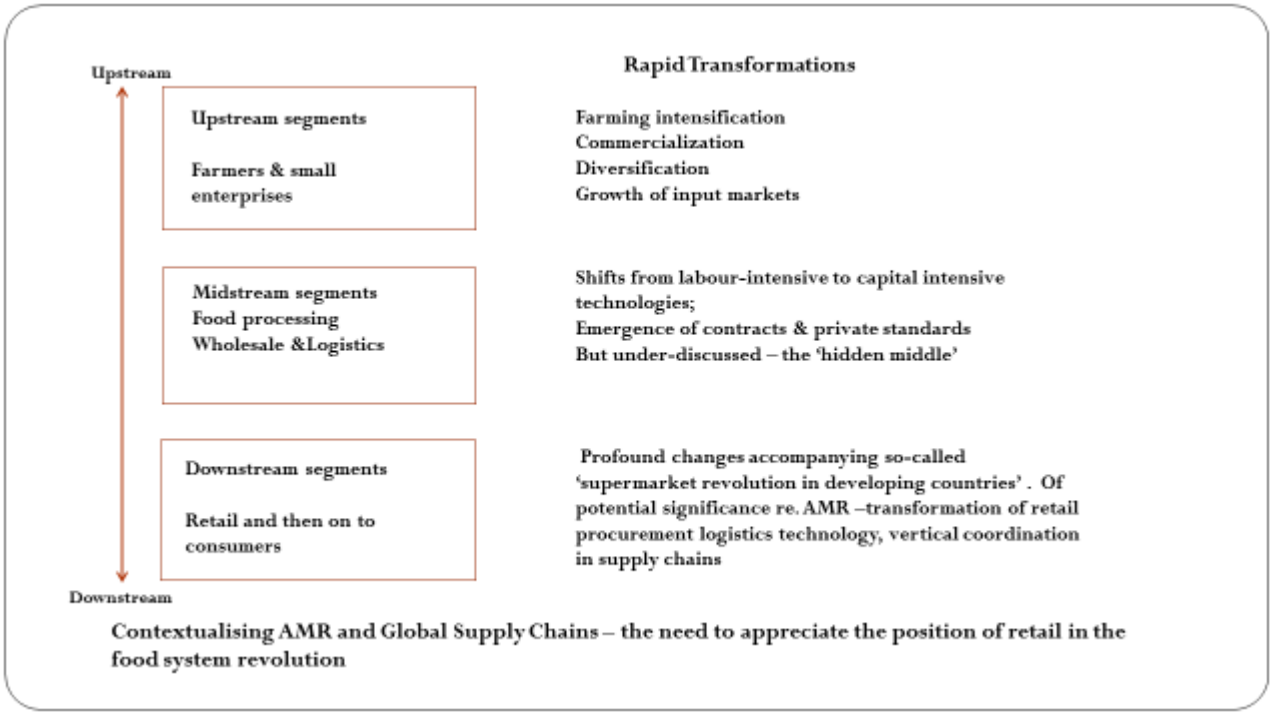


5.3 Tackling AMR beyond the management and monitoring of antibiotic use: Environmental vectors of AMR transmission beyond the farm

What type of response from the food sector, including retailers, is required beyond reducing antibiotic usage in supply chains? And where should it be targeted along complex international food supply networks and with so many potential reservoirs for resistance to flourish? Most commonly only one of the eight potential areas of AMR reservoirs (ACMSF: 2018) was routinely identified by interviewees – that is food producing animals, in other words taking the clinical setting of concern for humans and translating it to animals, which is ultimately what the antibiotic stewardship targets address. The other environmental reservoirs, human-food pathways through handling foodstuffs and food animals (alive/dead) barely featured in discussion with the retail sector. This is perhaps not surprising when the scientific evidence about these potential pathways of transmission is patchy and communication about these sites as carrying risk has to date been poor. However, alongside the new horizons for addressing AMR presented by international meat supply chains and global pathways of AMR linked to processed as well as fresh meat, routes of AMR transmission beyond the food itself represent important areas for future attention. Eating properly cooked meat carries a negligible AMR risk. However, pathogens resistant to antimicrobials, resistance genes and antimicrobial residues can travel and persist in soil, in water, and through direct contact of people including farmers, farm labourers, and abattoir workers with AMR carrying microbes in the environment. As UNEP explains, "antimicrobial concentrations in most effluents are too low to be lethal to exposed bacteria, but may be sufficient to induce antimicrobial resistance" (2017: page 15). Strategies and standards for addressing AMR therefore need to consider these vectors alongside continued programmes of work reducing farm-level antibiotic use. Moreover, these vectors also operate on a

global as well as local and national scale. There is therefore a challenge ahead in terms of addressing the flows of AMR in the context of what Figure 3 shows as key transformations in the food system, including not only upstream segments in a domestic context, where antimicrobial stewardship is currently focused, but also a wider set of AMR transmission vectors throughout the food system, including the 'hidden middle' and accompanying environmental reservoirs. In the *Government Response to the Review on Antimicrobial Resistance* (HM Government, 2016: page 16), "Codex Alimentarius (the joint FAO/WHO body dealing with food) … agreed to establish an intergovernmental task force on antimicrobial resistance in 2017". A key objective of Codex at the time of writing is to develop "the draft Guidelines for Integrated monitoring and surveillance of foodborne antimicrobial resistance".[10] It is important for these guidelines to incorporate pathways of AMR relating to environmental reservoirs and associated with the architectures of the global food system, which are in part coordinated by retailers and processors.

Figure 3



[10] http://www.fao.org/fao-who-codexalimentarius/news-and-events/news-details/en/c/1161586/ (accessed 09/11/18).

6. Findings and Recommendations

The presence of antimicrobials has changed the rates of transmission of genes that are detrimental to the health of humans and animals and to food security. Antimicrobials may not be magic-bullets. They are, however, for now at least, important tools in aiding recovery from pathogenic disease. Yet, the abilities of microbes to adapt to antimicrobial drugs mean that neither better prescribing, nor the development of new drugs will be sufficient to stop the spread of AMR. Across the food industry the key, widely-accepted messages are that a. any use of antimicrobials carries with it the risk of the development of resistance to that (and other) antimicrobials; b. antimicrobials should be used judiciously to reduce the frequency of the occurrence of resistance; c. the risk of resistance developing will never be reduced to zero.

The emergence and resilience of AMR is not a product of a linear cause and effect relationship. In the UK, cross-industry collaboration has been central to the production of accessible, bite-sized information and practical advice that has enabled significant strides to be made in understanding and antibiotic reduction targets to be met ahead of schedule. Retailers' pre-competitive agreements have been a key element of the success of these collaborations. Such agreements have aided a more holistic stewardship approach, which thinks ecologically about health, welfare, biosecurity, training and so on rather than being focused solely on antibiotic reduction. Such agreements have also aided an open conversation about both the limited AMR gains and the risks to health and welfare entangled with the use of antibiotic-free labeling.

6.1 Stewardship and collaboration

Findings:

- **The greatest strides in the UK have been made in reducing antibiotic use in domestically produced, fresh meat**. Meeting targets recommended by the O'Neill (2016) report, committed to by DEFRA and supported by the FSA, two years ahead of schedule without impacting on health, welfare or productivity is a significant achievement. The VARSS report published in October 2017 detailed a 27% reduction in antibiotic use in livestock and fish farmed for food to an average of 45mg/kg, exceeding the government target of 50mg/kg two years ahead of schedule. Stewardship involves understanding the health and welfare needs of animals in the context of the reduction targets, and our interviewees highlighted the role of data collection and analysis. Also, we note here the importance of integrated disease management plans. Integrated approaches can have significant impacts on reducing disease incidence and control of antimicrobial usage.
- Central to the success of antimicrobial stewardship programmes in the poultry and pork sectors to date have been the treatment of AMR as a pre-competitive issue and the **efficient collection and analysis of large datasets concerning on-farm antibiotic use, managed most effectively in food supply chains through stability, partnership, corporate responsibility and investment in training and infrastructure**.
- **The collaborative approach of the UK industry has allowed training materials to be developed for staff within some sectors**. However, as discussed above, AMR is a complex issue and across the industry understanding of the technicalities of AMR is variable.

Recommendations

- **Effective work has been conducted across food supply chains, including but not limited to RUMA, BPC, NPA, Red Tractor and the AHDB in rolling out platforms, guidance and training that enabled data collection on antibiotic use**. The publicly available figures for antibiotic use are averages over the year. This is important, as different farms have different challenges at different times. Disease outbreaks happen in all species, and farmers should

not be penalized for caring about the health and welfare of their animals. However, it would be useful going forward if **the same platforms could be standardized to allow research into any patterns that are emerging**.

- To understand more about the emergence of disease, and so the need for treatment with antimicrobials, **data collection needs to be comprehensive, collaborative, standardized and shared, whilst remaining pre-competitive**. Companies should be able to use such data for their own benchmarking, and the data can be anonymized and does not need to be publicly available. Such datasets should be available for scientific analysis into patterns of disease, as they relate to such things as weather, feed, stockperson skill, housing type and strain, with a view to producing recommendations for improving on health and productivity outcomes generally, as well as antimicrobial use specifically. What is key is that such data collection is the collective responsibility of the food chain as a whole. This raises key questions for the industry and policy makers to explore around financing such a system, and of ease of use on the ground. There are opportunities here for UK policies and companies to be world leading in their collaboration and holistic approach to AMR. The UK is already well placed to do this, for example by building on the electronic Medicine Book (eMB) system that has rapidly been rolled out across 90% of the pig industry.
- Dialogue is needed as the UK moves to a post-CAP landscape regarding **priorities for farm investment** in the context of AMR. The stewardship approach already situates AMR within animal health and welfare policy and practices. As such, there is potential for including consideration of future investment, e.g. in improved housing stock, within the lens of AMR oriented policies and practices. Related to this is discussion around small and medium sized farms. Our research had pig and poultry supply chains as its focus. These industries have been fast moving on AMR, in no small part aided by the consolidated and coordinated nature of these industries enabling training and investment within their systems. **Attention needs to be paid to the risks of passing the burdens of implementing change down the chain on to farmers**, and in so doing further squeezing small players who are forced to absorb such costs, often without security of contract.
- Our research suggests it could be useful to **supplement sector specific training with a knowledge based industry-wide training** (similar in structure to the basic food hygiene certificate) that sits before the sector specific training and situates AMR as a public health issue in an ecological context. This could include the food hospitality and public sectors, as well as food retail and production.

6.2 Consumer engagement

Findings:

- **Consumers have limited knowledge of AMR**. Consumers are already overwhelmed by the volume of conflicting information they are bombarded with around food, health and eating. The 'less but better meat' campaign is potentially valuable here, but it is also a sensitive subject as food choices are deeply entangled with abilities to pay. There have been campaigns aimed at encouraging consumers to eat a wider range of cuts of meat, but so far with limited success.

Recommendations

- **More research is needed on public engagement with AMR**, as knowledge is not sufficient to change behavior, given that food practices are mundane, habitual and embedded in familial and community routines.
- AMR raises important questions about public health, local practices and global connectivity, animal welfare, and household budgeting**. At school level AMR is potentially a productive lens to cut across disciplines such as geography and biology, but also food technology and**

citizenship classes. Many of our research participants raised the issue of consumer disconnect from food production. Initiatives such as Open Farm Sunday were seen as important here and there is potential to explore this further.

6.3 New Horizons

Findings:

- Whilst the monitoring and recording of antibiotic use in domestically-sourced fresh meat products to address the challenge of AMR is becoming more rigorous, robust and transparent, **calculation by UK retailers and processors of AMR risk associated with imported and processed meat products is at a much earlier stage of development.**
- **Environmental reservoirs, human-food pathways through handling foodstuffs and food animals (alive/dead) barely featured in discussion with the retail sector**.
- The mapping element of this research raised some significant issues with regard to understanding AMR in the context of public health and food systems. **The maps begin to demonstrate what might be achievable if granular data are available to researchers and industry practitioners**.

Recommendations

- **Mapping AMR risk** is likely to become particularly important, as the FSA highlights (Advisory Committee on the Microbiological Safety of Food, 2018), in the context of Brexit and should therefore be explored further. The European Parliament has recently moved to strengthen EU legislation on agricultural antibiotic use. If this legislation is adopted by the Council key changes include limiting prophylactic use to individual animals, and empowering the European Commission to reserve CIAs for human use.[11] If the UK post-Brexit moves to import less meat from the EU, which is globally leading on tackling AMR, there may be shifting risks that require research and strategic response.
- Alongside the new horizons for addressing AMR presented by international meat supply chains and global pathways of AMR linked to processed as well as fresh meat, **routes of AMR transmission beyond the food itself represent important areas for future attention**. Pathogens resistant to antimicrobials, resistance genes and antimicrobial residues can travel and persist in soil, in water, and through direct contact with people including farmers, farm labourers, and abattoir workers in the environment. **More research is needed on these transmission routes.**
- **It is important for Codex Guidelines for Integrated Monitoring and Surveillance of Foodborne Antimicrobial Resistance, into which the FSA is crucially feeding at the time of writing, to incorporate pathways of AMR relating to environmental reservoirs and pathways of AMR in processed and internationally-sourced foods**. These pathways are structured by the architectures of the global food system, coordinated in part by retailers and processors. **Social science research on the geographies of the food system and the roles of commerce, including retail, in shaping them need to be coupled with microbiological research and epidemiology on AMR transmission to build the most effective ways of implementing antimicrobial stewardship at an international scale.**

[11] http://www.europarl.europa.eu/news/en/press-room/20181018IPR16526/meps-back-plans-to-halt-spread-of-drug-resistance-from-animals-to-humans (accessed 14/11/18).

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8. Acronyms

ACMSF - Advisory Committee on the Microbiological Safety of Food
AHDB – Agriculture and Horticulture Development Board
ABU – Antibiotic use
AMR - antimicrobial resistance
BPC- British Poultry Council
BRC – British Retail Consortium
CAP – Common Agricultural Policy
CIAs- Critically Important Antibiotics
CCIR – Collectiona nd Communication of Inspection Results
DEFRA - Department for Environment, Food and Rural Affairs
eMB – Electronic Medicines Book
EFSA- European Food Safety Authority
EPSRC – Engineering and physical sciences research council
ESRC – Economic and Social Research Council
FSA – Food Standards Agency
LGT – Lateral Gene Transfer
HACCP - Hazard Analysis and Critical Control Points
NAMRIP – Network for anti-microbial resistance and infection prevention
NPA – National Pig Association
POST - Parliamentary Office of Science and Technology
RFID – Radio-freduency identification
RUMA - The Responsible use of Medicines in Agriculture Alliance
(UK)VARSS-Veterinary Antimicrobial Resistance and Sales Surveillance
UKRI – United Kingdom Research Innovation
UN – United Nations
VMD – Veterinary Medicine Directorate