NUFFIELD UK

A Nuffield Farming Scholarships Trust Report

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Dairy Antibiotics: achieving sustainable use

Duncan Williams BVetMed MRCVS

June 2020

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Nuffield (UK) Farming Scholarships Trust Report

"Leading positive change in agriculture. Inspiring passion and potential in people."

Date of report: June 2020

Title	Dairy Antibiotics: achieving sustainable use
Scholar	Duncan Williams
Sponsor	The Richard Lawes Foundation & The Dartington Cattle Breeders Trust
Objectives of Study Tour	Understand the key drivers of farm antibiotic use and the role of each area of the dairy industry in reducing use.
Countries Visited	The Netherlands, Ireland, Italy, Switzerland, United States of America, India.
Messages	• By focusing on the quality of stock, the environment and nutrition, farmers can reduce their antibiotic use. • We need increased transparency throughout the industry, and have policies designed together with farmers. • Some antibiotic use is a response to economic circumstances, and tightening margins sometimes lead to increased antibiotic use. • The level of antibiotic use in agriculture is ultimately a political decision; the responsibility lies across the whole production and governance chain.

EXECUTIVE SUMMARY

This report is the result of over eight weeks of international travel, covering seven countries over three continents. Numerous farmers, researchers, vets and industry folk gave up their time, lending both their experience and opinions. I argue that the issues around antibiotic resistance do not start and finish on the farm. Instead, they extend throughout the entire food and farming industry, right up to national governance.

Antimicrobial resistance is a growing and urgent threat across the entire world. The UK was centre stage in antibiotic history; from their discovery and increased use through to the early warnings regarding misuse, and subsequent regulation. We must act now to ensure that we are part of the solution and minimise any future harm.

I begin by discussing how the science around this subject will never be perfect; we do not know all of the specific, farm-level risk factors for high resistance. This knowledge gap should not deter us; the impacts of resistance are so significant. If farming might contribute, we must do all we can to fix it.

I bring in examples of how farmers around the world have already transformed their businesses to decrease antibiotic use. The tools for change lie with farmers; they must reduce disease levels, improve animal welfare, while also reducing their reliance on antibiotics. However, farmers do not exist in isolation. Their antibiotic use will often be a response to the economics in which their farm operates. Tightening margins can lead to higher antibiotic use. Farmers looking to decrease their risk of disease may be more likely to treat animals ‘just in case’.

I argue that to create better animal health outcomes, we must re-assess how we shape our industry. We must take sensible risk-reducing precautions and design targeted interventions for businesses underperforming. We must bring farmers into the policy creation process and be more willing to share data; farmers and corporates must contribute to local and national schemes wherever possible.

Finally, I contend that to encourage low farm antibiotic use, farms must sit within an aligned policy framework. These policies must cover everything from health to trade. Antibiotics shape the history, economics and politics of farming. We must harmonise our high-health, low-antibiotic goals through the entirety of the industry, or economics will be pulling us in differing directions.

As agriculture transforms over the coming years, it is the whole industry’s responsibility to shape it.

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Note that full reference details are given on the last page of this report. Only abbreviated references are given in the main body of the document.

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Please note that the content of this report is up to date and believed to be correct as at the date shown on the front cover.

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1. Personal Introduction

I grew up on an arable farm near Maldon, Essex, a 1,200 acre tenanted property currently run by my parents and older brother. I always assumed that my brother would be running the farm, and I would be somewhere else. I studied to be a vet at the Royal Veterinary College, where my passion for the dairy industry took off. I imagined myself to be a 'shirt and tie' old-school vet, roaming around the British countryside with a dog beside me. However, after graduating in 2011, I moved to America for an internship at the University of Illinois. Here I worked with a fantastic and knowledgeable team, who took time to train me, and instil in me the need for evidence-based medicine.

Figure 1: The author, Duncan Williams, on his family farm in Essex

My next stop was New Zealand. I worked as a sole practitioner within a larger vet group, on farms ranging from 150 to 5000 cows. Stark system contrasts between the US and NZ meant a lot of my time was spent learning on the job.

A chance trip to China in 2014 opened my eyes to the possibility of a different career path. I spent six weeks on an 8000-cow dairy farm just outside of Beijing. I witnessed intensive dairy farming up close and learned the principles of large scale production. I saw the challenges related to staff management, environmental protection and animal health, and felt there was a huge opportunity to influence change. As a vet, I wanted to leverage my skills. I saw large scale dairying as the way forward.

My return to the UK in 2015 saw me join Kite Consulting, a leading dairy consultancy company. With no previous personal roots in the South-West, I spent the next few years building a group of nutrition clients and forging new friendships around Exeter. With the support of Kite, I grew in confidence, learnt strategic and financial skills, and began to get involved with great dairy businesses.

2015 saw supermarkets and processors start to discuss antibiotics with their farmers. They wanted to instigate supply chain rules to protect their business and decrease risk. These changes took me into village halls around the country, talking to farmers. Suddenly, I was running farmer discussions and explaining benchmark results. I worked with processors to create antibiotic policies. I tried to balance the need for change with the realistic rate of this change on-farm. The whole time I was feeling quite out of my depth as a relatively new face on the consultancy scene.

Three years of this mixed, consultancy/antibiotic work led me to apply for a Nuffield Farminbg Scholarship. I could see the closing of the first chapter in the antibiotic reduction story, and wanted to understand the correct next-step.

My Nuffield Farming Scholarship changed my perspectives not only on antibiotics, but also farming and food in the broader sense. I hope the following report does justice to the money, time, energy and patience that others have expended on me over the last two years.

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Editor's Note: A UK Nuffield Farming Scholarship consists of:

(1) A briefing in London.

(2) Joining the week-long Contemporary Scholars' Conference attended by all new Nuffield Farming Scholars worldwide, location varying each year.

(3) A personal study tour of approximately 8 weeks looking in detail at the Scholar's chosen topic.

(4) A Global Focus Tour (optional) where a group of 10 Scholars from a mix of the countries where the scheme operates travel together for 7 weeks acquiring a global perspective of agriculture. (The author of this report participated in a Global Focus Tour).

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The Nuffield Farming Scholarships scheme originated in the UK in 1947 but has since expanded to operate in Australia, New Zealand, Canada, Zimbabwe, France, Ireland, and Netherlands. Brazil, Chile, South Africa and the USA are in the initial stages of joining the organisation.

2. Background to my study subject

"***Antibiotic resistance is one of the greatest threats facing humanity*"**, states the O'Neill Report from 2016 (O'Neill, 2015).

This UK government-backed review increased both media and political interest in the issues around antibiotic resistance. It estimated the full potential cost, both financially and in terms of human lives, of failing to tackle it: 10 million lives a year and a cumulative 100 Trillion USD of lost economic output. Behind each of the statistics is a real human case, with pain, suffering and long term health consequences. It is heart-wrenching to hear stories of people debilitated by resistant organisms and the suffering this brings to their friends and families.

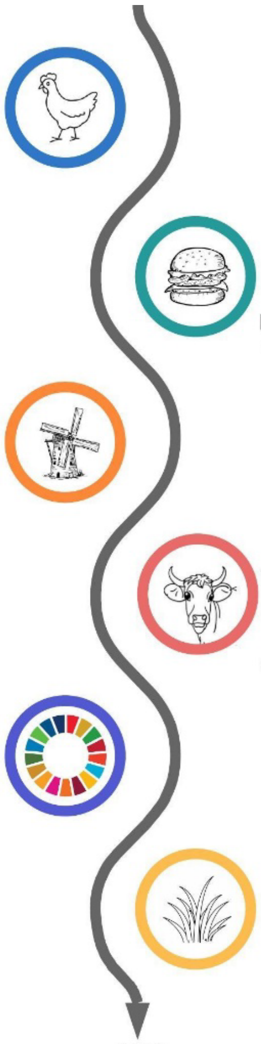
Resistance is an inherently complex subject. A lot of science is generated every year. Antibiotics are drugs that kill or inhibit the growth of bacteria. They were discovered in 1928 by the Scottish physician Alexander Fleming. Since then, they have revolutionised medicine and have added years to the life expectancy of people around the world. While some bacteria in their natural state are not affected by certain drugs, this is not resistance. **Resistance is the ability of bacteria to withstand the effects of a drug through the action of acquired genes.** The critical question is, why do they get these genes, and how can we stop this happening?

It didn't take long for the growth-promoting effects of antibiotics on animals to be discovered. The farming communities on both sides of the Atlantic began to incorporate antibiotics into their farming practices: not only for the treatment of disease but also for the growth-promoting effects that they conveyed. The 1969 Swann report stated that "*the administration of antibiotics to farm livestock, particularly at sub-therapeutic levels, poses certain hazards to human and animal health*" (Swann MM, 1969). The UK, along with some Scandinavian countries, was the first to limit antibiotic use in animals, eventually leading to the EU banning growth-promotion use in 2006.

The UK dairy industry has taken significant steps in recent years to make improvements. At the same time as antibiotic benchmarking, the roll-out of Selective Dry Cow Therapy began (where only cows with evidence of infection get dry cow antibiotics). Vets, supermarkets and milk processors started this process, supported by the research coming out of universities. Since then, this programme has widened to become the accepted gold standard in the UK. Collation of annual use is now part of the Red Tractor farm assurance, a half-way house to national benchmarking. Antibiotics irreplaceable to human medicine have disappeared from dairy farms. Farmers are more aware of the issues around antibiotics.

So does the dairy industry need to make further improvements, and if so, how do we achieve this?

3. My Nuffield Farming study tour



Ireland (June 19)

Visits: Vertically integrated chicken farms.

Other sectors are different distances along the antibiotic reduction journey. By learning from the broilers can we accelerate the progress of the dairy industry?

America (July 19)

Visits: Large and small dairy farms, vets, drug companies, and university researchers.

In the USA the regulatory environment is different. How does a looser farm assurance system and more of an emphasis on economics shape their industry?

Netherlands (April 19 and Oct 19)

Visits: Dairy and pig farms, government officials and lobbyists, universities, conferences and consultants.

The Dutch hare already dropped antibiotic use across all livestock sectors. How did they achieve this reduction and what impact did it have on their farm and vet businesses?

Switzerland (Aug 19)

Visits: Met with farmers, vets, researchers and NGOs.

The Swiss have a very different farming model to the USA. How does this highly preserved environment affect animal health outcomes, and does it change people's relationship with farming?

Italy (Oct 19)

Visits: The FAO veterinary team and debates at the Committee on World Food Security.

How do the debates happening at a UN level affect farm antibiotic use around the world, and how is Britain positioned going forward?

India (March 20)

Visits: Farmers big and small, milk coops, development specialists and researchers.

As a milk market, India is close to unique. It is also a country where antibiotic resistance is rife. How do the cooperative industry and emerging private sector differ in animal health outcomes? Despite the difference, are there lessons that can be drawn by comparing India with the UK?

UK

Visits: farmers, processors and supermarkets, historians, researchers, and the levy board.

Researchers and farmers around the country have already made great progress in reducing antibiotic use. How has that momentum has been created and how can it be maintained? What lessons can we draw from the long history of antibiotic use within UK agriculture?

Figure 2: Map to show the author's travels while on his Nuffield Farming study tour

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I learnt very quickly that asking anyone to discuss antibiotic resistance yielded very few responses. I hope I can show how interesting the subject is.

- It is the quintessential one-health issue, sitting perfectly in the gap between human and animal health.
- It is fundamental in the policies around international development, the future of food production both in the UK and across the world.
- It is also a mirror for the industry, to understand how we act under pressure, our ability to evolve alongside the targets.

If we do not learn the lessons from this issue, the next few decades will be very challenging indeed. I know some of my interpretation will be wrong or outdated before this report is even published but, for the most part, I hope I have been faithful to both the substance and spirit of the existing research.

To quote John Cyster NSch, Chairman of the Nuffield Farming Scholarships Trust from 1970-85: "*Nuffield Farming Scholars must be penetrating in their analysis, forthright in their reporting, courageous in their practice, provocative in their advocacy, and adventurous in their forecasts".*

Within the field of antibiotic resistance there are agreed facts as evidenced within scientific, peer-reviewed papers; but then there are also truths outside of this that need exploring.

I have tried to be bold in my analysis and conclusions, and to speak honestly, where I feel it is necessary.

The formal part of my report starts in the next chapter: Chapter 4, and begins by looking at how antibiotic resistance first arose.

4. The science of resistance

4.1 History

"The development of antimicrobial resistance cannot be stopped. It is a natural and ancient phenomenon that originated independently of either modern medicine or industrialised agriculture and is ubiquitous." (Woolhouse M. E. J., 2013)

Agriculture has played a role in increasing the level of antimicrobial resistance. Of the 137 academic papers reviewed as part of the O'Neill report, 100 supported limiting the use in animals. Only seven argued against it (O'Neill, 2015). The O'Neill review looked at global agricultural antibiotic use in all its different forms. Which of its recommendations are most important to enact in the UK is still unclear.

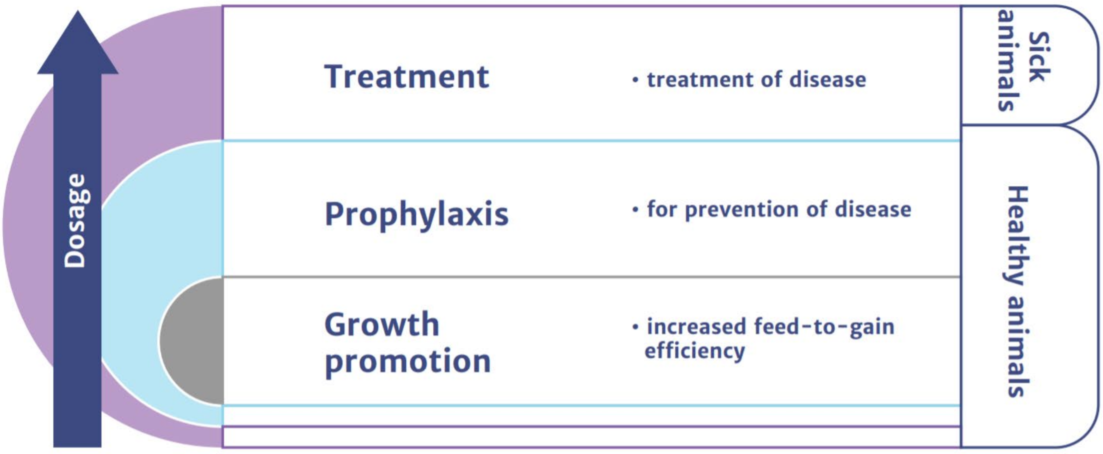

Figure 3: The spectrum of usages for antibiotics in veterinary medicine. (O'Neill, 2015)

Figure 3 explains the spectrum of drug usage: from growth promotion; antibiotics to improve feed efficiency; through to treatment, with clinically-sick animals getting individual treatment.

The first use of antimicrobials in animals was as growth promotion: scientists discovered that the waste coming from their production boosted chicken growth. While initially it was thought this was down to vitamin levels, it was the antibiotics. This discovery started a boom in the manufacture and selling of industrial quantities of antibiotics destined for animals. While scientists, including Fleming himself, had warned against the misuse of these new life-saving drugs, post-war meat production requirements needed meeting. The UK led the world with the publication of the Swann report in 1969 (O'Neill, 2015). However, rather than promote radical change across the globe, this was followed by decades of inaction and persistent antibiotic use.

While there is substantial evidence that, at a country and global level, antibiotic use in agriculture promotes resistance, the science behind which specific applications are the culprit is far less clear.

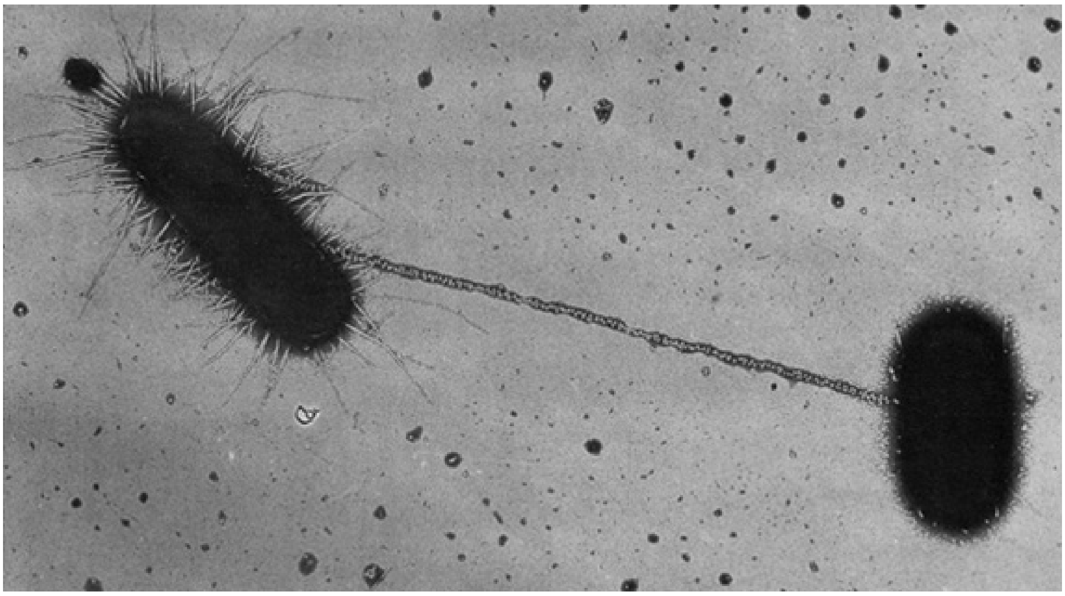

Figure 4: E.coli bacteria are exchanging genes. (US National Library of Medicine, 2020)

4.2 Transferring genes

Bacteria don't work as we do. They originated some 2 billion years before us, so it is unsurprising that they are not only complicated but also highly effective at survival.

We, humans, pass genetics on vertically, from parent to offspring. Once created, there is little we can do to change the genes we have. Bacteria, on the other hand, can pass genes both vertically and horizontally; between two already-living cells in a process called conjugation. It's not their primary genes that they do this with, but small circular pieces of DNA called plasmids. I discovered that these play a very significant role in the resistance story, and may help guide our best moves in countering it.

Just like all evolutionary stories, resistance starts with a genetic mutation. These changes in genetic sequences can give bacteria the ability to evade, break down, or expel certain drugs, rendering them ineffective. This process has been going on for a long time; up to 2 billion years, making them older than human or veterinary medicine, and was even present before the age of industrialised agriculture. But things have changed recently; the number of genes discovered is increasing. Once identified, scientists have been tracking their rapid transmissions around the globe.

If these mutations occur on a plasmid, then they can be transferred from one strain of bacteria to another. Equally, plasmids can mix themselves up, meaning that multiple-resistance genes can appear on the same piece of DNA. Using one drug will select for resistance to the other, so-called co-selection.

High-Priority, Critically Important Antibiotics (HP-CIAs) are classes of antibiotics that are life-saving in human medicine and have few or no alternatives. UK dairy focused first on removing these, with great success. However, some E.coli resistances are against both the 3rd generation cephalosporins (an HP-CIAs) and co-amoxicillin. Co-amoxicillin is not on the UK's Critically Important list. Using either of these drugs with the resistant bacteria around will promote resistance to both.

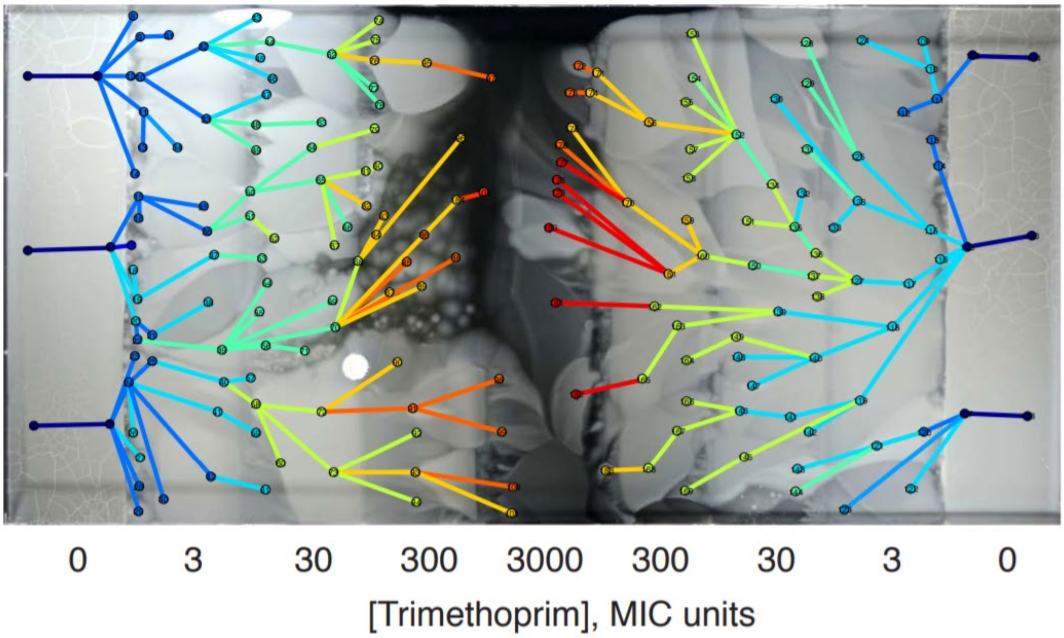

Figure 5: A four-step MEGA-plate, showing bacteria evolving as they move through increasing concentration of antibiotic. (Baym M, 2016)

When I started my travels, I thought resistance was like a rising tide: each antibiotic used raised the sea level a tiny bit. Eventually, we are all below water, and the antibiotics no longer work. My new frame of reference is different: by focusing on the genes, we are clear about what is causing resistance and how it travels. Figure 5 is from an experiment at Harvard, designed to show resistance in action. This giant petri-dish, with increasing concentrations of antibiotic towards the middle, was seeded on the outside with bacteria. When they reach a new layer, they must mutate to advance. Some strains will then mutate again, and again, as they cross into increasing antibiotic concentrations. It creates a tree-like pattern. Antibiotic presence drives both the creation of resistant genes and their expansion into new spaces. An internet search for "Evolution of Bacteria on a Mega-Plate" will show a short video of the 11-day process. It fits in with our knowledge of evolution and the concept of a family tree. It makes sense.

These genes can sometimes stick around in the population after antibiotic use has finished. Other times resistance genes confer a fitness cost on the bacteria, meaning they must expend so much energy keeping them when the drug is not present they die out. If reducing antibiotic use in animals is going to have an impact on human health, it is by stopping the branches of these trees from being formed, or from reaching through animals and into humans.

I first saw Figure 7, taken from (García et al., 2018), at the ICOHAR conference in Utrecht, Netherlands. One of the paper's authors presented it, explaining the significance of their findings. It shows how much E.coli resistance Dutch animals share with Dutch people. Each group is a different colour and number, detailed on the left of the graphic. The more two colours overlap, the more similar their bacteria are. Note that this is one set of genes, from one strain of bug, in one country, but it does show how there is only a small amount of overlap between these populations of bacteria. See how chickens

(16) and chicken farmers, (6) share bacteria. See how calves (19) and some hospital patients (4) have some but not all overlapping bacteria. See how much mess and overlap there is between each of these different colours. It indicates that, for this resistance type, agriculture may not be the primary pool of genes for human infection. However, resistance is still there. Pools of bacteria will circulate within a farm. Mixing of animals between farms will mix the bacterial populations as well. Any time that humans come into contact with an animal's bacterial population, such as occurs within the farming community, we will exchange bacteria also.

Figure 6: Cattle at a swimming spot, Exeter, Devon.
Exchange of gut bacteria can risk passing of resistance genes from animals to humans.
Photo author's own

See figure 7 over page.

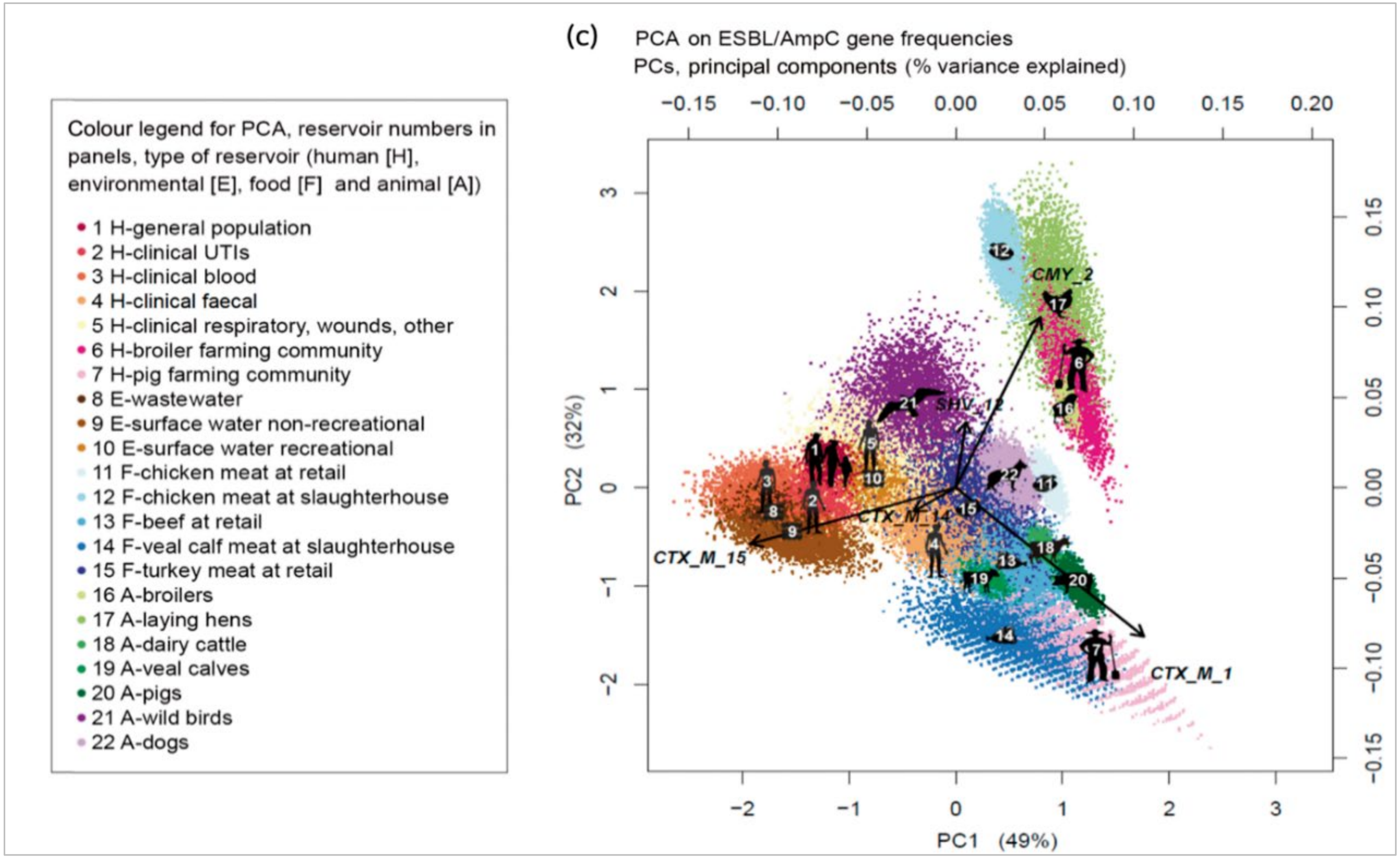

Figure 7: Principal component analyses of Dutch E.coli (García et al., 2018).

4.3 Implications

The uncomfortable truth remains that we don't yet know what drives individual farm resistance levels. At a national level resistance is likely to fall as use comes down, but different farms could be high or low irrespective of their actual antibiotic level. Individual drug-bug-gene-animal combinations will dictate the exact implications of a specific antibiotic's use at any particular time. Some are important, some less so.

In reality, it's a spectrum of risk that we will never truly understand. This spectrum does little to diminish the importance of taking a precautionary approach as science is likely never to be settled.

One of my final visits on my Nuffield Farming study tour was to a UK conference on antibiotic resistance. I heard of a young girl, fighting for her life. She contracted a multidrug-resistant infection following a lung transplant. Following a successful operation, she went on to develop a small rash over her incision site. This rash in turns grows and deepens, till it ends up engulfing her entire upper body, almost killing her. She is then placed onto a long list of highly toxic medications, causing horrendous side-effects. The very best medics in the country and some ground-breaking research just managed to save her.

She was a lucky one. Many thousands a year are not. There is a risk that, following the coronavirus epidemic, we become desensitised to health statistics. We need to remember that there is a huge human cost to antibiotic resistance. Many people in India and China are profoundly affected by resistance. So are people in the UK. Failing health systems hamper a nation's ability to grow and prosper and, with that, prevent millions of others working their way out of poverty.

Fighting antibiotic resistance is critical, not only because it is the result of failings in both human and veterinary medicine, but that it also drives the outcome of both fields. It is at the heart of healthcare inequality and wider income disparities as well. In my view, if there is even a remote chance that agricultural use can either cause mutations to occur, or allow them to jump into the human population, we must do all we can to mitigate this risk.

The science is not perfect, and it will likely never be. It is not helpful to play blame games, attempting to cast either human medicine or animal agriculture as the primary cause of this crisis. Instead, we must share the responsibility for finding its solution.

4.4 Chapter 4 conclusions:

- Farm use of antibiotics contributes to the global resistance level. However, we do not know the specific, farm-level risk factors.
- Co-selection has the potential to undermine the removal of HP-CIAs from dairy if other drugs are not also limited.
- Farming must ensure we focus on minimising the risk of transmitting resistant genes from farms into human populations.

The next chapter gives an example of how one company has almost completely removed the use of antibiotics from their farms.

5. Reducing antibiotic use within the broiler industry

5.1 Reduce, replace, refine

Diarmaid Kirby is an agricultural manager for Western Brand Group, the largest family-owned broiler producer in Ireland. After we visited one of the units he is in charge of, he described the journey the company has been on to reduce antibiotic use. The company worked through their supply chain, right back to the breeder stock of the day-old broiler chicks it receives. Throughout this process, they focused on three areas:

- quality of the animals
- environment
- nutrition.

Figure 8: The inside of a chicken shed at Western Brand Group. Photo: author's own.

Quality of animals: By improving the health status of the parent flock and adding in things like organic acids to enhance gut health, they found lower bacterial loads on eggs and thereby the hatching chicks. Next, they ensure these eggs are laid into clean environments, not accepting any eggs that need immersion cleaning and, possibly in the future, even removing floor eggs from their production chains.

Chicken genetics are some of the best refined of any animal species. They will be able to source precisely the type of animal they are after for the given production system.

Environment: The focus on every stage of the broiler production cycle includes the rearing stage as well. Diarmaid notes that most of the gut disease that they see is physiological, not from infectious causes. In other words, it's because of the stressors of one form or another that birds get sick. Fixing whatever caused the stress in the first place is key to preventing it from happening again. Good water quality is essential, and they ensure this by regular quality testing and cleaning of pipes. They overcome biofilm development, a massive challenge in the resistance field, by using hydrogen peroxide-cleaning between batches.

Nutrition: The final stage of their plan is to optimise nutrition. Diarmaid searches for ingredients to increase bird health and optimise growth rates. The farm is trying nutraceuticals to replace antibiotics and decrease the likelihood of disease.

They continuously focus on achieving better results and maintain tight linkages between processor, nutritionist, vet and farmer. They had great attention to detail and knew the results of every flock from every farm. Sharing and using this data is a crucial way of driving positive change. A similar, all-encompassing focus on health prevention, along with open and transparent data exchange, could be applied in the dairy industry.

Diarmaid says: "*In the post-antibiotic era, which the poultry industry is entering, it is becoming increasingly important to get the basics of husbandry right. Antibiotics will no longer be available to compensate for poor farming practices*".

5.2 Chapter 5 conclusions:

This broiler business has dramatically reduced its usage of antibiotics. This reduction was achieved by focusing on:

- The quality of the stock (including genetics),
- The environment in which animals live,
- Animal nutrition and water quality.

These principles of reduction are directly transferable to the dairy industry. Much of the variation in antibiotic use that we see within the dairy industry is because, on some farms, this attention to detail and methodical eradication of disease has not occurred. The onus is on these farmers to ensure that they engage with this process. They must reduce disease to improve welfare and productivity, and with that reduce their antibiotic use.

Next, I will consider how the broader farming economy shapes individual farm antibiotic usage.

6. Antibiotic use within the farming economy

The regional differences in American dairy farms are as stark as in any other continent. The family farms of Pennsylvania and Wisconsin reminded me of the South-West of England. There is a mix of old and new: shiny robots put into old, wooden sheds, and the latest GM corn silage packed into rusty silage towers.

This type of farm contrasts with the larger farms of Texas and New Mexico. Here the realities of dairy seemed far harsher and less forgiving. The farms tended to be large, often run as part of a multi-site operation. They are commodity-transformation businesses; buying silage and cows on the open market to convert to milk and meat. Large corporate farms developed this process. It then trickled down to the smaller ones. The farmers I visited undoubtedly had a better understanding of costs and profitability than many in the UK. This clarity also opened their eyes to the fast-spinning economic cycles.

Figure 9: Large scale dairy in Southern USA. Photo author's own.

A

6.1 Antibiotic use in the USA

America uses a large amount of antibiotics, especially in the beef industry. Agricultural use in the USA in 2018 was estimated to be 160mg/PCU vs 30 in the UK (Alliance to Save our Antibiotics, 2020). The USA's Veterinary Feed Directives has made all over-the-counter antibiotics prescription-only from 2017 onwards. This law signalled the end of growth promotion; however, in reality, much remains unchanged, there's just additional paperwork.

Some farmers are making fantastic, positive change, but this is far from universal; some beef cattle will be on antibiotics their whole life.

In certain parts of Texas, suckler beef cows were on constant tetracycline to prevent Anaplasmosis, a tick-borne blood disease not even caused by bacteria. On weaning, their calves may be taken to a feedlot and placed on Tylosin, another antibiotic, this time to prevent liver abscesses. Both of these treatments work and are very cost-effective. At the same time, they are increasing selection pressure on environmental bacteria populations, potentially extending chains of resistant bacteria.

Severe Anaplasmosis will kill an adult cow, and a lesser infection will cause significant suffering. Owners have a duty of care to ensure their animals do not suffer from the disease. In this case, treatment is understandable. Progressive farmers and vets in the US are working out different treatment strategies. Young animals are more resistant to clinical disease. Potentially, allowing them to catch the parasite early may help build immunity. The veterinary feed directives have acted as a springboard for producers to start engaging more with their vets. Changes are happening, and progressive farmers are leading the way.

The US industry needs to work together to eliminate historical usage, some of which will be unnecessary.

I witnessed farmers buying and selling cattle through online auctions. They were matching their purchases with trades on the futures market: locking in the slimmest of margins and, even so, only being able to realise this if their efficiencies matched their expectations. In an industry this competitive, farmers are forced to use the tools at their disposal to stay afloat. At a simplistic level, they need to turn grain into beef more efficiently than the competition to stay afloat. Liver abscesses are inherently a production-related disease in cattle, caused by feeding high grain diets to animals not designed for it.

6.2 How this applies to the UK

Disease pressures and farming systems are different in the UK, so neither of these examples necessarily apply. However, we do have comparable situations.

The UK dairy industry has had an issue with bull calves for decades. I spoke with a Jersey spring-block-calving farmer who was struggling to find a solution. Each spring, he is faced with a dilemma of raising bull calves in old sheds and dealing with the inevitable outbreaks of pneumonia. His options as he sees it are:

1. To take a financial hit and build a new calf shed to rear his already loss-making bull calves.
2. Euthanise them - arguably not a long term solution with recent changes to the industry and supply contracts.
3. Cause some environmental damage in the form of resistance by feeding antibiotics to avoid pneumonia.

His situation is by no means unique.

The cheapest solution is to continue to use antibiotics preventatively. Our economy does not have the cost of resistance built-in. This farmer built his business in the UK milk market; he was responding to its financial pressures and operating within its laws. If he were to invest in a new shed, he would increase the cost base for the business. If he can't add any additional value, he will become less competitive. If his competitors go on using antibiotics as before, the competitors will be more profitable and out-compete.

Our current business model incentivises operating at the lowest permissible standards. These standards might be legal requirements, assurance scheme or milk contract.

6.3 Negative externalities:

The consequences of on-farm antibiotic use will be both positive *(healing of the sick animal and a reduced risk of other animals getting sick)* and negative *(costs associated with treatment, additional poor perceptions of the industry, and extra selective pressure on environmental bacteria)*.

The immediate financial costs are known, and simple to calculate. Supply contracts are beginning to include brand protection elements. The additional selective pressure on bacteria and how that affects both animal and human health is not present in the current economic models.

This gap is what is called a negative externality. It is a cost that affects someone else, who didn't choose to incur it.

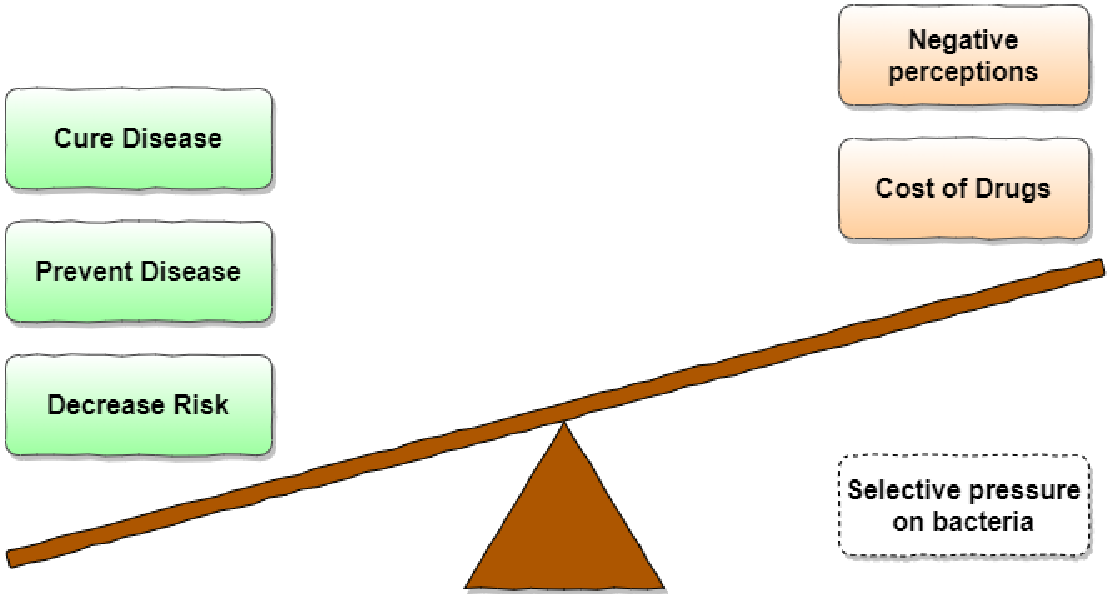

Figure 10: Diagram showing how economic models do not include negative externalities (in this case, increased resistance) Image: Authors own.

Negative externalities are at the core of every sustainability issue. Fossil fuels, air pollution, biodiversity destruction - all share this same issue. The initial action doesn't take into account the full cost on the rest of the world. Suggestions to counteract this include a carbon tax; increasing the price of burning fuel until it matches the impacts of global warming.

6.4 Taxing antibiotics

"By forcing farmers to pay an additional cost for every antimicrobial they use, they will then (have to) take into account the costs that their action has on society at large." (O'Neill, 2015)

Some suggest an antibiotic tax. The argument goes that antibiotics are too cheap, and increasing prices would decrease their usage. The drugs would be available to treat genuinely sick animals. While this is true, it is not the whole story: if you increase the price of treatment in this country, you make our farmers slightly less competitive. This imbalance risks importing cheaper food from countries without the tax.

There are two options then available: firstly, either protect your home market from those imports to an amount equal to the cost you just added; or secondly, use that tax to decrease the price of something else within the system. This second option means that farms as a whole retain their profitability. One example could be shifting medicinal usage from antibiotics to a vaccine or other preventative treatment. The researchers I talked to suggested applying this tax at the point of manufacturing or import, keeping implementation simple.

6.5 The economics of decision making:

".......the rationale of using medicines as a mechanism for maintaining high levels of productivity remains prevalent in contemporary farming systems" (DEFRA, 2015)

When a farmer decides to use antibiotics to treat a disease, it makes sense that they expect the cost of the drugs (including any withdrawals) to be less than the production losses of the illness that they are treating.

When farmers are uncertain whether an animal has a disease or they are using drugs preventatively, they not only take into account the costs, but also the probability of sickness, and the consequences if it were untreated.

Risk aversion plays a crucial role in this decision-making process; the more risk-averse a farmer, the more likely they will treat. This risk aversion is where the economics of the farming system come in. In economic stress, farmers will prefer to spend a guaranteed amount of money today, to prevent an uncertain loss tomorrow.

The tighter the margins within a production system, the more farmers are incentivised to use antibiotics as a production guarantee.

Within the dairy industry, we often refer to ever-tightening margins as a way of driving progress. Some see it as a way of increasing the quality of farm management. However, it may well be the case that these tightening margins will incentivise more antibiotic use.

6.6 Chapter 6 conclusions

- Some antibiotic use is a response to the economy within which a farm is operating.
- We need to create a situation where farmers can afford to take the risk of reducing antibiotic use.
- Tightening margins promotes antibiotic use and so may not be a positive way of driving change.
- One solution is to tax antibiotics. By using the money to make preventatives - such as vaccines – cheaper, farmers are no worse off.

The next chapter will focus on how The Netherlands has reduced its antibiotic use over the last 15 years.

7. How The Netherlands reduced its antibiotic use

Headlines can certainly motivate change. That is what happened following reports of resistant bacteria in a Dutch child back in 2005. It made headlines because this resistance was not common in The Netherlands, and it had originated on the family pig farm. Back then, the Dutch had some of the lowest per capita human antibiotic consumption in Europe, but some of the highest usage in animals. All of this was about to change. Farmers, vets and government teamed up to create a reduction plan.

The following ten years have seen wide-scale and sustained reductions in Dutch agriculture's use of antibiotics, with levels of resistance starting to reduce as well *(see figure 11 below)*. Antibiotics didn't feel like a big deal in The Netherlands now. Schemes were in place to control their use, and all the farmers I spoke with were aware of them. The priorities of most of the dairy farmers seemed to be the nitrogen emission protests that were happening at the same time, and the high cost of the phosphorus quota introduced a few years previously. They had sorted the issue by taking rapid, centralised action.

How did they go about this?

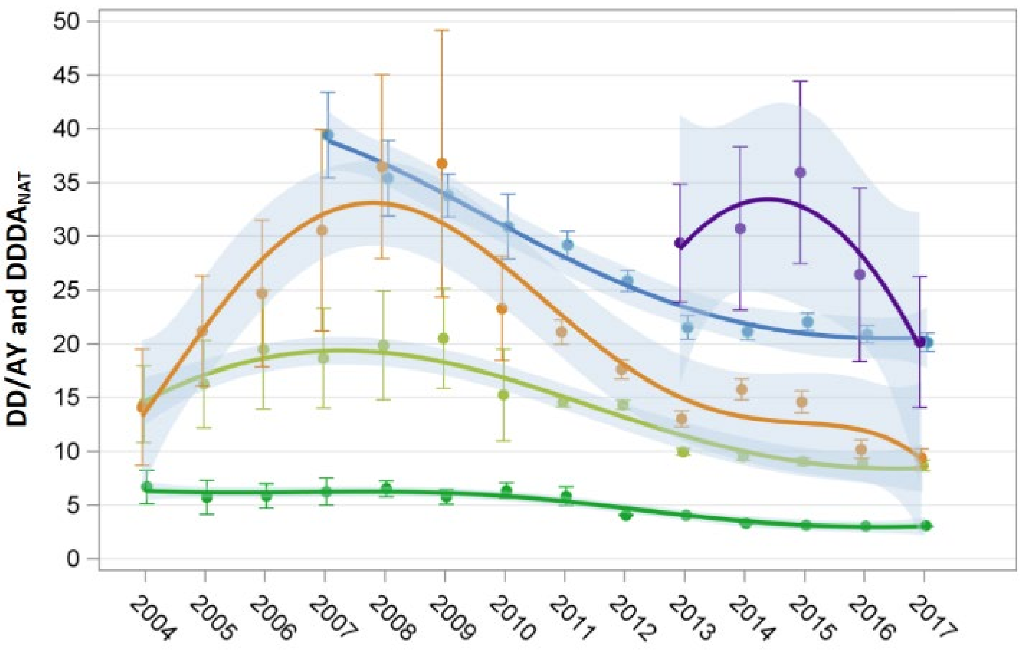

Figure 11: Long-term developments in antibiotic use in the Netherlands by the farming sector. Purple: Turkeys, Blue: Veal, Orange: Broilers, Light Green: Pigs, Dark Green: Dairy Cattle. (The Netherlands Veterinary Medicines Institute, 2018)

7.1 Transparency

The Dutch rolled out monitoring and benchmarking systems. The government initially tendered for the creation of databases for each livestock species. These were then brought together under the newly formed Netherlands Veterinary Medicines Institute, known as the SDa. They track individual prescriptions which are uploaded by vet surgeries in a semi-automated fashion, and benchmark both farmers and vets anonymously.

7.2 Vets

There is a stipulation for 1-to-1 relationships between farmers and vets. Each farmer must state who their vet is, so that the databases can link them together. This rule seems to have placed accountability into the system. There are no grey zones regarding who is responsible for the drug use on any given farm.

7.3 Governance

Another law requires that only vets store and administer antibiotics. However, an exception was built in allowing farmers to store '1st line' medications if they have regular vet visits and a frequently updated health plan. It was interesting how a strict law was created, so that the default position became limited use, with the exception allowing more relaxed regulations.

7.4 Bans

The Dutch implemented a complete ban on preventative antibiotic usage, going above and beyond what the EU has mandated. There is a grey zone within this; where does treatment stop and prevention start? - particularly apparent with something like calf pneumonia and the often-liberal use of antibiotics in milk powder.

The Dutch antibiotic system is not perfect. Even with one of the most advanced veal systems in the world, they still are struggling with high HP-CIA usage, and have overall usage plateau above other sectors. Eight hundred thousand calves a year are imported into the Netherlands, often at just a few days of age. Transport stress is a known immunosuppressant. They are then co-mingled, a known risk-factor for disease.

While there is variation between different farms in antibiotic usage, reductions will have been harder to come by because of intrinsic industry factors.

Had antibiotics not been available, this industry and the complex supply chains that feed into it might look very different today.

7.5 Chapter 7 conclusions

- Dutch agriculture combined new laws with transparent data systems to reduce farm antibiotic use. Their goal was to take antibiotics off the table, so they were free to tackle the subsequent issues that would arise.

The next chapter focuses on how farmers can lead the antibiotic reduction process.

8. Farmers driving the change

8.1 Targets Task Force

The Responsible Use of Medicines in Agriculture (RUMA) Alliance is a non-profit group comprising organisations throughout UK agriculture. It aims to promote and coordinate best practice in animal medicine use. In 2016 it was tasked by the UK government to set individual sector targets. In late 2017, RUMA's "Target Task Force" reported targets for both overall usage and HP-CIAs reductions.

2016 was not the first time farmers, vets and the government have sat down to discuss farm animal antibiotic use. First happening in the 1960s, it led to the publication of the Swann report (Swann MM, 1969). Swann led directly to antibiotic regulation in Scandinavia, but the UK was caught between the views of scientists and the farming community. Inaction resulted, and while Scandinavia went on to adopt the precautionary principle, the UK was left to follow what eventually became EU regulations.

Deciding to delay changes to regulations has left the UK industry playing catch-up for the last 50 years.

Dairy Sector Targets

	Subject	Baseline Figure	Targets 2020	% Change
1	HP-CIA injectables (mg/PCU)	1.075*	0.538	-50%
2	HP-CIA intra-mammary use (DCDVet)	0.332*	0.166	-50%
3	Intra-mammary tubes – dry cow (DCDVet)	0.842*	0.674	-20%
4	Intra-mammary tubes – lactating cow (DCDVet)	0.808*	0.727	-10%
5	Sealant tube usage (average number of courses per dairy cow)	0.5*	0.7	+40%
6	Total usage (mg/PCU)	26.2**	21.0	-20%

* Measured using 2015 UK sales data ** Measured using FarmVet Systems survey

Figure 12: Target task force. (RUMA, 2017)

The targets created by the task force were not particularly challenging for the country to achieve over four years. Wholesale reduction in antibiotic usage was not the only goal. Initially, awareness of resistance needed building. Next, farmers and vets required time to build confidence in both the reasons behind reduction and the process itself.

The targets created a direction of travel, echoing the private initiatives taken by retailers and supermarkets around the country. By the time the task force reported, almost half of UK dairy farms had seen recent additions to their assurance schemes. Most supermarkets had a form of benchmarking in place with or without restrictions on HP-CIAs, and some had made selective dry cow therapy compulsory. Then, when Red Tractor changed the requirements for HP-CIA use, real movement occurred throughout the entire UK industry.

8.2 Farmer involvement

One of the most crucial elements of the above Targets Task Force was that farmers were involved. This inclusivity is not always the case when it comes to policy creation in the UK, but is crucial if policies are to drive lasting, meaningful change.

Speaking with Dr Andy Johnson, a vet from Wisconsin, he echoed this, saying that "*farmers must steer the ship".* I interpret this in two ways:

1. Farmers must be at the helm of their industry, making decisions about their future.
2. When a new direction is required, farmers must change course.

I haven't yet met a farmer who cannot name a nearby farm he considers not up to scratch. Yet the very same tanker collects milk from all farms within a given area. Every farm assurance scheme aims to add value to milk; they move it away from being a base commodity product. But dilution of quality milk – caused because all milk is collected together in one tanker - prevents this from happening.

Farmers, and their representatives on advisory boards, should not be afraid of increased regulation. They should be front and centre: calling for it, guiding how it can be created and implemented. Without this, we risk losing control of the direction in which the industry moves.

Arnstein's ladder (see next page) was created to describe public involvement in the American planning process, but is relevant to all forms of policy creation.

The ladder starts with dictating, command style policy creation, and moves through to full autonomy at the top. Simply put: if the first a farmer hears of a policy is its impending arrival, it is too late. Consultation or farmer committee member involvement is a legitimate step in the right direction. However, real power could be given to farmers to set the course. If policies target animal health, vets could be involved as well.

Fortunately, this has already happened in the UK and Netherlands. Farmers, vets, retailers, and researchers combined to create a strategy to achieve responsible antibiotic use (van Dijk, Hayton, Main, & al, 2016). When we are looking for long term solutions, this participatory policy-making could be adopted to great success.

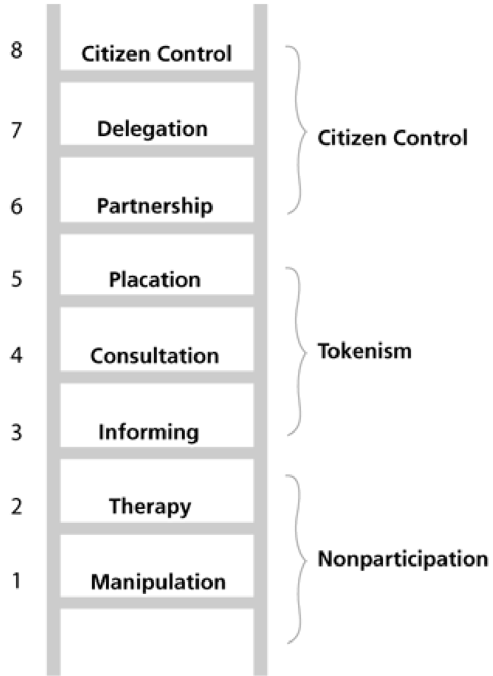

Figure 13: Arnstein's ladder of participation
(Arnstein S.R, 1969)

8.3 Transparency

Within the dairy industry, a vast amount of information is generated, then stored on the farm computer. Data will cover management, production, disease and physiology. Refinement of on-farm systems to ensure this process is efficient and accurate is essential.

From what I saw in America, the farm computer was often as far as information went. The tendency was for farms to shut themselves off from everyone but their close circle of advisors. This shutting-off is called information asymmetry; data is on-farm and not passed up either to the supply chain or to the industry.

With the introduction of aligned supply pools in the UK, supermarkets began asking for information. Producers were required to submit everything from health data to farm business accounts. More recently non-aligned contracts are starting to request more data, including antibiotic records and carbon footprint. Handing over this data can add value to products and decrease a processor's exposure to risk; this is a worthwhile aim. Unfortunately, the transfer of the information is often manual and time-consuming, and therefore costly to the farmer.

Similar to what is starting in The Netherlands now, farmers could embrace a radical increase in data transparency, whereby as much data as possible is sent through the supply chain to levy bodies and researchers. By unlocking the data, farmers clearly show the industry what they are achieving. High-quality farms set the benchmark against which poor farms are judged. Farmers capture the full value of their data and ensure they are front-and-centre in the decision-making process.

Transparency is opposite to what is happening in America but is a more positive direction in which to travel. Information asymmetry slows the rate of progress in the industry, weakening every member.

Large-scale data analysis could inform health and production decisions. If a product or protocol isn't working, right now the industry struggles to find this out; with a more open data system this could be seen, investigated and changed across the industry far more rapidly. A presumption of sharing and collaboration could link new data systems with nationwide programmes. This openness should not be limited to farmers; companies are often positioning themselves as gatekeepers of information, hesitant to share for commercial reasons. If the UK dairy industry thrives, then these companies servicing it also thrive. When collaboration with national schemes becomes the default, positive change can occur, and everyone wins.

8.4 Chapter 8 conclusions

- We need to break down the information asymmetry that exists in our supply chains.
- Within policy creation, empower farmers, adopting a participatory policy-making wherever possible
- In exchange, farmers must be more willing to change course when necessary.
- The whole industry should contribute data to supply chain projects wherever possible.

Next I will look at how the wider industry can play its part in reducing antibiotic use.

9. Actions within the industry

9.1 Knowledge exchange

The team at Bristol University have been conducting fantastic studies on the role of farmer action groups in reducing antibiotic use on farms. In their groups, farmers set the agenda for the discussions and don't rely upon external 'experts' to bring additional knowledge into the room. Facilitators ensure the conversations remain on the pre-arranged subjects, but all input and target setting are by the farmers.

This model fits in well with many of the coaching methods now employed throughout the country. Coaches rather than teachers guide farmers to come up with their solutions, giving them more ownership and buy-in. The scary thing about these meetings is that the agenda cannot be prescribed externally. You cannot link finance to specific goals. Those higher up the food chain cannot approve slides. It is not widespread yet, but forward-thinking groups are moving in this direction.

9.2 Milk Sure

Led by Dairy UK, the milk processor industry body, the Milk Sure initiative aims to reduce the number of antibiotic bulk tank failures in the UK. I put myself through the course in 2019 and was very impressed. By training the vets, who then train the farmers, the industry has aligned itself towards a common goal and has begun to get positive effects.

Training won't have the desired impact if not paired with appropriate testing policy. Testing of bulk tank loads is variable between processors, with some testing more regularly than others. Reportedly, when a processor shifts to more frequent testing (generally with the new generation of Delvo test) they initially find more tanker loads failing. Feeding failures back to farmers and vets allows them to put better processes in place. Generally, this more frequent testing leads to a subsequent drop in contaminated loads, to a level much lower than before. We should introduce blanket testing, drive down failure rates and, with it, the risk of food contamination. Increased testing will provide farmers with more rapid feedback from accidental contamination, and so should help refine on-farm processes.

9.3 Veterinary and supporting industries

Vets have historically had a unique role in the animal health industry. They are the primary point of contact for farmers wanting to decrease disease incidence.

"*My constant endeavour will be to ensure the health and welfare of animals committed to my care*" is the RCVS declaration made on admission to the veterinary profession (RCVS, 2020).

This primary driver has left vets in a tricky position: they want reduced antibiotic use, but they don't wish to see decreases in animal health or welfare. When milk contracts introduced Selective Dry Cow Therapy, some vets were rightly apprehensive, knowing that failure to comply with strict hygiene requirements may end up killing cows. Equally, under-invested facilities may end up killing cows. Animal health does not occur in isolation from other elements of the business. While most processors will have consulted vets to create these policies, the veterinary industry is left to implement them. Cursory vet meetings are no substitute for intricate involvement in policy creation. Like farmers, they must ensure they are at the helm of the animal health discussions, but equally, when a new direction is required, be prepared to change course.

The veterinary business model is changing from reliance on selling and towards fee-based advisory and consultative work (Woodward H, 2019). In the USA, I witnessed the profession facing competition from less regulated advisors. Advisors were supplementing their fees by selling products. If this is done instead of charging for time, it may decrease the perceived value of time-based consultancy. This competition also risks weakening the vet's position within the farm team as their advice now has to compete with other voices.

Ideally, we would have farmers paying vets for services, not drugs. The revenue generated by drug sales makes up varying percentages of veterinary practices' income. While several farmers mentioned it as a possible way of changing prescribing behaviours, I couldn't find an example where this seemed to have much of an impact. However, forcing this policy now may not necessarily be positive for the industry. A wholesale move to third-party drug sellers could make drugs the cheaper option compared to the purchasing of advice, furthering the exclusion of the vet and increasing antibiotic use. Also, the massive disruption in fee structures could push some vet practices out of business, presenting a challenge to what is already an under-staffed profession.

The veterinary industry is competing with the less regulated advisory sector. If we force vets to separate their advice from sales, then the same standards should be applied to all farm advisors. Vet practices around the country and the world have already stepped up to the challenge of increased competition; however, it is still unclear what shape the advisory networks of the future takes.

9.4 Testing food for resistance

"*There is . . . a lack of [resistance] data on commensal bacteria in food at retail level in the UK."* (Food Standards Agency, 2016)

This report, commissioned by the Food Standards Agency, summarises the available resistance data on UK retail meat and dairy products. It points to gaps in the surveillance of both UK and imported products. This gap prevents us from defending ourselves against accusations; stating the limited contribution of UK food animals to the human burden of resistance, without proper evidence to back it up. Research points to one route of resistant strain introduction being imported food, but we currently do not carry out enough testing to know how big a problem this is.

Detection gaps also prevent us from tracking outbreaks that do occur. Outbreaks of resistant, foodborne illnesses have occurred and will likely happen again. A robust testing regime would spot the emergence of resistance genes, whether that be from hospitals, farms or imported product.

"We need to radically improve the surveillance of antibiotic use in agriculture and the impact this and manufacturing have on resistant bacteria in animals, humans and the environment." (O'Neill, 2015)

9.5 Withdrawal times

We set withdrawal times depending on how quickly drugs clear from the tissues of the animal. Testing determines how long it takes for a drug to dip below safe levels.

Texas researchers challenged me to reconsider how I viewed these withdrawal times. Rather than just looking at the drug, the team at Texas A&M was showing how long it took bacterial populations to go back to normal. In their studies (Taylor EA, 2019), resistance genes spiked just after administering a drug and often didn't return to normal till well after the animal was allowed back into the human food chain. This fact is significant because one of the potential transmission routes of resistance to humans is through meat sales. If, as above, we are not testing for its presence, at the very least we should formulate withdrawal times so that we minimise the likelihood of its transmission. This change would mirror the organic industry, using extended withdrawal times relative to drug clearance from a risk minimisation viewpoint.

9.6 Current usage

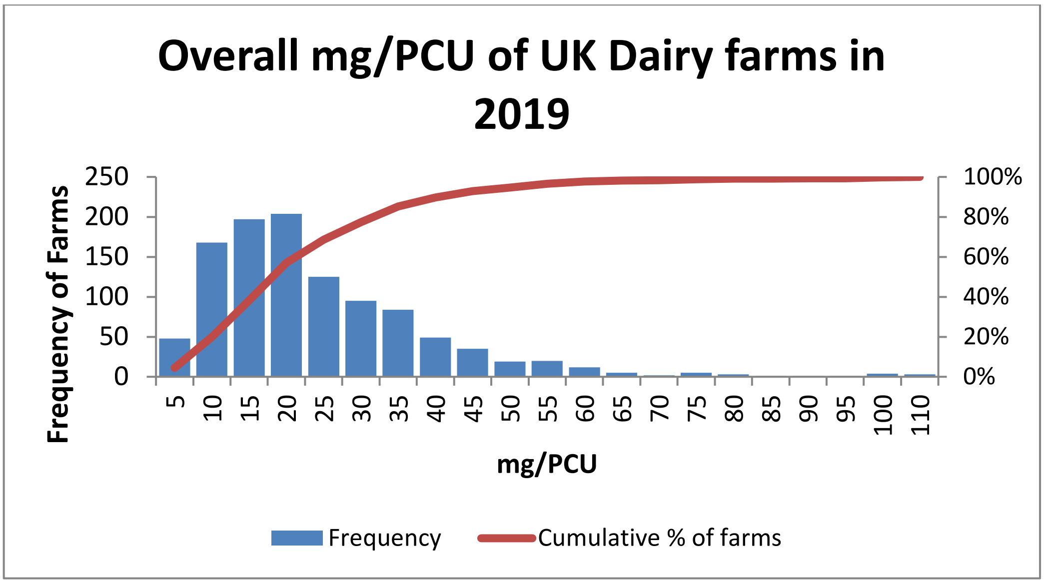

Figure 14: A histogram of UK dairy farm usage for 2019. ***Source: Kite Consulting***

Figure 14 shows the antibiotic use of about 1100 farms for 2019. The bars represent the number of farms at each usage level, with the orange line representing the cumulative percentage of farms. More farms being on the left than the right of the graph is consistent across almost all antibiotic data sets. It indicates that the majority of farms use small amounts of drugs, while a small number of farms use a disproportionately large amount. In this case, the top 25% of users consume 55% of all medicines. 8.8% of the farms are twice the previously mentioned RUMA target, using a combined 29% of all drugs. This group of farms is a reasonably small subset of the industry; targeted interventions here would be an efficient way of using resources for maximum impact.

9.7 Chapter conclusions

- Increased competition from non-vet advisors may hamper vets switching to consultation-based services.
- Future development programmes should balance expert-led education with farmer-led peer-assisted learning.
- We need to improve resistance testing of animals, the environment and in food products.
- We should consider the extension of withdrawal times on antibiotics to decrease the risk of gene transmission.

9.8 Next steps for the industry

Even after all the changes that the industry has been through, there are many things we don't know, and high-risk practices still ongoing. As such there are steps we could take:

- Create a national prescription benchmarking system, similar to The Netherlands. This process is essential to understand as an industry what is happening. To facilitate this change:
- Stipulate one-vet to one-farmer relationship. This ensures appropriate recording, accountability and responsibility of farm antibiotic use.
- Decrease the tolerance for poor on-farm record-keeping of antibiotic use.
- Create action zones of high antibiotic users, possibly set at 2x national target, requiring a reduction strategy to be in place and results to be achieved.

Having looked at the role of the wider industry, I will now consider what happens when markets are left to set industry direction.

10. No Antibiotics Ever!

Figure 15: Chicken on sale in an American supermarket. Photo: author's own

10.1 Lessons from the USA

Tyson was the first company to do it, but others have now followed: "No Antibiotics Ever!" proudly displayed on frozen chicken across the country. These products are similar to the Danish 'Antibiotic-Free' Pork, which launched several years ago. Other countries emulated it as well. In the UK, we are starting to see individual premium milk contracts go in a similar direction.

My initial response to seeing such programs was one of concern; the possible animal welfare implications of removing health and welfare tools from industry, the insinuation that the rest of the sector was 'Antibiotics Always'.

The story behind Tyson's decision to go down this route is quite a positive one. In an agricultural system that has been hesitant to self-regulate, and with a resistance burden steadily growing, Tyson invested in a solution. They spent years working on husbandry factors that would lead to reduced antibiotic consumption until they were confident enough in their processes to launch the product to market. Similar to what I witnessed in Ireland, here was the corporate solution to resistance; it addressed a real issue and then used this point of difference as a sales tool.

"*We stock what the customer wants to buy, but we promote what we want to sell".*

So said the manager of the chain selling the Tyson chicken. Hearing this, I reflected on how heavily we rely on supermarkets to drive change within the UK. Supermarkets drove positive changes, but it also passed the responsibility for change from vets and farmers to the supply chain. When this corporate model is used to drive change, the industry has far less redress. Newly created regulations or market expectations cannot be pushed back upon, becoming the new normal with widespread adoption to follow. Some supermarkets and processors developed antibiotic policies because there was no detailed, industry-wide, coherent change strategy. We risk losing control of future direction if other sustainability issues go down the same route.

10.2 Chapter conclusions

- Leaving commercial businesses to drive agricultural policy risks that farmers may lose ownership of their direction of travel.

11. India's aligned agricultural policy

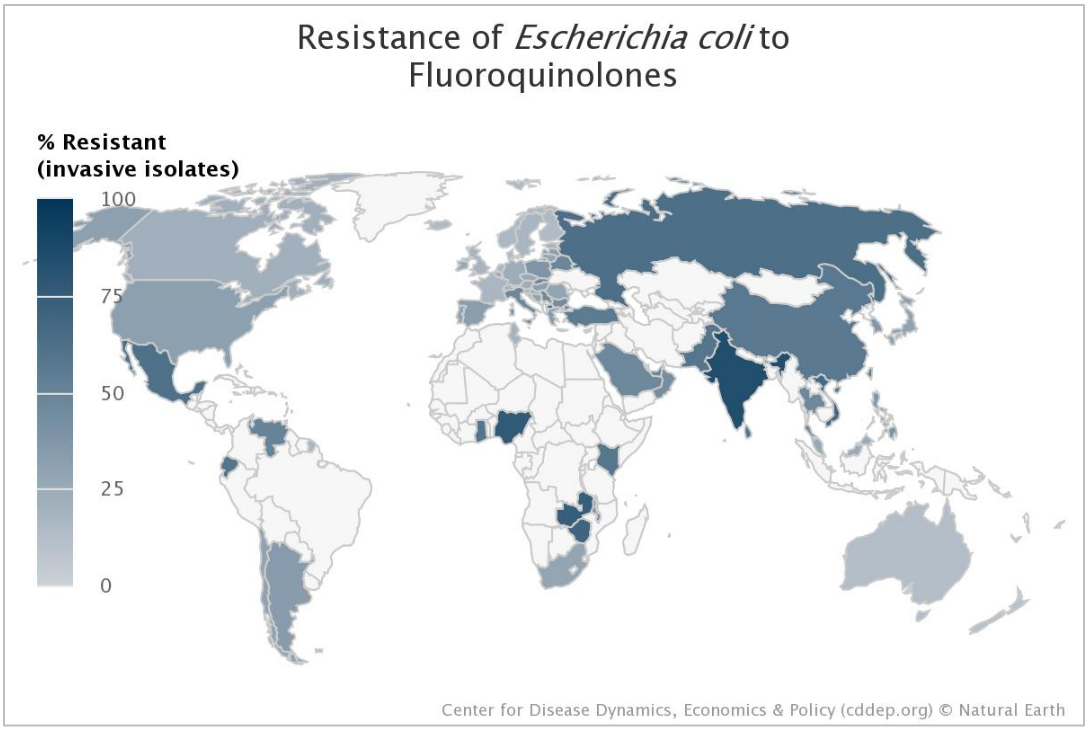

Figure 16: Global resistance levels (The Centre for Disease Dynamics, Economics & Policy, 2020)

11.1 Overview

As resistance is a global issue, you cannot view the UK in isolation. Like many of today's challenges, Low and Middle-Income Countries (LMICs) feel the impacts the hardest.

Fluoroquinolones are HP-CIAs used to treat kidney and lung infections in people. Poorer poultry farms use these drugs to overcome bad hygiene. Figure 16 shows 84% of Indian hospital *E.*coli was resistant to the drug, compared to just 11% in the UK.

The Indian healthcare system is reliant on doctors of varying qualifications operating across a wide range of facilities; 57% of 'doctors' have no medical qualifications. These 'quacks' are prevalent across the veterinary industry too, and presented a consistent challenge throughout the regions I visited. 50-60% of all Indian antibiotic use is without a doctor's prescription. Poverty, while in steep decline in recent years, is an ever-present challenge and intrinsically linked to healthcare; the equivalent of the UK population is pushed into poverty each year through health expenses.

I have always believed that farming is the best way out of poverty for rural communities. It was a privilege to visit farmers throughout northern India and see this first hand. These visits challenged me to reflect on the British farming situation with fresh eyes.

11.2 Farm policy

In the 1970s farming policy in India was focused on food security; however more recently it has pivoted towards development.

Figure 17: The author discussing animal disease issues with Indian dairy farmers. Photo: author's own

An example of this is the coop milk system, now known as the Anand model. The 1970s' 'Operation Flood' was a mission to get India dairy self-sufficient. It ended up with India leading the world's milk production league tables. The resulting tiered cooperative structure ensures consistent dairy supply to major cities and a route to market for millions of small-scale farmers around the country. It is by no means perfect; while a cold chain exists, it appeared precarious.

Many times I heard issues around the potential contamination of products, and assurance and testing were almost non-existent. I still drank milk when offered. In Bihar, I visited all levels of the coops: one-cow farmers; village coops; the state-wide coop.

This coop model has its strengths and weaknesses, but the base it provides for farmers is astounding. I visited farms that, following access to a local aggregator, had been able to double their herd sizes (up to 4 cattle) and hugely increase their financial security. Villages without access roads for milk collection floundered with no route to market, and a dwindling industry. In all these places, farmers wanted to return to more mixed farming systems, with an emphasis on soil health, biodiversity and minimal chemical inputs. They felt dairy was crucial, now that cultivation doesn't use animals. They explained how cattle and buffalo helped maintain good rotations and build soil organic matter.

It was clear there were issues within the knowledge exchange industry, mainly around institutionalisation and private advisors being the sellers of solutions. This conflict of interest resulted in the over-use of medicines at extortionate prices, and poor animal health outcomes.

Figure 18: The author at Sudha milk processing plant, Bihar, India. Photo: author's own

Across all my visits, I heard how barriers were starting to build for new entrants. A lack of land ownership and diminishing profitability were deterring youth from staying in the field. Access to finance was hard to come by, preventing farmers, both large and small, from progressing. There was, however, still a sense of alignment. People from central government, all through the research industry, State coops and private farmers, knew the sheer amount of good done by the Indian dairy industry and the need to keep it functioning.

11.3 Reflections after visiting India

Reflections on the UK industry that this visit to India gave me included:

- Artificial barriers within the market can interrupt the supply and demand balance, preventing farmers from accessing the full value of their products.
- Mixed farming systems promote soil health, biodiversity, help minimise chemical inputs and can help create varied income streams for farmers.
- Barriers to entry, including access to land, affect the ability of an industry to attract youth to farming.
- Correct incentives within knowledge exchange networks and farm advisors promote positive outcomes.
- Centralised, aligned food policies can lead to benefits beyond only the production of food.

The next chapter follows on from these reflections, looking at how government policy decisions shape their agricultural systems.

12. Governance and society

Figure 19: The author at the FAO HQ in Rome. Photo: author's own

12.1 Leveraging our position

Similar to in the 1960s with the Swann report, the UK has recently led the world in resistance-awareness and funding. The 2016 O'Neill report helped move the issue up the priorities of governments around the world. On the back of the report's recommendations, the UK created the £265 million Fleming Fund, targeting improved resistance surveillance in low and middle-income countries.

While discussing this in the corridors of the FAO in Rome, it became clear how crucial this fund had become in the international antibiotic-resistance effort. As a ring-fenced budget for surveillance, it could not be diverted or objected to by national governments intent on slowing progress. As political uncertainty increases and NGO budgets get challenged, this investment seems even more critical. Lord O'Neill and Dame Sally Davis, the former UK Chief Medical Officer, are key figures in the resistance fight, furthering the UK's position on the global stage.

These impacts highlight some of the strengths of the UK: global leadership and excellence; in-depth institutional knowledge; and a plethora of talented animal health experts. Our veterinary universities are consistently ranked among the world's best and are engaged in projects in LMICs on animal health and resistance reduction.

12.2 How the Swiss system differs

Figure 20: Alp dairy farms where summer grazing produces bespoke, high-value cheese.
Photo: author's own

The Swiss mountains are picture-perfect. The country has an agricultural system designed to keep them so. Many of the farmers I met brought up the same issues as in other countries: low prices and rising costs. Even so, it is clear that the 'payment for environmental and social good' model is helping to preserve a way of farming no longer common in much of the western world.

Along with payments to keep the countryside looking a certain traditional way, farmers have sculpted many niche and high-value products; each valley will have several kinds of cheese with the designation of 'Alp Käse'. Cheese must have been from cows grazing above a certain altitude over summer to get this high-value certification. Consumers pay more for food and thus preserve the countryside for generations to come.

On a hill just outside of Zurich, looking out over a 20-cow organic Simmental herd, I discussed politics and environmental regulation with its owners. They make a living selling local villagers' eggs and vegetables to supplement the income from their 400L of milk produced per day. Smaller farmers represent a hugely historic section of knowledge, skills, and capital (human and financial). To lose this would be to the detriment not only of the Swiss farming population but also the world. The Swiss public is well aware that they supplement their countryside. Perhaps they are realistic about what they pay for; preventing the development of large-scale farming and ensuring they keep the value in the landscape.

Figure 21: Milk churns lined up after washing in Switzerland. Photo: author's own

Figure 22: Milk churns lined up after washing in India. Photo: author's own

Both Switzerland and India have created policies to retain more traditional agricultural practices.

12.3 Post-Brexit choices for UK

Antimicrobial resistance linked to the use of antimicrobials in animal and human health leads to an estimated 33,000 human deaths in the EU each year. The Commission will **reduce by 50% the sales of antimicrobials for farmed animals and in aquaculture by 2030.**

Figure 23: Taken from A European Green Deal: From Farm to Fork Strategy. (European Union, 2020)

Governments have made commitments to reduce antibiotic use. These commitments need to be backed by a coherent, aligned agricultural policy.

Figure 24: Swiss cows in the mountains. Horns and bells are a common feature in the countryside.
Photo: author’s own

The UK faces the option of going down the commodity route of production, opening the UK borders to cheap imported dairy products in the hope that we will win the economic rat race.

The alternative is to build environmental and social standards into the financial framework and focus on higher value, internal markets. Farming is a response to the governmental and societal need for food. No agriculture is outside of the geopolitical environment. The UK government, relative to some others, likes a hands-off approach; but doing nothing is still an active decision. Allowing farmer turnover to accelerate is an active choice to reshape the agricultural landscape. In the antibiotic sphere, the world is calling for international collaboration, indicating now is not the time for a 'hands-off' approach.

Class Kirchhelle, a medical historian I spoke with, says that "*policymakers need to remember the long history of regulatory failures that have resulted in current antibiotic infrastructures. For effective international stewardship to develop, it is necessary to address the economic dependencies, deep-rooted notions of development, and fragmented cultural understandings of risk, which all contribute to driving global antibiotic consumption and [resistance*]" (Kirchhelle, 2018).

Antibiotics, and decisions around how much we use them within agriculture, are - at their core - political decisions. While farmers get much of the blame, the actual responsibility lies equally along the whole production and governance chain. An aligned policy framework, governing everything from health to trade, is necessary to ensure that the environment in which farmers operate is encouraging of low antibiotic use.

13. Discussion

Society and the government have communicated that they want lower antibiotic use in animals, and the industry has begun to respond. As such, the total use of antibiotics has fallen over the last few years. It is clear from both UK- and overseas-based farms that it is possible to reduce the average consumption to lower than current levels. Up until now, this has been voluntary, alongside the push for improved animal health. Refinement of prescribing and administration practices has played a role in this reduction. After these voluntary reductions and improvements, further drops become more challenging.

Antibiotic use is both a cause and effect of the farming ecosystem. This issue intertwines into the history, economics and politics of farming. As agriculture transforms, so we are faced with the choice of the type of agriculture we want to see. We must align our position through the entirety of the industry or economics will pull us in differing directions.

Further reductions in use must be part of a new food and farming deal; if we ask farmers to reduce further, which is reasonable, then equal responsibility must be taken on the part of governance. Farming can transform, through the integration of information systems and full national benchmarking, re-focusing our production systems on environmental stewardship and minimising externalities, including resistance.

The rules of the game need to match this way of playing.

If UK farming moves into a low-cost, high-externality system, we will continue to be torn between what is best for the planet and the population, and what is best for business. There is a better way available, and the whole of UK agriculture should come together to champion it.

14. Conclusions

1. Farm use of antibiotics contributes to the global resistance level. However, we do not know the specific, farm-level risk factors.
2. Focus on the quality of the stock (including genetics), the environment, and nutrition to drive down antibiotic use.
3. Some antibiotic use is a response to economic circumstances, and tightening margins can promote antibiotic use.
4. Empower farmers with policy creation and, in exchange, they must be more willing to change course when necessary.
5. Leaving commercial businesses to drive agricultural policy risks farmers losing ownership of the direction of travel. Instead, centralised and aligned food policies can lead to benefits beyond only the production of food.
6. Smaller farms are an important source of knowledge and skills that may not be fully valued within the economy.
7. Antibiotics, and decisions around how much we use them within agriculture are, at their core, political decisions. While farmers get much of the blame, the actual responsibility lies equally along the whole production and governance chain.

15. Recommendations

Farmers should be at the heart of policy creation. As such, these suggestions are only my contributions to the ongoing discussions on this topic:

1. Ensure we focus on minimising the risk of transmitting resistant genes from farms into human populations.
2. Consider the extension of withdrawal times on antibiotics to decrease the risk of gene transmission.
3. Improve resistance testing of animals, the environment and in food products.
4. The whole industry should contribute data to projects wherever possible.
5. The industry should adopt participatory policy-making as default.
6. To drive down use, tax antibiotics and use the money to make preventatives cheaper.
7. Future knowledge-exchange programmes should balance expert-led education with farmer-led peer-assisted learning.
8. Create a national prescription benchmarking system, with stipulated one-vet to one-farmer relationships, low tolerance for poor on-farm record-keeping, and action zones of high antibiotic users.

16. Next Steps

Antibiotic resistance is not going away. As it inevitably increases around the world, so the learnings from the UK's reduction journey will need to be shared and expanded. I will endeavour to champion aligned agricultural policy, farmer partnership in policy creation, and swift action wherever possible.

The learnings from the world's ongoing antibiotic journey need not stop here.

Sustainable resource use is at the heart of every issue facing the dairy industry. I will begin to apply the learnings I have made over the last two years to all the other problems that arise. Rightly, climate change is moving back up the agenda of people around the globe. There remains much work to do.

When I began this journey, I was convinced that efficiency was at the very heart of progressive agriculture, that it was the key to a successful future on this planet. I now view resilience as a far more worthwhile pursuit. I see that the UK can play a more significant role than mere importer or exporter of food. We can lead the re-alignment of global food production towards a truly sustainable place.

I hope to play my part.

Duncan Williams

June 2020

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