Moovin’ on up

(How) can we use new technologies to improve productivity on Britain’s livestock farms?

Linus Pardoe
Aveek Bhattacharya

SMF Social Market Foundation

Moovin’ on up

(How) can we use new technologies to improve productivity on Britain’s livestock farms?

Linus Pardoe
Aveek Bhattacharya

Kindly supported by

MSD
Animal Health

FIRST PUBLISHED BY

The Social Market Foundation, October 2022
11 Tufton Street, London SW1P 3QB

THE SOCIAL MARKET FOUNDATION

The Foundation's main activity is to commission and publish original papers by independent academics and other experts on key topics in the economic and social fields, with a view to stimulating public discussion on the performance of markets and the social framework within which they operate. The Foundation is a registered charity (1000971) and a company limited by guarantee. It is independent of any political party or group and is funded predominantly through sponsorship of research and public policy debates. The views expressed in this publication are those of the authors, and these do not necessarily reflect the views of the Social Market Foundation.

CONTENTS

ACKNOWLEDGEMENTS

The Social Market Foundation is grateful to MSD Animal Health for sponsoring this work. SMF retains full editorial independence with respect to its research.

The authors are grateful to all the farmers we interviewed for this research and those who participated in the roundtable that informed our analysis.

ABOUT THE AUTHORS

Linus Pardoe

Linus Pardoe was a Research Associate at the Social Market Foundation. Prior to joining the SMF in 2019, Linus worked for the University of Warwick's Department of Global Sustainable Development and holds a BA in History from Warwick. He holds an MSc in Social Policy and Social Research at University College London. He left the SMF in Summer 2022.

Aveek Bhattacharya

Dr Aveek Bhattacharya is the Research Director of SMF, having joined as Chief Economist in September 2020. Prior to that, he was Senior Policy Analyst at the Institute of Alcohol Studies, researching and advocating for policies to reduce alcohol-related harm. He has also previously worked for OC&C Strategy Consultants, advising clients across a range of sectors including retail, consumer goods, software and services.

Aveek studied Philosophy, Politics and Economics at undergraduate level, and has Master's degrees in Politics (from the University of Oxford) and Social Policy Research (from the London School of Economics). He holds a PhD in Social Policy from the London School of Economics, where his thesis compared secondary school choice in England and Scotland. Aveek is co-editor of the book *Political Philosophy in a Pandemic: Routes to a More Just Future.*

EXECUTIVE SUMMARY

Post-Brexit farming policy offers the opportunity to address Britain's agricultural productivity challenges

- British farming is at a pivotal moment, as governments determine what agricultural policy looks like outside the EU.
- This task is made trickier by a lack of clarity from policymakers over the purpose of farming. Farmers have long had to balance multiple imperatives – economic, social, environmental – but their context is increasingly challenging, with the expectation to pursue a range of different objectives:
    - Boosting efficiency
    - Achieving food security
    - Protecting the environment
    - Improving animal health and welfare
- The confusion has been exacerbated in recent weeks with the new Government in Westminster signalling it wants to prioritise economic growth over the environment, though without spelling out what this entails for farmers.
- However, one clear issue is productivity: British farms are generally believed to be less efficient and dynamic than their counterparts in other countries.
- This is not a universal problem, and there are success stories such as the soft fruit sector, but livestock farmers – particularly the bottom half of farms – have hardly seen any productivity growth in the last 30 years. Many beef and sheep farms consistently run their agricultural enterprise at a loss and are sustained by subsidies and non-farm income.

Increasing use of precision farming methods can help address the issue

- In this context, precision livestock farming (PLF) – the use of technologies such as electronic IDs and weighing systems, GPS collars, wearable activity monitors, and farm management apps – offers a promising route to more efficient, data-driven farming.
- Adoption of precision methods appears to have driven productivity gains in other countries (notably Australia), and is endorsed by the OECD. A growing body of academic literature suggests a range of benefits to labour productivity, and animal health and welfare.
- There are also potential indirect benefits to the environment through efficiency gains.
- Yet uptake of precision technologies and methods remains low. Less than half of farmers regularly weigh livestock and only 9% use pasture management tools.
- For this report, we conducted in-depth interviews with ten livestock farmers, as well as a number of industry experts, in order to understand the benefits to farmers of using PLF technologies, and how barriers to greater adoption might be overcome.

Many farmers are open to precision technologies, but cost, policy uncertainty and a lack of trusted evidence is holding them back

- On the whole, British farmers are open to using new technology and recognise its benefits:
    - Many farmers see a potential business case for investment. Those using new technologies enjoy improved labour productivity, farm safety and animal health, productivity and welfare, just as academic evidence would lead us to expect.
    - However, many also feel unable to exploit the full benefits of the technology, due to shortfalls in knowledge and skills.
- Some types of farmers are more eager than others to adopt new methods:
    - Younger farmers seem to be more open to using precision technologies.
    - More commercially-minded, professionalised farms are more willing and able to make the necessary investments.
    - Higher-skill farmers are also better placed to make use of the technology.
    - Precision farming appears to be most advanced in dairy farming, with sheep farming behind it, but ahead of beef.
- Decisions to invest in technology are most likely to be driven by evidence of success from trusted, local sources:
    - In-person demonstrations, and 'over the farm gate' advice tends to carry most weight.
    - Farmers also make use of information from the farming press, local colleges and social media.
- Moreover, uncertainty about the future of farming is holding back investment:
    - Concerns over the future are taking a severe psychological toll, engendering deep pessimism and causing some to doubt whether they will remain in the sector.
    - Uncertainty over subsidies means farmers are not confident enough of their cash flow to make investments.
    - Waiting and delaying investments has become relatively attractive, given the potential costs of making investments that may be undermined by unpredictable events or policy.
- Ultimately, cost is the fundamental barrier to utilising technology.

We recommend five ways in which policymakers and the sector can promote the use of precision technology

1. **Improve funding incentives**
    - Direct payment subsidies are widely recognised as damaging farm productivity. Paring these back – as in New Zealand – could be positive, though it is likely to be politically challenging.

- Subsidies should be shifted towards productivity-enhancing grants: in England, the Government plans to keep the share of farming support aimed at raising productivity constant at 9% – that figure should rise.

2. **Facilitate better knowledge exchange**
    - Investment in R&D and knowledge exchange is critical and should be increased, but also robustly evaluated. The promised What Works centre for agriculture and horticulture should be established within the next 12 months, ensuring the insights from the UK's agri-tech centres are easily accessible to farmers.
    - Building peer-to-peer mutual support groups, critical to boosting use of technology in other countries, is a particularly promising initiative.
    - Improving demonstration farms and making them more accessible could also help provide the sort of evidence farmers value.
    - It is worth exploring investments in farm advisory services – though many farmers' scepticism towards consultants would have to be overcome.
    - Continuing education has a role to play in upskilling farmers to make use of novel methods.

3. **Create better data sharing infrastructure**
    - The beef and sheep sector suffer from limited data sharing between farmers, and up and down the value chain.
    - Better data is critical to ensuring farming is more data-driven: this requires closer coordination across all stakeholders, including farmers, processors, regulators and vets.
    - The Livestock Information Service is a welcome step, but more needs to be done to make sure that farmers are able to actively make use of data to improve decision-making.

4. **Use regulation to promote change**
    - Regulatory changes have been shown to jump start technological adoption – requiring electronic IDs for cattle seems a particular priority.

5. **Rejuvenate farm management**
    - Farming ought to be more enticing and accessible for younger entrants and those from non-traditional backgrounds. The UK government's lump sum exit scheme may help, but other proactive recruitment and training methods are needed.
    - DEFRA's pilot of a new entrant programme akin to those run in Wales and Scotland is an important opportunity to demonstrate ambition for the future of farming.
    - Post-CAP, Government has headroom to reform young farmer payments. An evaluation of the generosity and eligibility criteria should be conducted to assess whether changes to payments could encourage a shift in farm management towards younger generations.

FOREWORD

Jan Moehlenbrock, managing director at MSD Animal Health UK & Ireland

When you think of farming and livestock farmers in the UK today, who do you picture in your mind?

Building on years of insight and experience, professionals with a deep personal bond to their animals and an innate insight into their wellbeing remain the lifeblood and the backbone of the industry. UK livestock farmers are a highly skilled community.

Their productivity and efficiency must be a policy priority for the country. Their enterprise has never been more critical to our food security than it is today. As a country, the quality and reliability of our meat exports are central to our international competitiveness and our trade success in demanding markets worldwide.

Not so many years ago, they and the veterinary professionals supporting them used entirely manual monitoring techniques to manage illness, nutrition, reproduction and every other aspect of husbandry.

Yet the UK's world-leading farming and animal health expertise is challenged today by an ever-more-demanding marketplace for food that is highly competitive and highly international. Those demands include the need to move rapidly to more sustainable farming practices, with a strong eye on the environment and on climate change – while also being as efficient and productive as possible throughout the livestock farming process. And the need to deliver on the highest animal welfare standards remains an absolute priority for food consumers and the industry alike.

New technology in livestock farming is enabling those same innate skills in animal husbandry, with devices and data that transform the insights available to the modern farmer. This brings new opportunities to succeed in the challenges that the industry is being asked to address.

Beef and dairy farmers can now optimise conception rates in their animals, while reducing other input costs, labour and time, by monitoring physical activity, rumination, eating and other behavioural data to deliver accurate heat detection and precise guidance on the timing of breeding.

Health monitoring applications empower farmers to detect health issues in individual cows early on and to quickly evaluate response to veterinary treatments – bringing more informed and timely decision-making on intervention and treatment, helping reduce deterioration and antibiotic use, and mitigating negative impacts on milk production and mortality.

Precision livestock farming is reshaping the ways that farmers, veterinarians, processors and retailers make animals' lives better. The new technology helps farmers and their veterinary professionals predict welfare issues, prevent illness and protect the future of the animal and the public as food consumers. The technologies now available allow the very best of the UK's livestock farming expertise and experience to be combined with all of the benefits of the information age.

Let's work together to ensure farmers can access these benefits. Let's help them make the investments that will uphold the UK's place at the very forefront of animal health and livestock farming excellence in the next decade. Let's ensure a flourishing farming future.

CHAPTER ONE – INTRODUCTION

A new dawn for British farming

Last year, giving evidence to the House of Commons Environment, Food and Rural Affairs Select Committee, Dr Ruth Little noted that agriculture is facing "the biggest change in 70 years", as the UK develops new regulatory and subsidy schemes to replace the EU's Common Agricultural Policy (CAP).[1] Until recently, each of the four UK nations had signalled their intentions to replace area-based subsidies with 'public money for public goods' schemes to help farmers achieve the following aims by 2028[2]:

- Run a sustainable business that does not rely on public subsidy
- Deliver profitable, internationally-competitive food production
- Reduce the environmental impact of agriculture and support biodiversity
- Improve animal welfare

A raft of pilot schemes and new programmes have already been introduced, mostly so far in England. These include the new Animal Health and Welfare Pathway; the Sustainable Farming Incentive (part of Environmental Land Management Scheme); the Farming Equipment and Technology Fund; the Future Farming Resilience Fund; the Lump Sum Exit Scheme; and the National Test Programme (Scotland).

Yet the direction of English farming policy has been thrown into doubt as a result of the arrival of a new Government in Westminster. Last month, newspapers reported that the Environmental Land Management Schemes (ELMs) which paid farmers for environmentally-friendly activities like planting trees, improving biodiversity and reducing fertiliser and pesticide use, was being paused. Instead, there is to be a full review under which "everything is on the table",[3] including a return to area-based payments similar to the old Basic Payment Scheme (BPS) inherited from the EU, which was to be phased out between 2024 and 2027.

Throughout the farming sector, amongst environmental campaigners, academics and policy researchers – and politicians themselves – there was considerable confusion about the Government's ambitions for farming in the long-term and their achievability. A recent Institute for Government report outlines a "complex web" of reforms that have led to frustration in many quarters and a sense of attempting to appease all but pleasing none.[4] Uncertainty over the future of ELMs and BPS has only added to this feeling of concern and disorientation.

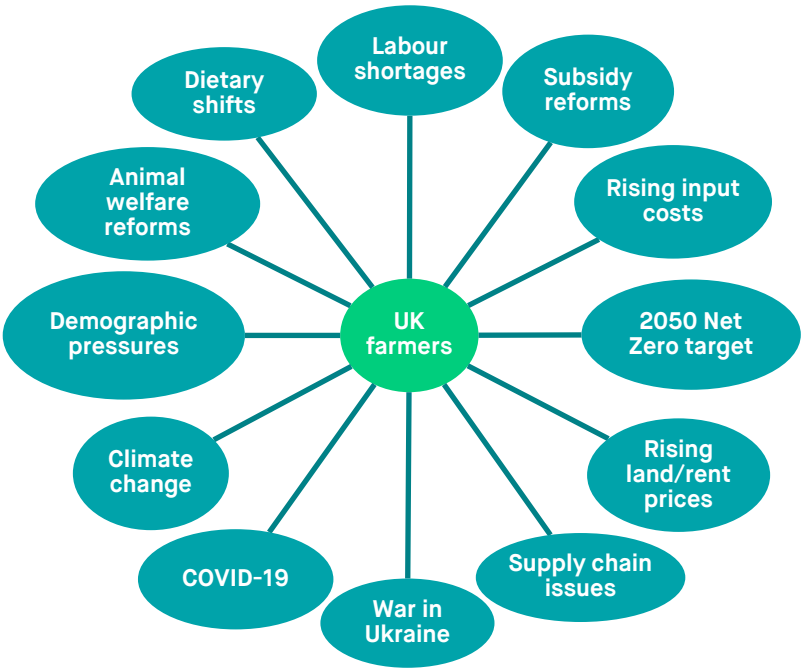
For all this ambiguity, one thing that the new UK Government does seem committed to is improving the efficiency of farming as a route to enhancing economic growth. In September's Growth Plan, published alongside Chancellor Kwasi Kwarteng's 'mini budget', the Government pledged to set out plans to rapidly review frameworks for regulation, innovation and investment in agriculture to increase slow productivity growth.[5] In his speech to the Conservative Party Conference earlier this month, Environment, Food and Rural Affairs Secretary Ranil Jayawardena pledged to make his government department "an economic growth department" and tasked his junior minister Scott Mann as being "minister for Growth".[6]

This report explores one key way the Government might achieve that objective of improving agricultural growth: through technological investment and innovation within livestock farming. We find that though post-Brexit reforms have the potential to stimulate improvements in farming practices, as things stand such improvements are being held back by an increasingly uncertain political and economic environment.

Under pressure

As we illustrate in Figure 1 below, the Government's post-Brexit plans for farming are only one of a wide range of systemic pressures on UK farmers. Some of these are acute but transient, like COVID-19 and the war in Ukraine. Others are evolving more slowly, but are growing into chronic challenges, like the effects of climate change and demographic pressures. It is in this context that farmers are making decisions on a day-to-day basis about how to run their business. As we discuss in our findings, this environment frequently induces short-termism.

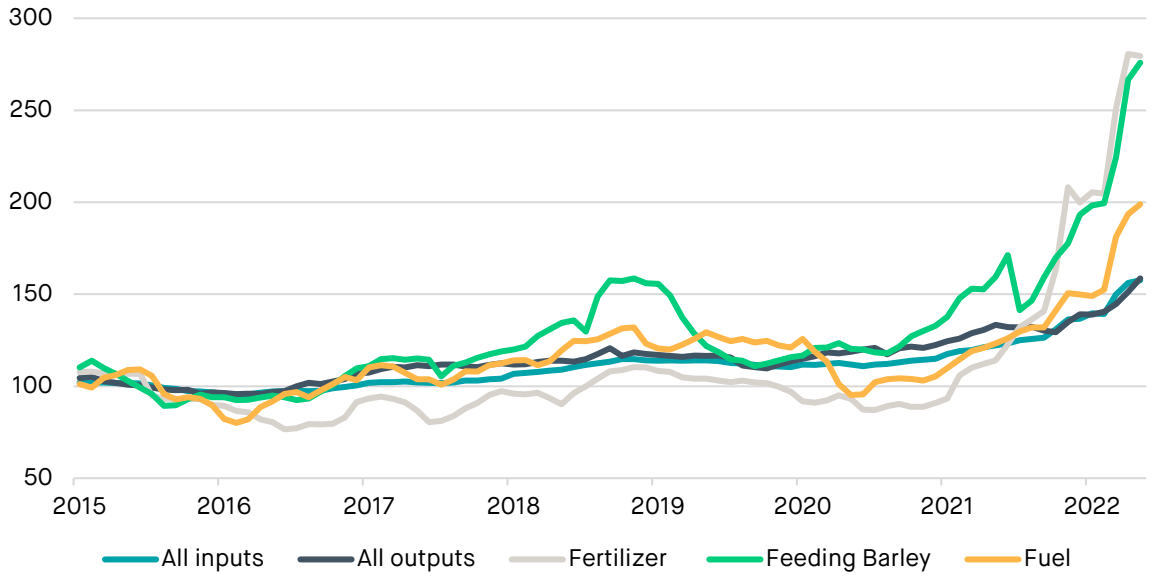
Figure 1: Systemic pressures on UK farmers



Source: SMF analysis

Rising input costs are a significant concern at present. Data from members of the AF buying group indicate that the cost of key inputs rose on average by 24% between September and March 2022.[7] Clouds were already gathering for farmers prior to the Russian invasion of Ukraine, but the war has catalysed cost pressures. The most recent Agricultural Price Index data show that whilst overall input-output ratios are still holding steady, the cost of certain inputs such as animal feed, fertiliser and fuel has increased sharply in recent months.

Figure 2: Selected Agricultural Price Index measures, Jan 2015–May 2022 (Base=100) (2015)



Source: DEFRA, SMF analysis

Framing the problem

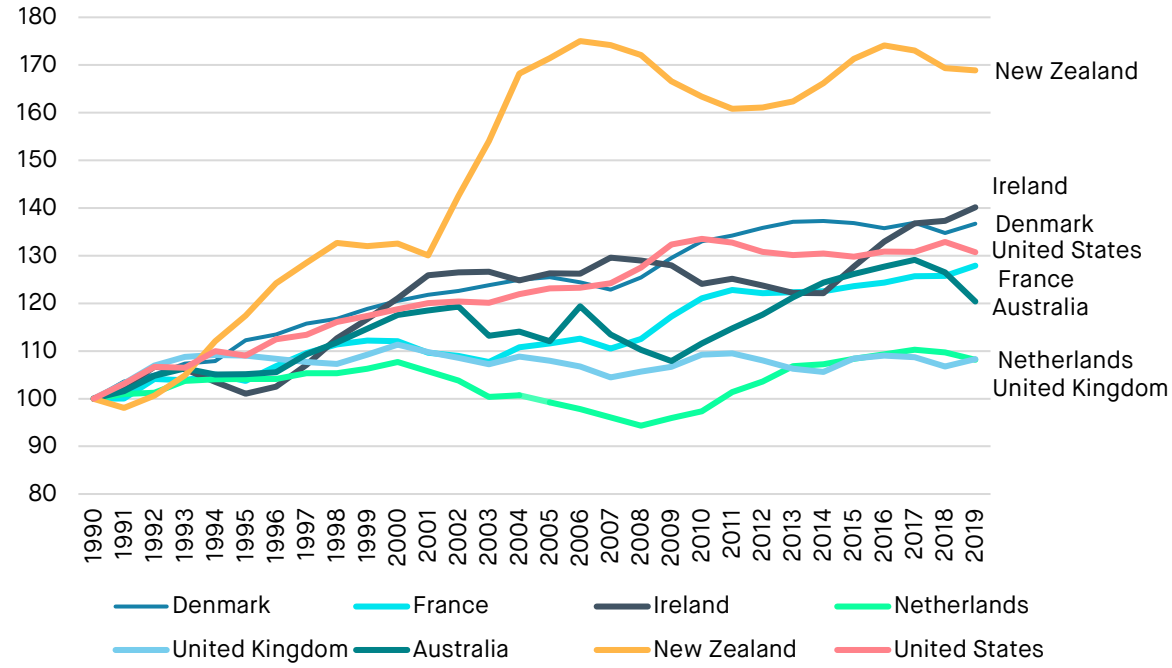
UK agriculture appears to be experiencing what in policy studies is sometimes referred to as 'substantive ambiguity'.[8] That is, there are alternative and sometimes competing framings of what the policy problem is in a given space. Historically, farming has only had to respond to one relatively clear challenge: feeding a growing population. That objective remains fundamental[9], but is today joined by a suite of additional problems: animal welfare, antimicrobial resistance, habitat destruction and biodiversity loss, soil erosion, and greenhouse gas emissions are just some of the challenges facing British agriculture. Perhaps unsurprisingly, that can leave farmers in the position of feeling confused and overwhelmed by what policymakers want of them.

> *"The first step that we need is a very clear articulation from government but also from the market about what the role of agriculture actually is, and* ***what the problem that we want agriculture to respond to actually is****."* *(roundtable participant)*

A productivity problem?

A common diagnosis of British agriculture is that it suffers from stagnant productivity, and is falling behind peer nations. But farming's productivity problem is more complex and nuanced than such broad generalisations would suggest. Such analyses are often based on international comparisons of total factor productivity (TFP) growth, as we illustrate in Figure 3. There are two issues with this type of assessment. Firstly, it obscures the fact that the UK made considerable productivity gains after the Second World War but these petered out towards the end of the 1980s (Figure 4), after which international competitors began to catch-up and surpass UK farmers.

Figure 3: International comparison of total factor farm productivity. Base (100) = 3 year average to 1990)



Source: US Department for Agriculture

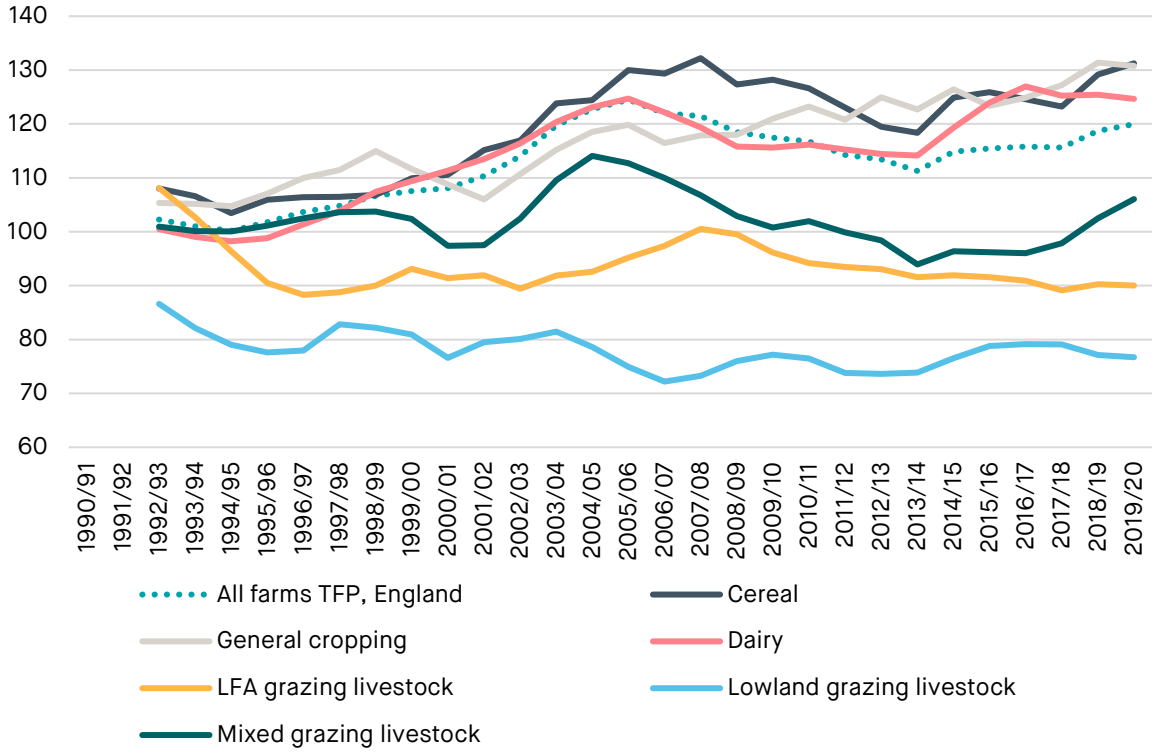
Figure 4: Annual average growth rates by period for UK agriculture

	Output index	Input index	TFP Index	Output per Unit of Land	Output per Unit of Labour
1953-1984	1.9%	0.2%	1.7%	2.1%	4.4%
1984-2000	0.1%	-0.4%	0.3%	0.2%	3.0%

Source: Thirtle et al., 2004 [10]

Secondly, aggregate estimates disguise relatively significant subsector variation in productivity. Between 1990/91 to 2019/20, annual TFP growth on farms in England was 0.93%. This average is pushed upwards by arable farms. Cereal farms and general cropping farms experienced annual TFP growth of 1.19% and 1.04% respectively for the same period. Meanwhile, dairy farms ran at the English average, whilst mixed-, LFA (less favoured area)-, and lowland-grazing livestock farms averaged 0.24%, -0.26%, and -0.83% respectively.[11]

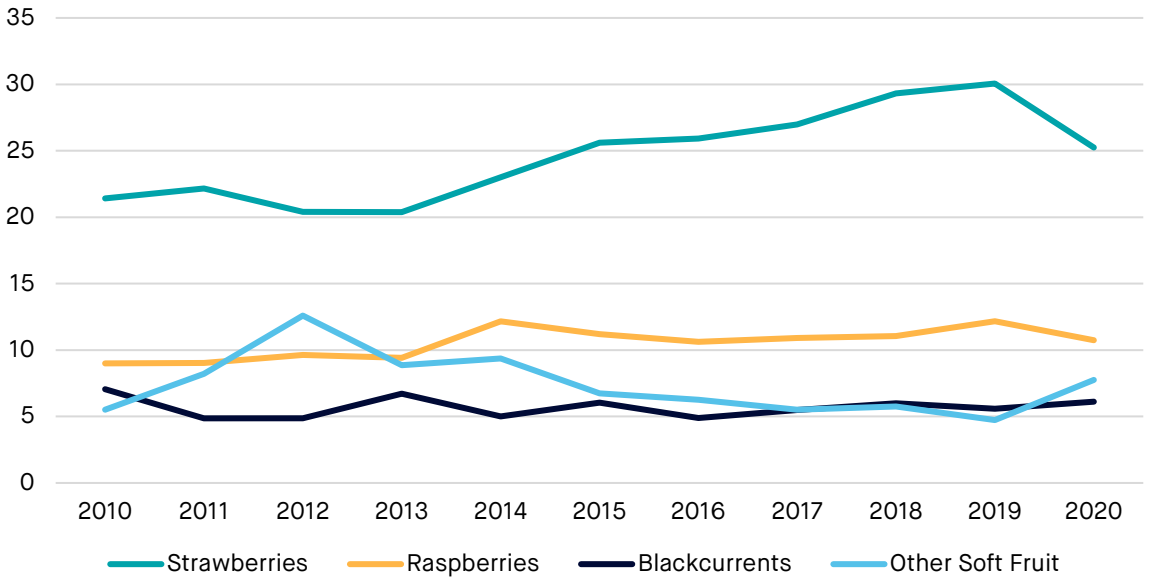
Figure 5: Total factor productivity growth, moving three-year average (base=100)



Source: DEFRA

One particular success story highlighted at our roundtable was the UK soft fruit sector, which has witnessed strides in innovation through the use of new cultivars and growing systems. For instance, yield per hectare of strawberries planted grew by 40% between 2010-2019 (Figure 6).

Figure 6: Soft fruit yields (tonnes) per hectare planted

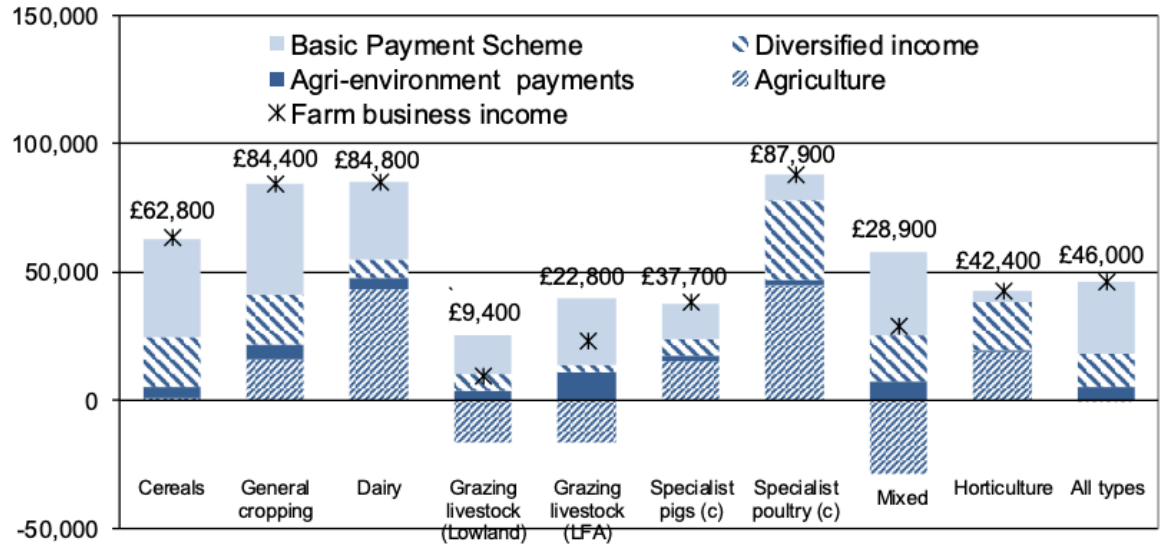


Source: DEFRA

Even within the livestock sector, there is noticeable variation in productivity. A study that matches like-for-like farms on the basis of a set of observable characteristics has estimated that the upper 25% of grazing livestock farms make up to £60,000 more than their counterparts in the bottom 50%.[12]

These statistics point to a conclusion that reflects the consensus at our roundtable, and has been recognised elsewhere:[13] that a significant proportion of UK's pasture-based livestock farms are lagging behind other domestic farming sectors and internationally. There are a host of reasons for this, ranging from rates of innovation adoption to personal motivation to build a profitable business. But two structural constraints on productivity growth stand out. Firstly, beef and sheep farmers cannot intensify in the same way that farmers in other countries like the United States and Australia can, due to natural resource constraints and welfare standards. Secondly, subsidy payments and diversification enterprises have kept afloat a considerable proportion of farms who are making year-on-year losses from the agricultural side of their business. Figure 7 shows that on the eve of the COVID-19 pandemic, the agricultural enterprise of grazing livestock (lowland and LFA) and mixed farms ran at a loss of respectively £16,300, £16,600 and £29,000 annually.[14] We recognise that, as one academic recently put it, these "farmers have delivered exactly what they were asked" – to produce food on subsidised pasture-based farms. However, the negative effect of subsidies on productivity has been well observed[15], and there can be little doubt that the outgoing subsidy regime has facilitated the survival of a significant number of farms who are skewing productivity estimates downwards.

Figure 7: Average farm business income by cost centre for different farm types, England only



Source: DEFRA

An environmental problem?

Growing understanding of climate change has induced greater scrutiny of agriculture's impact on the environment, particularly livestock farming. The Government's projections for farming, forestry and land use suggest emissions will need to fall by up to 40% by 2035 (relative to 2019) in order to reach net zero by 2050.[16] Meanwhile, a target to reverse biodiversity loss by 2030 has been introduced in legislation,

alongside a raft of additional measures for England announced in a nature recovery Green Paper published in March 2022.

Even before the uncertainty over the future of environmental land management payments (ELMs) emerged, farmers were questioning how these transitions will be funded. For many farmers operating profitable, environmentally-harmonious businesses ELMs payments might be sufficient. Yet for others, even that system would land a fresh problem at the farm gate. The expectation to produce food without direct subsidy and contribute more heavily to environmental sustainability will require many farms to shift their business model to a different footing. Put simply, many in the farming industry – including some of our interviewees and roundtable participants – argue that there is a growing expectation to do more with less.

An animal health and welfare problem?

Whilst productivity and the environment may be relatively new concerns, one that has remained in the minds of policymakers for many years is the health and welfare of farm animals. Rates of bovine tuberculous have remained stubbornly high in England and Wales in comparison to much of Europe [17] [18], whilst a recent study draws attention to high rates of calf mortality (up to 7.9%) and the low level of involvement of veterinarians in decision-making about newborn calves.[19] The introduction in 2022 of the Animal Health and Welfare Pathway, which provides one free annual vet visit to farms, attempts to foreground positive animal welfare outcomes in the minds of farmers. Indeed, improving animal welfare is viewed as a tenet of the new public money for public goods approach. We should note that improving health and welfare outcomes is related to addressing farming's productivity and environmental problems. For instance, a DEFRA-funded study has found that treating and controlling endemic disease can potentially lead to significant gains in greenhouse gas emissions reductions and productivity gains, though the full benefits of this are conditional on the cost-effectiveness of the intervention for farmers.[20]

Or something else?

One policy problem that has rapidly risen up the agenda is food security. In the wake of the COVID-19 pandemic and the on-going war in Ukraine, there have been calls for the UK to be less reliant on food imports and for government to recognise the risk to food security induced by the spike in input costs that we discussed earlier in this chapter. The Labour Party has recently backed the National Farmers Union's call to delay the introduction of ELMs for two years and look to bolster food security.[21] Rishi Sunak, in his campaign to become leader of the Conservative Party, endorsed the idea of a new statutory UK food security target.[22] Others have pointed to farm loss as a policy problem that receives insufficient attention. For example, a report by the Campaign to Protect Rural England advances the view that declining farm numbers and diversity in England is negatively impacting rural communities and reducing job opportunities.[23]

In sum, today's farming environment is changing rapidly and increasingly challenging for many. No single problem or objective has gained traction above all else, leading to ambiguity in post-Brexit agricultural policy. As the findings of our qualitative research indicate below, this ambiguity is not simply an abstraction for the pages of a think-tank report, but a reality experienced by farmers.

Precision livestock farming – a (partial) technological solution?

Whilst no silver bullet, an area of particular interest for addressing several of the policy problems we set out above is increasing the uptake and integration of new technologies in farming. Following the literature on this topic, we use the term precision livestock farming (PLF) technologies – single or multiple integrated tools to assist managing "individual animals by continuous real-time monitoring of health, welfare, production/reproduction, and environmental impact".[24] The simple premise of PLF is that producing more and better-quality data can improve decision-making on farms, helping farmers to operate more productively, sustainably and enhance animal health and welfare.

PLF technologies were first developed for the pig, poultry and dairy sector.[25] Examples of application in this context include sensors to measure air quality in poultry sheds, wearable-accelerometers to monitor calving, fertility and lameness, and the use of radio-frequency ID tags integrated into automatic feeding systems for pigs.[26] However, a number of studies have recently been conducted exploring the application of PLF technologies in extensive farming systems, including animal identification, monitoring reproduction and other animal health and behaviour traits, and tracking and locating livestock.[27] Below are some of the technologies used by the farmers we spoke to:

- **Sheep and cattle EIDs** (electronic identification devices) – electronic ear tags that carry a unique ID for each animal required for movement and slaughter. IDs can be linked to veterinary records and other data about the animal such as weight. Some tags capture biometric data to enable genetic planning and traceability in the food system.
- **Electronic weighing/handling system** – captures the live weight of an animal. Some systems can be used to manage herds/flocks according to characteristics like weight.
- **Farm management apps** – designed to digitise paperwork, such as movement forms, and store animal-specific data, for example about breeding cycles.
- **Monitoring collars & ear tags** – for remote monitoring of animals, usually cattle.
- **Computerised feeding systems** – helps farmers to precisely mix and deliver animal feed to maximise growth and efficiency. Some systems can be fully automated, delivering feed via machines.

Benefits and limitations of using PLF technologies in extensive systems

Studies piloting and evaluating the use of new livestock technologies and innovative practices highlight four primary benefits to: [28] [29] [30]

- **Labour productivity** – e.g. wearable devices allow for remote monitoring of animal behaviour, whilst also providing data on indicators such as activity, grazing, and parturition.
- **Animal productivity/output** – e.g. precision weighing and feeding systems support farmers in raising animals more efficiently and in line with market demands.

- **Animal health and welfare outcomes** – e.g. smart rumen boluses (orally-administered sensors for animals) provide data on internal temperature, water intake and pH level.
- **Farm safety** – e.g. handling systems such as auto-drafters and cattle crushes reduce the need for stockpeople to directly handle animals – and to do so more safely when required.

A literature review has identified that no PLF technology has specifically been developed to reduce the environmental load of livestock farming.[31] However, there are potentially significant indirect benefits to the environment where PLF improves animal productivity, health and welfare. The basic principle is to run more efficient (and in some cases smaller) herds and flocks. For instance, research indicates that raising fertility rates in dairy herds to a 60% conception rate could reduce GHG emissions by more than 20% per herd.[32] Similarly, there is an indirect benefit to be found from early intervention and prevention in terms of reduced antibiotic usage in livestock farming.

A number of studies have linked technological adoption, and precision farming in particular, to aggregate-level improvements in productivity. In Australia, substantial improvements in milk yield per cow have been attributed to improved milking sheds, feed quality, breeding and better management techniques.[33] A study of US pig farming through the 1990s found that productivity gains were largely explained by improved technical efficiency (as well as economies of scale).[34] The OECD recommends that policymakers should "facilitate innovation directly by supporting investments in…precision farming", among other cutting-edge methods.[35]

With many PLF methods still relatively novel, the evidence base behind specific products and interventions vary. There is less still robustly estimating the size of the productivity gains of PLF adoption for individual farms. Overall, though, the evidence is encouraging. For instance, a literature review conducted by academics in Italy identified 137 articles demonstrating a wide array of tangible benefits of PLF to farmers.[36]

There are also some valid criticisms of using more technology in livestock farming. One of the most commonly cited is that some PLF technologies risk "replacing farmers' eyes and ears". This could negatively impact on animal health and welfare, for example increasing animals' fearfulness towards stockpeople.[37] However, we note that many of these concerns are directed at the use of PLF in more intensive farming practices.[38] Another criticism is that investing in technology does not necessarily equate to effective usage and improved decision-making.

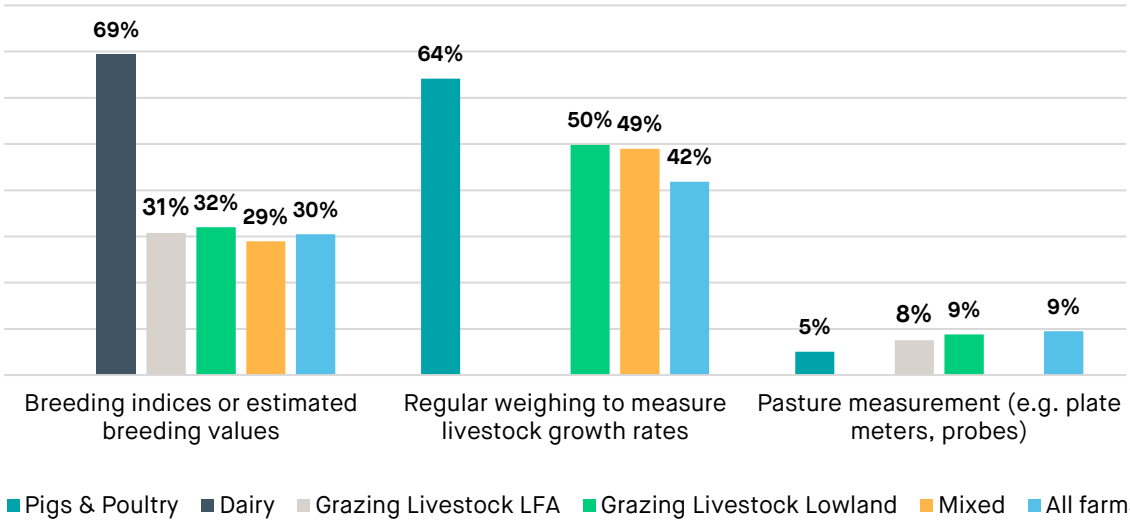
Nevertheless, based on the available evidence from the literature, it seems clear that PLF technologies can have a wide range of applications across UK farms and that adoption will lead to direct and indirect benefits for farmers' long-term profitability, the environment and animal health and welfare. In Chapter Two, we discuss additional research on the benefits of PLF in relation to our participants' experiences.

What do we currently know about uptake of PLF technologies in livestock farming?

As we have already noted, precision technologies have emerged in intensive farming sectors. Existing technologies are now filtering down and new innovations brought to market specifically for smaller-scale, extensive farms. However, from the patchy evidence available, uptake appears to be fairly low. A recent survey of sheep farmers in England and Wales found that despite sheep EID tags being mandatory, only one in five (21%) of respondents were using technology (such as electronic readers) to manager their flock; this may be an overestimate, judging by the low response rate to the survey.[39] Given that EID tags and readers are some of the more basic PLF technologies, this data suggests there is considerable untapped potential for future adoption.

DEFRA's Farm Practices Survey (England only) gathered data on PLF uptake in meat and dairy farming in October 2019.[40] Regularly weighing animals was the most commonly reported livestock technology used across all farms (42%). Encouragingly, 38% of small farms were regularly weighing animals. Breeding indices and estimated breeding values were by far the most frequently used technology in the dairy sector (69%). Technologies more associated with intensive farming were far less commonly used. For example, only 8% of all farms were using automated heat detection systems and 9% used pasture measurement tools like plate meters.

Figure 8: Use of selected precision livestock farming technologies (England only)

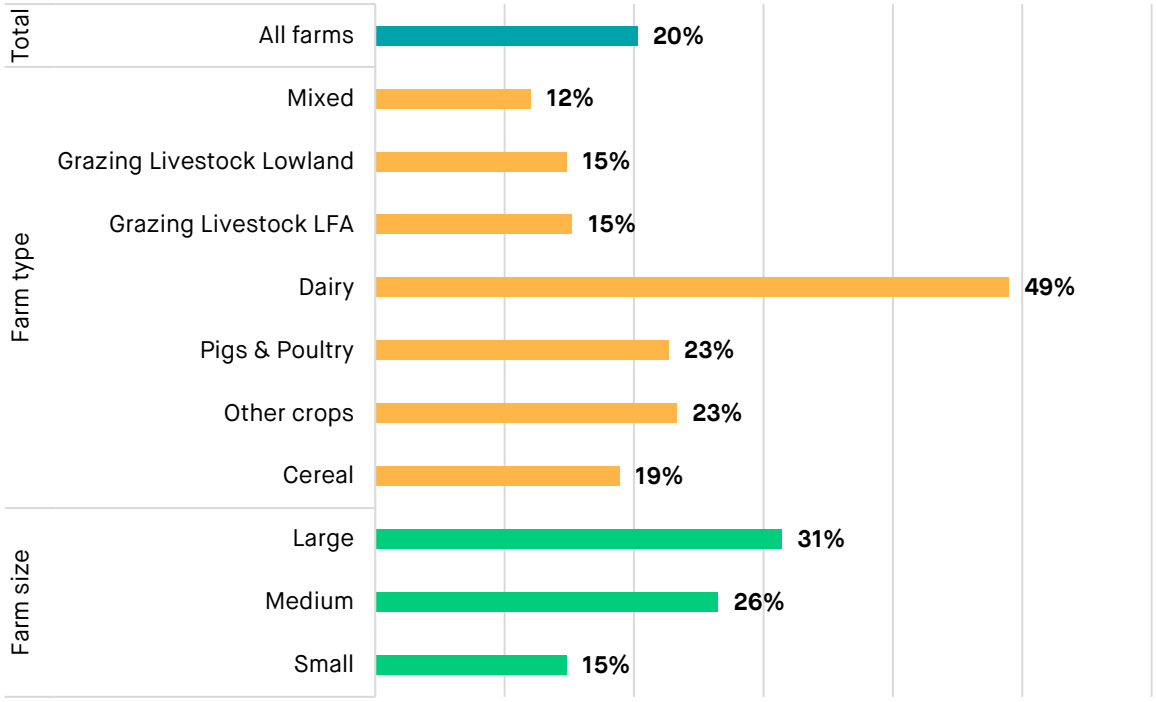


Source: Farm Practices Survey

N.B. Some data has been suppressed to prevent disclosure of information about individual holdings

Overall, 14% of farmers were using a smartphone for farm operations or management. This was more common in dairy and on larger farms. This estimate mirrors the findings of the survey of sheep farmers we discussed above, where 11% said they were using a smartphone to record information on the farm.[41]

Figure 9: Use of a smartphone for farm operations and management (England only)



Source: Farm Practices Survey

Methods & participants

This paper draws on the findings of qualitative research with farmers from across England, Scotland and Wales. In early 2022, we conducted semi-structured in-depth interviews with 10 livestock farmers. Descriptives of the sample are provided below. We should emphasise that almost all interviews took place prior to Russia's invasion of Ukraine on 24th February 2022, and thus the severe impact on input costs were only just beginning to be felt by participants. It is likely that the consequences of the war, the political maelstrom fostered by the resignation of Boris Johnson, and the subsequent uncertainty over the direction of farming subisidies will only exaggerate our findings on uncertainty and costs.

Figure 9: Descriptives of interviewees

n	Age range (mean)	Farm types	Geography	Farm size**
10*	27-60 (44)	Dairy (20%) Sheep only (20%) Cattle only (10%) Sheep & cattle (40%) Poultry egg (10%)	England (50% Scotland (30%) Wales (20%)	Small (20%) Medium (50%) Large (30%)

** One interviewee was not recruited independently but via Allflex Livestock Intelligence, a subsidiary of MSD Animal Health who have sponsored this research. This participant used products sold by Allflex, but has no affiliation with the company.*

*** Based on Farm Business Survey classification of farm size. Small = 1<2 full-time employees (FTE); Medium = 2<3 FTEs; Large = 3<5+ FTE; Very large >=5 FTE*

Participants' usage of technology varied quite considerably. Broadly, there were three types of individuals and farms:

- **Non-adopters** – two participants made no use of precision technologies, though demonstrated some limited familiarity with products available.
- **Adopters** – the majority of participants were using some more basic precision technologies, most commonly electronic ear tags and readers, weighing systems and smartphone farm management apps. This group were usually aware of other more advanced technologies but were yet to invest extensively. This group tended not to maximise technology usage and farm practices were not necessarily changing as a result of the technology or the data captured by it.
- **Outriders** – two participants could reasonably be described as leaders in their usage of technology in a pasture-based system. They were using multiple complex technologies and had invested more heavily. They were actively searching out new opportunities to use technology and were letting technology drive decision-making and farm practices.

Alongside the qualitative research, the Social Market Foundation also convened an expert roundtable in Spring 2022. The session was held under Chatham House rule. Attendees included academics, industry experts and representatives and policy researchers and officials. The views of those who attended are used to contrast and supplement the findings from our qualitative work.

CHAPTER TWO – FINDINGS

In this chapter, we review the key findings from our research, drawing on interviews with farmers and industry experts, as well as a review of the international literature. We find that:

- On the whole, British farmers are open to using new technology and recognise its benefits.
- However, some types of farmers are more eager than others to adopt new methods.
- Decisions to invest in technology are most likely to be driven by evidence of success from trusted, local sources.
- Moreover, uncertainty about the future of farming is holding back investment.
- Ultimately, though, cost is the fundamental barrier to utilising technology.

Farmers are open to using new technology and recognise its benefits

Farmers can sometimes be caricatured as traditionalist or stuck in their ways, and indeed as we shall see, in some cases that reputation is warranted. Overall, though, we were struck by the openness we found in those we interviewed to different approaches and new technologies. Nobody we spoke to was outright dismissive about technology, and many were effusive in their enthusiasm for it. For example, one farmer described their farm management app as indispensable: "*I couldn't live without it…it's really, really good*". Others presented it as unavoidable evolution:

> *"We've got to move with the times" (Beef farmer, 34)*

> *"If you've got the technology there, that has been invented to help you do your job more efficiently, and do it better and take care of your animals better, it's stupid not to use it." (Poultry egg farmer, 44)*

Farmers generally see a potential business case for investment

Those that had made the necessary investments were generally positive about their experiences. For the most part, these investments were driven by economic imperatives. The business case is generally premised on improving productivity through efficiency gains and reduced labour costs. In particular, participants perceived there to be substantial benefits from making processes less manual and optimising rearing practices:

> *"On occasion I have had the odd person come in, that we will obviously have to pay a wage. And they'd have to give me a hand, whereas now I don't have to. I don't have to have someone there, reading the numbers and me dictating it on a piece of paper." (Sheep & beef farmer, 27)*

> *"We use all these digital [ear] tags. And we can weigh our sheep, so we know exactly optimal time to sell our lambs so that we don't keep them too long, they're not too fat – we hit the market right at the right time." (Sheep farmer, 60)*

The capacity for technology to improve product quality and livestock characteristics was mentioned less frequently, but was still recognised by some participants. One dairy farmer described how analytics to support judgements over the type and quantity of feed had improved the output and quality of milk they produced. Another discussed the potential for genetic improvements in the farm's beef herd through using breeding indices. Similarly, a dairy farmer was using smart DNA-capturing ear tags to identify health characteristics and predict future problems, facilitating optimal breeding practices: *"that's the biggest thing we've taken on technology wise, it is just a game changer".* Several participants at the SMF roundtable were optimistic about potential gains to productivity if genetic technologies were to be more widely used in the livestock sector, but suggested that progress is needed to increase adoption and data sharing across different parts of the value chain.

Farmers' interest in technology was not only driven by financial considerations. Animal welfare was often a secondary motivation, and in rare cases, the main justification for action. Participants recognised how new technologies created a welfare-enabling environment and could improve farm safety:

> *"The daily live weight gain calculations that the computer does – as [the sheep] go through the weigh scales – they will instantly see that daily-live weight gain dropping off, and you can look at it and think, 'well, why is that doing that?'. And then you might spot some things quicker than what the visual signs will be"* (Cattle & sheep farmer, 30)

> *"It comes down to a welfare issue really. Because we have the crush, there's less stress on the animal. Before it would be kind of like get a big field gate and try and pin [the cow] against the wall and or get it in the corner there. Now... It's less stress on the animal, it's less of a danger to us". (Cattle & sheep farmer, 54)*

Our literature review highlighted a number of concerns about the risk of "replacing farmers' eyes and ears" with modern technologies and practices that worsen the human-animal relationship.[42] However, these concerns are usually limited to intensive livestock systems.[43] Only one interviewee identified with these concerns, and even then only in hypothetical terms. Most recognised the welfare-enhancing potential of technology in terms of pre-emptively identifying health issues such as lameness and reducing stress from unnecessary handling. This view is supported by a recent systematic review that concluded there is potential for PLF technologies to support farmers' decision-making and improve welfare outcomes.[44]

Though there is a sense that the benefits are not being fully realised

For all the recognised advantages of more technologically advanced methods, interview participants often hedged or qualified the perceived benefits, identifying a number of factors that meant they cannot be exploited to the full. In general, there is a sense that the technology that is installed is under-utilised:

> *"we use the simplest, simplest aspects of what it can do, and they [older farmers] understand that, but it's capable of so much more" (Cattle & sheep farmer, 30)*

> *"I bet there's lot more that I could probably do with like that [herd management] app, I'd be able to send all my movement [forms] but I just can't, it goes over my head…[it's] like talking another language." (Cattle & sheep, 27)*

> *"I don't think I'll ever get the most out of it. But I will try. I'll probably end up asking my daughter to come in and sort it." (Cattle & sheep, 58)*

Another issue is interoperability. Technological investments were often undertaken individually and in isolation, which makes it harder to exploit the benefits of linking devices, and utilising their combined data and insights. That fits with international evidence – the challenges of integrating systems was cited as a common frustration of dairy farmers in Australia and New Zealand in utilising precision technologies.[45] A related problem is that application of technology and innovative practices was not uniform across the farm business. For instance, several participants talked about investing in the sheep-side of the business but not beef.

More fundamentally, many farmers lacked awareness of specific technologies that are available and how they could help farmers. A sense of option parallasis was also common, something that was recognised by a roundtable participant:

> *"We talk about genetics, grass management, soil management, then there's technology on top of that. As a farmer, people are going 'what do I actually need to go and do?'" (Roundtable participant)*

Most interviewees were familiar with at least some precision technologies – most prominently electronic ear tags, weighing systems and farm management apps. Understanding of more novel technologies, such as soil sensors or smart rumen boluses was much weaker. Again, that fits with experiences abroad. In a 2008 survey of dairy farmers in Kentucky, the majority of respondents – 55% – said that they were not familiar with the technologies that are available, making it the leading stated reason for slow adoption of precision farming techniques.[46] The flipside of this is that many farmers feel new technologies are not for them. Data from the Farm Practices Survey suggests 63% of farmers in England felt precision technologies were not relevant to their farm, though we note that this could be a product of the limited number of technologies farmers were asked to choose from.[47]

Some farmers are more eager than others to adopt new methods

Younger generations are believed to be more open to change

It should be clear already that there are significant variations in the propensity of different types of farms to explore and invest in technology. The factor that came up most frequently in our interviews was age, with younger generations presenting themselves and seen by others as more optimistic and capable with new methods. By contrast, older farmers were often regarded as a barrier to change, and more tied to traditional approaches. What is striking from the interviews is that these generalisations were endorsed by younger and older participants alike.

As many farms are multi-generational, this dynamic can be a positive one, with younger farmers keeping their older partners and colleagues up-to-date. For example, one farmer (aged 60) we spoke to told us how her daughter had worked in New Zealand for a period *"and she came back with a load of new tech ideas and that's been a great help"*. Another highlighted the symbiotic relationship between the institutional-experiential knowledge of older generations and the positive attitude to innovation that young people have.

More often, though, technology seems to be a recipe for frustration, with older farmers daunted by or disinterested in technology, whilst having overall say on investment decisions:

> *"9 times out of 10, farm change only happens through the younger generation" (Cattle & sheep farmer, 27)*

> *"My uncle and my father run the cattle together. When you put them in front of computer screens, they're a bit bewildered by it all. So we've got the challenges of the stratified age system within the business causing serious problems." (Cattle & sheep farmer, 30)*

> *"A lot of farmers when it comes to livestock farming are back in the old days. You know, their minds are not up with modern times." (Sheep farmer, 39)*

The physicist Max Planck argued that scientific advances often require generational change, as one group of practitioners gains standing and influence and sweeps away the habits and techniques of their predecessors.[48] We found some evidence to suggest the same is true of farming, with younger farmers having to wait for the older generation to move on before they can install their new approaches:

> *"My dad was very much old school, old fashioned. And it's only now that sadly he's no longer with us, we've actually been able to progress with a much more modern outlook." (Dairy farmer, 54)*

Interestingly, empirical analyses of farm productivity suggest that age may be less important than these findings would lead us to believe. An OECD study of dairy farms found that in England and Wales, controlling for other farm characteristics (such as size, area type and capital investment), there is no association between the age of the operator and productivity.[49] By contrast, in Estonia farms run by younger people are, all else equal, more productive, whereas the reverse is true in The Netherlands, with older farmers doing better. We should therefore be careful of taking anecdotal evidence at face value.

New entrants to farming are an other dimension to consider here. DEFRA is currently developing a targeted intervention to support new entrants, whilst Scotland has a dedicated group to develop opportunities for new entrants. Only one participant matched this profile and they had not made significant investments in technology, though they were open to doing so. However, it was noted at our roundtable that:

> *"we see it an awful lot, the best innovators are new entrants to farming who look at it from a clean state" (Roundtable participant)*

Two studies in the Irish dairy sector support this claim, identifying that new entrants tend to be a younger, well-educated and well-resourced cohort[50] who demonstrate high rates of tech adoption in their farming practices compared to established dairy farmers.[51] New entrants are likely to be an important avenue of opportunity for increasing productivity in the livestock sector.

More commercial and professional farms are more likely to invest

Another distinction apparent from the interviews – one recognised by several participants – is the distinction between more and less 'commercialised' or professional farms. On the one hand, there are those that are more committed to seeking profit. On the other, there are farms run by 'hobbyists' – recognised as particularly prevalent in the grazing livestock sector[52] – or enterprises that make their money from other forms of activity (for example, using land for tourism or environmental purposes). In practice, of course, there is no clear dividing line between the two, which are more like ends of a spectrum, but the conceptual difference is still meaningful. The following quotes illustrate different points on this spectrum:

> *"[We do] egg sales and veg sales. We've just moved into breeding ducks for sale but only on a very small scale. But we also loan out a field for dog walking. We do camping in the summer; we fund local retreats; provide food for local businesses, things like that. (Poultry egg farmer, 44)*

> *"We're just in the process of splitting the business. So my brother is taking the diversified side of business, and my wife and my kids and I are keeping the dairy farming-ice cream [business]…Unless you're improving things and get more efficient and get the cost down and doing the job better, less sick animals. Unless you keep driving at that you gradually slip backwards, then you become uneconomical and have to come out."* (Dairy farmer)

OECD analysis shows that the more that dairy farms rely on non-farm activities for their income, the less productive they tend to be, a finding replicated elsewhere in the literature.[53] We found participants with more highly-specialised farms were more likely to have made more substantial investments in livestock technologies, whilst those with more diversifed farm models were less likely. Yet many participants told us that they had diversified, often as a way to "plug the gap" caused by the loss of BPS.

More broadly, we found a pessmism among many farmers about the possibility of ever making a profit and a resistance to running their organisation like an 'ordinary' business. A couple of interviewees were explicit about the fact that economic success was not their primary motivation:

> *"I know you're on about modern technology, but I don't personally farm to make a huge amount of money. I enjoy what I do, it's not necessarily all about profit. To me, it's the quality of life, it's where we live. 99% of the time I've got a smile on my face. (Dairy farmer, 54)*

> *[My daughter] is heavily invested in technology. They've just got a burning desire to get on. Maybe our age is beginning to wane our enthusiasm if I'm honest". (Sheep farmer, 60)*

More generally, there is a fatalism in some quarters that losses are inevitable, and an implicit belief that it is impossible to make money in farming. That leads many to diversify away from farming activities, which in turn means they provide less attention and resources to agriculture, creating a vicious cycle. This lack of a commercial mindset is a significant barrier to seeing technology as a justified investment and seeing the sacrifices involves in paying for that investment as worthwhile.

Larger farms are generally more productive

Our research focused primarily on smaller farms, but there was an awareness in our interviews that scale makes it easier to make technological investments. As we shall go on to discuss, up-front costs for new products and systems can be substantial and larger farms are more likely to have the cash on hand to be able to afford them. There are also issues with government subsisidies that may make them more accessible to bigger enterprises, another we return to.

That impression from our qualitative research is, again, borne out by quantitative analyses. A consistent finding in the academic literature is that larger farms tend to be more productive.[54] For example, the OECD analysis of dairy farms described above found that the main driver of productivity in England and Wales was the exit of smaller farming enterprises and the growth of larger ones.[55] This stood in contrast to the Netherlands, where productivity growth was driven more by technological adoption.

Across our interviews, many expressed the belief that some degree of rationalisation is necessary in British farming. In particular, the 'long tail' of inefficient producers includes many of those less commercially-minded farmers discussed in the previous section. Whilst recognised to be politically very challenging, this was acknowledged by one representative at the roundtable:

> *"Our industry is too fractured. There's far too many people trying to get a slice out of a pie that's shrinking. And everyone is trying to get their* own little bit.*" (Roundtable participant)*

Some farmers lack the skills to use technology effectively

Across our interviews, there was some discussion of skills and formal training, with an understanding that these could help farmers better understand what products and techniques exist and how to make the best use of them. For some, this was about basic digital literacy: *"the understanding of the technology isn't there".* Several participants described muddling through with new equipment or even giving up using it altogether. Such experiences are more common for older farmers, but by no means exclusive to them. A small number of interviewees characterised their lack of adeptness with technology as a product of their trade:

> *"We're not technically minded, we farm for reason, because we're better at the hard graft than what we are the paperwork." (Cattle and sheep farmer, 27)*

> *"I'm a farmer. I know about cows and stuff...I can't do things like programme computers and any technical faults and anything goes wrong in the slightest, and the whole system grinds to a halt. (Dairy farmer)*

From others, there was a desire for more thorough and subject-specific continuing education. This could be from formal educational institutions – particularly, agricultural colleges. Or it could be from trade bodies or even industry groups:

> *"We go on courses available, we take up any of them. We try to keep up to date with everything." (Sheep farmer, 60)*

> *"I'd quite happily go and do courses. I'm one of the few that has qualifications" (Cattle and sheep farmer, 27)*

In general, it seems that higher skilled farmers tend to adopt more innovative practices, though the evidence is not as clear cut as we might expect. Surprisingly, the OECD's analysis of dairy farms suggests that university-educated farmers in England and Wales and the Netherlands have lower productivity, controlling for other factors.[56] However, even by the authors' own reckoning, this seems to be a somewhat anomalous finding. They point to other research in German dairy farms that indicates that education does have a positive effect, and – importantly – that it is complementary to technological investment. Specifically, they find that technological investments need to be accompanied by a certain level of farmer education in order to pay off in the shape of higher productivity.[57]

Technological adoption also varies between different types of livestock farming

In general, the perception within the sectors we are examining in this report is that dairy farming is most advanced in terms of technological adoption, with sheep farming behind it, but ahead of beef. Perhaps unsurprisingly, this mirrors the variation in sector productivity that we discussed earlier in this report. Roundtable participants agreed that grazing livestock as a whole makes far less use of technology than the arable sector. This is partly a function of the availability and demonstrated success of technologies specific to dairy such as automated milking parlours.

However, it also – at least in part – seems to be driven by regulation. Since January 2015, sheep farmers have been required by law to use electronic ear tags for their animals. By contrast, while all cattle must be tagged, the tags need not necessarily be electronic – although the Welsh Government is currently consulting on moving to electronic identification systems.[58] This contrasts with the situation in Australia, where the National Livestock Identification System, covering sheep and cows, was introduced in 1999. This encouraged farmers to invest in government-subsidised electronic tags, which experts say "provided a technological base for the precision dairy system" in Australia.[59]

Technology investment is most likely to be driven by evidence of success from trusted, local sources

It is often the case that people are more likely to be motivated into action by seeing and experiencing the benefits of a different way of doing things, rather than being won over by abstract arguments or data. That certainly seems to be true of novel agricultural technologies and practices. The people we spoke to placed greatest stock in 'over the farm gate' advice from friends and neighbours. Moreover, they particularly valued being able to watch them demonstrated in action, allowing for close up inspection.

Several interviewees emphasised the importance of peer-to-peer recommendations and direct observation of peers:

> *"We all go up the pub and stuff and you speak to other farmers and it'd be sort of word-of-mouth…'somebody up the road uses this and saved them money and it saved them time'". (Sheep farmer, 39)*

> *"It's probably word-of-mouth and just meeting up with people and discussing different things and you know, going around other people's farms and seeing what they're doing." (Cattle & sheep farmer, 58)*

Another described how their novel techniques had drawn visitors and encouraged them to emulate their practices:

> *"We've invested a lot and we're actually probably quite leading in that. Because people have then come to us: 'where did you get that? We need that and we've seen it working with you'". (Sheep farmer, 60)*

Two participants discussed a more formalised peer-to-peer system in the form of sector-specific discussion groups. These included routinised farm visits and data sharing. In both instances, participants described their peers as progressive in their practices and thinking. We can draw links here to the literature on peer effects and their association with adopting new agricultural technologies. So-called 'information cascades' depend upon early adopters sharing knowledge with their peers, and the effect of peer-to-peer information exchange diminishes as tech uptake becomes more widespread. [60] [61] With PLF technology adoption still in its infancy on extensive farms, facilitating word-of-mouth knowledge could help accelerate it.

It is striking that the farmers we spoke to were by and large open to sharing their ideas and methods with others, seeing them as colleagues rather than competitors: *"we really want to help anybody that's in it and we have shown people what we've invested in and then they've gone off and done it"*. Interestingly, this contrasted with views expressed at the roundtable that peer-to-peer knowledge sharing of data and best practice was more common in dairy and not the beef sector, due to perceived or actual competition in response to the market structure. It is possible that our small qualitative sample may not be representative in this regard.

Participants also showed a lot of interest in practical demonstrations, at model farms, local agricultural colleges or trade shows. One described their local livestock market as a *"bit like a mini shopping mall"*, with exhibitions from the National Farmers' Union, the local college and agricultural businesses. Such first-hand experience is able to influence even older and more conservative farmers: *"even the old boys would go and have a look at other people's farms"*.

In some cases, trade press and social media are also useful sources of information on technology and methods. Many follow *Farmers Guardian* or *Farmers Weekly* to keep up to date: *"unless it goes in Farmers Weekly…there's no way of knowing what new equipment goes out"*. It was also noted that industry-provided information was not always aimed at smaller-scale farms. Again though, peer-to-peer information tends to be valued more. Several participants referred to Facebook groups where farmers can exchange tips:

> *"[My friend] puts videos on Facebook of her whizzing through things. She's got a scanner for the EIDs [electronic identification tags] and that and she whizzes through them like there's no tomorrow" (Sheep farmer, 39)*

> *"unless you subscribe to certain pages on Facebook, you'll never get through to them" (Cattle & sheep farmer, 27)*

In general, there was some suspicion towards commercial salespeople and consultants. Some participants could relate positive experiences, particularly where they have developed a relationship and built trust with a particular firm or individual:

> *"There's a company [I purchase bull semen from] that are very switched on…two or three companies that are looking for trade and some of them are very good" (Dairy farmer, 54)*

However, there was also wariness of the 'hard sell' from aggressive salespeople or consultants that did not instil confidence in their expertise: *"You had every Tom, Dick and Harry coming to use trying to sell his, that and the other"*. This was felt to be particularly prevalent when time-limited government grants were available, seemingly raising suspicions of profiteering on behalf of salespeople.

Government agencies that seek to support farmers in their decision making, such as the Farming Advice Service, were conspicuous by their absence from most of our interviews. The exception was the Welsh Government's Farming Connect Service, which had made a positive impression on the two participants we spoke to in Wales:

> *"Farming Connect, they're really good, you know, they send out courses and stuff. We're trying to do a funded trip, a 30% funded trip through Farming Connect to go and visit micro dairies somewhere in the country so that we can talk to people who are already doing it, to see what we might need and what technology they're using". (Poultry egg farmer, 44)*

Uncertainty about the future of farming is holding back investment

Though our discussions were primarily focused on technology, it usually did not take long for the conversation to turn to the policy environment, whose impact on farmers was felt to be near universally negative. Time and again, participants expressed a feeling of uncertainty, driven first and foremost by the lack of clarity over reforms to subsidy, but more broadly by the structural pressures on the sector. Recall that these interviews took place when the broad direction of subsidy reform – 'public money for public goods' – seemed to be firmly established, and it was only details and transitional arrangements that needed to be worked out. In England, the news of a more thoroughgoing review with 'everything on the table' following the change in Government, is only likely to have made things much worse.

For many, the psychological impact has been severe, with deep pessimism regarding the future of farming:

> *"The uncertainty is unbearable. To be honest, I have sleepless nights about it. And I'm quite a tough cookie, but I shoulder a lot of the worries for my husband because I don't want him being ill because of it." (Sheep farmer, 60)*

> *"I don't feel overly positive about the future. I mean, farming is all I've ever done. So I hope that I've got a future in farming, but when you're talking to people the future looks quite bleak." (Sheep farmer, 39)*

> *"We all want more technology and want to change, but just worrying times at the moment. We're just in survival mode." (Cattle farmer, 34)*

For all the demonstrable interest farmers had in new methods and technologies, everyone we spoke to viewed policy uncertainty as a major obstacle to investment, and for many an active disincentive. This operates in at least two ways. First, because it means farmers are unsure what they will be doing in the years ahead – whether they will switch to other forms of agriculture or even abandon the sector altogether. As such, they are not sure whether they will be around for long enough to see a return on investments they make, leading to short-termism:

> *"I'd actually be pretty blunt to you, it is because with the way the farm subsidies and the single farm payment are going at the moment, it's all in change. I personally don't know which way to go" (Dairy farmer, 54)*

> *"At the minute, we're stuck in a bit of a limbo, doing what we've been doing, because we can't plan forward, because we don't know what to plan for." (Cattle & sheep farmer, 30)*

Second, because of the importance of policy and subsidy to farms' financial circumstances, they cannot be confident of having the cash flow to buy new products.

> *"We'd love all this technology, but we've got to focus on plugging the gap for BPS first, how are we going to do it?" (Cattle farmer, 34)*

> *"If I've got £5,000 a month of outgoings on higher purchases and stuff and my income drops to zero, I want to dig a hole really fast eh"* (Dairy farmer)

These sentiments were widely recognised by attendees at our roundtable. The view was expressed that subsidies, particularly in smaller-scale pasture-based systems, have *"kept many businesses afloat"* but *"for the next two years, farmers are saying 'batten down the hatches. Am I going to stay afloat? Have I got money left to invest in technology?"*.

UK businesses have been plotting a course through widespread uncertainty for at least six years now and it has been widely recognised that this has disincentivised investment.[62] Farms are no exception. Indeed, British farming seems to be experiencing an acute case of what the economists Avinash Dixit and Robert Pindyck call 'the option value of waiting'.[63] That is, during times of uncertainty, the decision to delay and do nothing becomes more attractive relative to the decision to invest. Irreversible expenditure on capital carries a significant risk premium, especially capital with high sunk costs where benefits are not instantly recovered over and above the value of investment. For farmers who already struggle with cash flow problems and are facing the loss of an income stream through subsidy reforms, it is unsurprising that spending on new technologies is a second or third tier priority.

Cost is the fundamental barrier to utilising technology

Our discussions of technology and investment in farming covered a range of topics, but invariably, they converged on one factor above all that acts as a barrier to change: cost. Repeatedly, people said they would be interested in trying new approaches and methods, but that they lacked the cash on hand or access to finance in order to make it happen.

> *"Cost is always an issue because we don't have a lot of money…we would rather build things up very gradually." (Poultry egg farmer, 44)*

> *"I think for many farmers at the moment cost is a huge deal. So trying to modernise things right now, when the money is very tight probably isn't going to happen. (Sheep farmer, 39)*

Larger farms are perceived to be better able to bear the cost of investments. To some extent this is the natural consequence of scale: spending £10,000 is easier if your turnover is in the millions rather than hundreds of thousands. As one roundtable participant put it: *"it's really important to recognise that the economics have a really positive correlation in terms of intensification"*. Those farms that have fixed contract agreements with suppliers may also be better-placed to manage the costs of investment, but such models are the exception rather than the rule, with most livestock farmers 'price takers'. Interviewees also linked cost barriers to the nature of government support, with smaller farms suggesting that grants are less suited to their needs, and generally aimed at bigger investments than the sorts they need and can afford:

> *"Most of the grants are for the bigger boys, they're not for family run farms. They're not for us little people"(Cattle & sheep farmer, 27)*

> *"There's not an enormous amount there for people who are at smaller scale. So that's where we kind of fall into a hole where we're not new entrants to faming so we don't get the grants that new entrants to farming get. But we're also not big enough to get the bigger grants." (Poultry egg farmer, 44)*

It was noticeable from the interviews that the investments that farmers had made tended to be in low-cost solutions such as farm management apps and smart EID tags. Some pointed to 'simple things' like using spreadsheets and electronic payment systems. One interviewee also had purchased several pieces of second-hand technology, giving the example of an auto-drafting system with an electronic weigh-head which was around 25% the price of the latest version *"essentially exactly the same thing"*.

Intriguingly, confounding our expectation that poor digital infrastructure would be a significant barrier to technology use, most interviewees said it was not a major obstacle for them. That said, we note that the NFU has previously highlighted that poor broadband is a widespread issue on British farms.[64] What was more apparent was that technology costs were often placed in the context of competing investment decisions. Some of these were about diversification rather than productivity-enhancement: camping and rental properties were mentioned several times. Others discussed the need to spend on 'bricks and mortar' on the farm was as a priority and in some cases this was a prerequisite for investing in technology:

“If the solid infrastructure of like gates and steel and stone isn't there in the first place, it's pointless having the electrical technology if you haven't got anywhere to use it.” (Cattle & sheep farmer, 30)

CHAPTER THREE – RECOMMENDATIONS

Improving the uptake and use of precision technologies on British livestock farms will not be straightforward. As we have seen, we are beginning from a low base and there remain significant barriers to investment in new methods, which have to be overcome if technology is to play a role in helping meet the various policy objectives that Government has for agriculture.

At the same time, there are grounds for optimism. The farmers we have spoken to are often open to change, if only in principle. The evidence of positive returns to use of technology suggests that the business case for investment is likely to be strong, where farmers come to recognise it. And there is a small cohort of livestock farmers pushing the boundaries, alongside many in the arable sector and overseas, showing that it can be done.

As a Westminster think-tank, in this chapter we aim our recommendations primarily at government policy. Indeed, we will suggest that there is a lot that Government can do to improve upon the status quo. At the same time, it is important for Government to understand its appropriate role in farming – to create necessary infrastructure and positive incentives, to support and advise in spreading good practice, but to have the humility to recognise that it does not always know better than farmers how to run their farms. The corollary of that is that there is a responsibility on farmers themselves and on private suppliers (for example makers of technology) to do their bit in advancing progressive approaches.

In this section, we focus on five ways in which policymakers and the sector can promote the use of precision technology:

1. Improve funding incentives
2. Facilitate better knowledge exchange
3. Create better data sharing infrastructure
4. Use regulation to promote change
5. Rejuvenate farm management

Improve funding incentives

The future of government funding is the single biggest issue in agricultural policy, and it is the single most important factor in shaping the future of technological adoption. First and foremost, it is critical that the uncertainty that reigns over the subsidy system is resolved as soon as possible by the new government to give farmers a clearer picture of the future and how to adapt to it. Second, the government must develop a well-designed funding system that encourages the uptake of technology, rather than a poorly designed one that holds it back.

Paring back direct payments could be beneficial, though politically problematic

There is a widespread consensus that badly targeted subsidies are actively harmful for farm productivity. As the OECD puts it, "The first step to improving the policy environment is to roll back policies that keep farmers in uncompetitive and low-income activities, harm the environment, stifle innovation, slow structural and generational change and weaken resilience".[65] We highlighted in Chapter One that many livestock

enterprises in the UK do not turn a profit and survive largely because of subsidies. Studies have shown that direct support payments undermine efficiency and that farms that rely on government support for a greater share of their income tend to be less productive.[66] Subsidies based on a farm's level of output or use of inputs are believed to be particularly harmful. If reports are correct that the Government is considering a return to area-based payments, the evidence suggests this would be a retrograde step in conflict with its stated desire to boost growth.[67]

There is a case to be made for a radical approach here – many admire New Zealand's decision to all but eliminate farming subsidies. In 1984, around a third of New Zealand livestock farmers' revenue came from government support. By 1987, that had more than halved, and by 1990, it was less than 5%.[68] Yet despite this shock, New Zealand agriculture has thrived. Many sheep farmers shifted to dairy, but those that remained have become more efficient: the number of sheep being reared has more than halved with little change in the amount of meat they produce.[69]

Those we spoke to for this project do not believe the political and economic environment in this country would allow governments here to follow similarly drastic measures. However, some did suggest that agriculture may become more productive if subsidies were reduced and restructured. First, in order to sharpen incentives to improve productivity by removing the relatively comfortable safety net farmers have. Second, by forcing out the least profitable and commercially minded farms, and consolidating the sector:

> *"We're never going to go to the New Zealand system and take subsidies out but that would defracturise the industry a bit" (Roundtable participant)*

Strikingly, almost all of the farmers we spoke to for our research displayed either a reluctant acceptance of subsidies or an outright dislike for them, whilst maintaining that these were not widely-held views across the farming community. Several held the opinion that they didn't wish to be seen as surviving off of the state, but the underlying structures of farming had made this an inescapable reality. Whilst we cannot generalise from our small qualitative sample, it was one of the most surprising findings of this research that some farmers would be pleased to see direct payments ended.

> *"I'm probably one of the very few farmers that you'd speak to in that I don't particularly agree with all the subsidy that farms get. I think we should not have any and no other business has one. But I'm not saying if there's £20 on the floor you don't pick it up because course you do — it's there so you take it" (Dairy farmer, 54)*

Support should be shifted towards productivity-enhancing grants

Without going as far as New Zealand, a less dramatic option might be to follow the Australian model. The OECD holds Australia up as an example of a country with minimal policy distortions.[70] We recognise the structural differences between UK and Australian livestock farming, but the basic principles are transferable. Australia continues to offer support to its farmers, but this primarily takes the form of funding for knowledge transfer systems and infrastructure to encourage productivity and sustainability.

We would favour a similar rebalancing of government agricultural spending in the UK, shifting away from general subsidies to a system that uses its funding primarily to incentivise productivity-enhancing investments and socially- and environmentally-beneficial activities. The "public money for public goods" approach that the Westminster Government has explicitly adopted, and devolved administrations also seem to favour, offers a useful framework for such a shift.[71] However, it is important that encouraging efficiency-improvement investment receives due focus in this strategy, alongside environmental priorities.

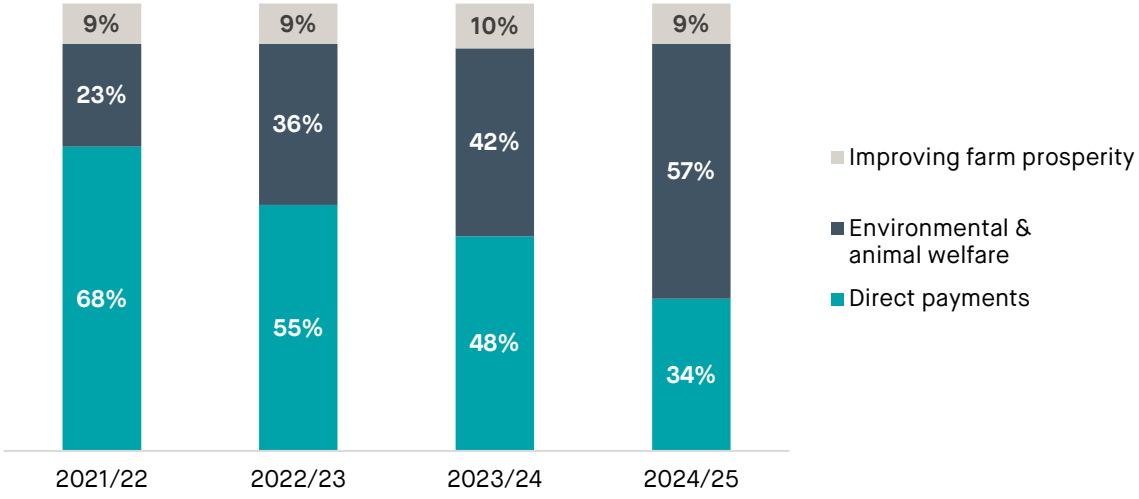
For farmers in England, the primary source of financial support for investing in new technologies is via the Farming Investment Fund.[72] This comprises the Farming Equipment and Technology Fund (FETF) – grants worth between £2,000 to £25,000 to part-fund purchases from an approved list of products. Eligible items are currently being reviewed after the first round of funding closed in January 2022, but it is positive to see that many of the technologies discussed in this paper were available for grant funding. The FETF sits alongside the Farming Transformation Fund, which makes larger grants of £35,000-£500,000 for large-scale projects installation of robotic equipment.

These grants are a welcome step. But there are several concerns that we would raise, many of which were recognised by the farmers we spoke to. Firstly, funding is relatively low compared to overall agricultural support. For example, the first round of the FETF amounts to less than £50 million of the Government's multibillion agricultural support spending.[73] The fund was oversubscribed for the first round, suggesting funding is insufficient. Further, the structure of grants may be disadvantaging smaller farms with limited cash on hand. To illustrate the point, consider that the Spring 2022 FETF paid out £1,800 for an automatic cattle weighing system (purchased as a full unit), but some systems cost more than £7,000.[74] Given that total average farm business income for a lowland grazing livestock farm over the last decade has been around £20,000[75] the £5,000+ that a farmer would be expected to contribute may be quite challenging to spare. Similarly, to access the Farming Transformation Fund, the minimum upfront spend is £87,500 to access the 40% grant (minimum £35,000 claim). Importantly, farms need to purchase equipment before recouping money via the Rural Payments Agency, with no guarantee that the grant will be approved. It is plausible that the payment terms and generosity of grants could be disincentivising some farmers from applying.

As well as the structure of grant funding, some consideration could be given to increasing the flexibility of grants and taking a broader view of what technologies improve productivity. For instance, farm management apps and other integrated animal monitoring systems require a subscription but since they are not a capital investment in the conventional sense, they are not eligible. Further, only new items can be bought with grants, despite the fact that many farmers rely on the second-hand market. We recognise that broadening eligibility and increasing flexibility risks over-bureaucratising the system. Nonetheless, particularly for lower-income farms and those who are at the early stages of technology adoption, a more flexible funding system may help to ensure a greater proportion of farmers are supported.

According to the previous government's categorisation of farm support funding in England, the proportion dedicated to improving farm prosperity (i.e. enhancing productivity) was set to remain around a tenth, with direct payments falling and environmental and animal welfare based payments rising. With the Government apparently reconsidering the form and shape of subsidies, it should not increase direct payments at the expense of environmental and welfare payments. Rather, it should shift direct payments towards incentives to encourage investment and usage of technology. We also encourage the government to continue to optimise the structure of grant funding to appeal to the maximum number of farms, with attention paid to small farms and those who struggle with a consistent revenue stream.

Figure 10: Government planned farm funding breakdown 2021-25



Source: DEFRA, The Path to Sustainable Farming

Facilitate better knowledge exchange

While cost is the main obstacle to investment in technology, and we would hope that a reformed grants system could help overcome that issue for many farms, it is far from the only barrier. There remains a need for a better knowledge and information system to develop innovative technologies and get them into the minds and hands of farmers.

Improving R&D and knowledge exchange is critical

Though upstream innovation has not been the focus of our research, this needs to start with continued public investment in research and development. Reductions in British R&D spending have been linked to stagnating agricultural productivity.[76] In particular, a recent analysis of productivity on Scottish farms bemoaned the fact that public 'near market' R&D was "effectively ended" in the 1980s, and that it is only in recent years with the 2013 Agri-Tech Strategy that this mistake has been recognised and reversed.[77] In particular, the development of the Centre for Innovation Excellence in Livestock, one of four national agri-tech centres, has been positive development – investing in advanced research facilities in conjunction with the livestock sector.[78]

Yet at the same time, DEFRA's net spend on R&D has fallen by 75% since 2009.[79] Confirmation of the Farming Innovation Programme in the Government's response to the National Food Strategy is certainly welcome, but amounts to only £34 million annually until 2029. By comparison, the overall UK R&D budget is £39.8 billion for 2022-2025 alone. It seems likely that a substantial increase in agricultural R&D spending will be a necessary component of making a success of on-going reforms to subsidies.

It is equally important to foster a more effective knowledge transfer ecosystem. This was raised as a particular source of British weakness in our expert roundtable, compared to continental peers:

> *"Most of the advances were actually developed in the UK. What have we got wrong in the knowledge exchange from the theory, practice and development of the technology to getting the uptake on farms?" (Roundtable participant)*

That fits with international evidence, which shows that the adoption of precision technology has generally been driven by strong knowledge transfer systems.[80] By contrast, a report by the Food and Drink Sector Council described knowledge exchange networks in the UK as "highly fragmented" and lacking a central point for evaluating the quality and relevance of advice. It recommended the foundation of a new What Works centre for agriculture and horticulture, which was piloted by the Agriculture and Horticulture Development Board (AHDB) in the form of the Evidence for Farming Initiative last year. The National Food Strategy response has committed to developing a What Works Centre "to provide farmers with evidence that supports the adoption and on-farm take up of new innovations".[81] This should be coordinated with the Centre for Innovation Excellence in Livestock, ensuring that the evidence that emerges from its research is easily accessible to farmers. There is no time to waste – the Government must now turn words into action and ensure the centre is launched within the next 12 months.

Building stronger peer to peer networks seems particularly promising

In particular, given the evidence we have presented in the previous chapter of the weight farmers place on the experiences and testimony of other farmers, developing peer-to-peer networks seems to be a particularly promising avenue for improvement. In countries like the Netherlands and Norway, the development of 'communities of practice' – groups of 8-15 farmers, meeting three or four times a year – was critical to the success of automated milking systems.[82] These farmer groups could share teething problems, help interpret data and act upon on it and find ways to make the most of the new technology. We have found some groups like this in the UK that have developed organically, through direct personal contacts or social media, but they seem to be much more limited than elsewhere. Elsewhere, government financial support can help grease the wheels, as can the assistance of private technology firms or consultants to coordinate. For example, precision technology companies could perhaps make better use of brand ambassadors and provide better 'aftercare' to support use of their technology.

Better demonstration farms could also help

A more formalised version of direct demonstration comes in the shape of model farms, recognised in the literature as a key mechanism for disseminating experiential knowledge.[83] Again, these already exist to some extent, but the evidence of our interviews is that they are not adequate to meet the needs and expectations of farmers. Participants in our roundtable observed that many model farms exist, like the networks operated by AHDB and the Agri-EPI Centre, but there is need for some degree of consolidation as it is often unclear where farmers should go for support with a particular issue. Scotland is perceived to be ahead of England in its use of commercial 'monitor' farms to trial and demonstrate best practice, following a model developed in New Zealand. A qualitative evaluation of the Scottish monitors found that participants believed it had improved their efficiency. However, Scotland only has one demonstration farm (run commercially with a remit to use innovative practices to show their profitability), which is focused on wildlife conservation. Smart farms, which exist to allow researchers and teachers to showcase cutting-edge technology, have not yet made it to the UK.[84] The EU's FarmDemo project – bringing together over 1,500 demonstration farms across Europe – may provide a useful starting point for the UK. Any future reforms should aim to involve harder to reach groups, rather than only creaming off those most likely to adopt new innovations.

It is worth exploring the advantages of investing in advisory services

Another source of best practice comes from professional consultancy and advisory services. These take quite different forms in different countries. In many places, they are state-run and publicly-financed. Indeed, in Brazil and Colombia, government services take active steps including offering incentives to engage farmers that do not use them. By contrast, in the Netherlands advisory services have been privatised and a flourishing commercial sector has emerged.

In England, three in ten farms pay for specialist advice on productivity, but this is considerably lower for LFA and lowland livestock farms (11%); only 5% of farms use government advisors.[85] As described above, in our interviews, we found significant scepticism towards British advisory services, both public and private, with the exception of Wales' Farming Connect. Such wariness is likely to be tricky to overcome, but some experimentation with more ambitious support for public or private advisory services may be worthwhile to see if they can be more effective. A successful What Works centre will in part depend upon advisers, who can play a role ensuring the best academic evidence reaches farmers.

Upskilling farmers also has a role to play

As in any industry, investing in skills and training has the potential to improve productivity. As noted above, there is evidence to suggest that a certain level of education can be complementary to technological investment, allowing farmers to make better use of the tools they use.

The farmers we spoke to were somewhat split on the value of additional formal education. However, particularly for younger farmers and for those more open to returning to learning, colleges have an important role to play. There may be scope for greater use of apprenticeships, following a model being piloted in the North East of

Scotland – where classroom-based introduction to the sector is combined with hands-on experience and mentorship.[86] Encouraging farmers to engage in continuing education may be trickier, but as we have seen at least some are open to investing in upskilling. Government agencies like Wales' Farming Connect and Scotland's Farm Advisory Service can help here, as can government facilitation of private training providers. The new Institute for Agriculture and Horticulture launching this year is a welcome development. Private technology providers could also train farmers in the use of their products after purchasing them.

Knowledge exchange programmes must be well evaluated

Given the range of ways we have set out for policymakers to promote awareness and adoption of new technologies, it is easy to spend a lot of money on initiatives that could vary substantially in their efficacy. British governments should therefore follow international best practice in evaluating their knowledge exchange programmes, identifying 'what works' and channelling their resources to the most cost-effective. In the Netherlands, for example, research institutions are expected to carry out self-evaluations on an annual basis, and are subject to independent review every five years. In Latvia, organisations are assessed by international peers.[87] Even in other countries, the OECD says that says that R&D is more likely to be assessed in terms of the quality of research than its practical application, suggesting that networking and knowledge exchange ought to be better evaluated. An expansion of such activities in the UK would offer a good opportunity to put those recommendations into practice.

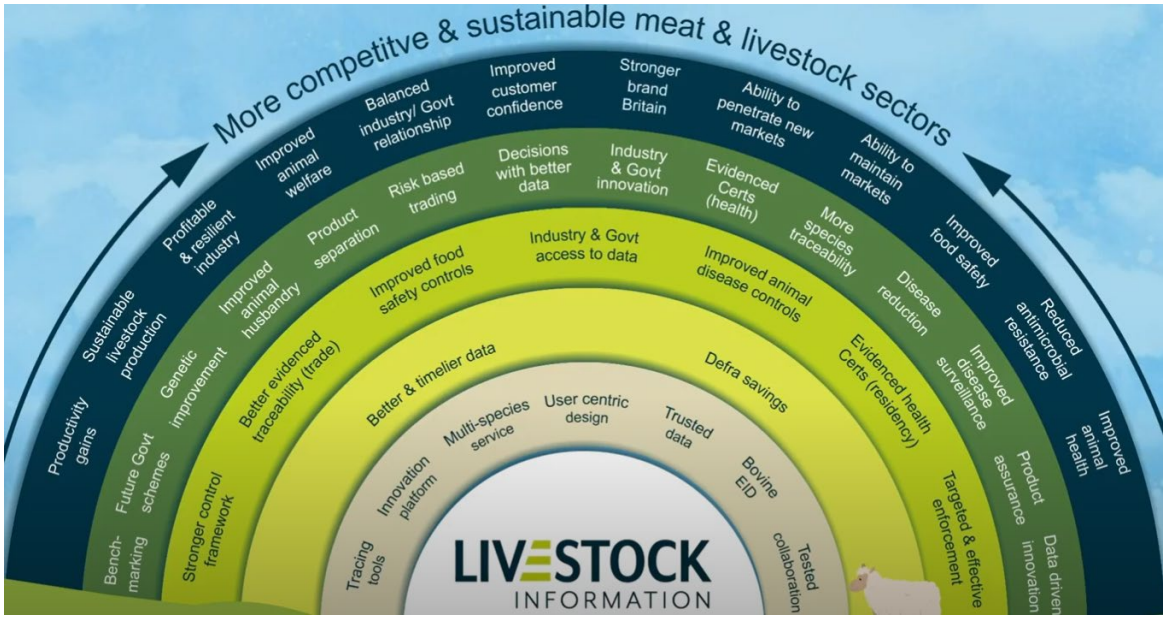
Create better data sharing infrastructure

Better coordination of systems, and in particular integration of different data sources, has the potential to boost farming productivity. First, because – as we have seen – the existing fragmentation of products, and the frictions involved in using different ones together, can discourage farmers from investing in them. Second, because combining data from different sources and products can make them more than the sum of their parts in terms of improving efficiency.

In our expert roundtable, there was a sense that Britain has some way to go to providing livestock farmers with the data that they need to make effective decisions. For example, farmers may have difficulty adjusting their methods to market signals (for example, as to the weight of their animals at slaughter) because "we don't routinely get that information down the supply chain". There was frustration that even statutory data that is routinely recorded (like carcase weight, quality, date of slaughter) is not made available to support farmers' decision-making. There is some cause for optimism with the launch of the Livestock Information Service – the government's new livestock movement reporting system. The ambition is to facilitate data exchange throughout the supply chain and, crucially, back to farmers so they can make improvements to disease eradication and better decisions about their livestock. One participant at our roundtable involved in a pilot project demonstrating the productivity and climate benefits of benchmarking to farmers suggested there was considerable enthusiasm amongst participants.

Nevertheless, other countries are perceived to be further ahead in this space. SEGES, a Danish private non-profit research agency, was seen as an exemplar, aggregating data from milk producers, farmers and vets, into a central database. The Irish Cattle Breeding Federation's database combining genetic information with information on weight, milk quality, survival etc, was presented as another model to follow.[88] Participants recognised that such efforts can be laborious and painstaking, but they felt that the benefits would be worth it, with farmers better able to benchmark their performance, receive feedback on different activities and adapt their approaches accordingly. As of 2016/17, 21% of farms in England were benchmarking their enterprise practices, suggesting a significant window of opportunity.[89] However, we would caution that, based on our findings, many farmers will struggle to reap the rewards of data generation and benchmarking, and again this may be an area where input from public and private advisers and education institutions could help.

Figure 11: Aims and benefits of the Livestock Information Service



Source: Livestock Information Service

Use regulation to promote change

Experience, both in the UK and elsewhere, has shown that regulatory changes can often be used to jump start technological adoption. Mandating farmers to use certain technologies to collect administrative data can then encourage them to use that data to shape their farming practices.

The most prominent example is electronic ear tags. As discussed in the previous chapter, the Australian National Livestock Identification System, introduced in 1999, incentivised and supported investments in electronic IDs, which in turn formed the basis of precision farming there. In the UK, only sheep farmers are at present required to use electronic IDs. The UK and Scottish governments should follow the Welsh example, and seek to introduce a similar system for cattle. It is positive to see that Scotland is considering compulsory bovine EID tagging by 2024[90] and that the Westminster Government is planning a consultation for England.[91] We note that policy

'sticks' can only go so far: in England and Wales there is evidence that despite making EIDs mandatory in sheep farming, this has not translated into widespread use of the data generated for improving farm practices. [92] Nevertheless, regulation can certainly play a role in providing a platform for proliferating the use of PLF, especially in more affordable technologies. Policymakers should avoid delays on compulsory cattle EIDs, especially given the opportunity presented by the new Livestock Information Service in England.

Rejuvenate farm management

Throughout this research, we have heard that the current composition of farm owners and managers is a major obstacle to the use of precision methods and new technology. That has often been couched in terms of age – though as we have seen, the evidence on the relationship between age and productivity is less clear cut than we might imagine. But more generally, it is a matter of outlook and temperament: too many farmers set in their ways and lacking openness to new ideas. Policymakers should try to find ways to inject new blood into the sector.

The Westminster Government's lump sum exit scheme for England, which offers farmers cash incentives to retire or leave the industry, may help. Opened to applications in April 2022, the programme offers farmers an advance on their Basic Payment Scheme entitlements for future years, up to the value of £100,000 if they stop farming. The hope is that this will lead older farmers to make way for younger entrants.

There appears to be at least some appetite from younger farmers to take over vacated enterprises, and this offers encouragement that a new generation with fresh ideas could take over. However, there may still be problems if too many of these come from farming backgrounds and simply continue with longstanding practices. In our roundtable, there was a desire to encourage more people with radically different skills and experiences into the profession. One participant spoke of the need to make farming "exciting and sexy", shifting the image of farming, presenting it as a more innovative and high-tech field than common perceptions would have it. A positive development is DEFRA's new entrant to farming pilot – mirroring similar schemes in Scotland and Wales aimed at encouraging those with non-farming backgrounds to enter the sector. Based on the evaluation of Wales' young new entrant programme (2010-2012), which reported positive results, we would urge the Westminster Government to be as ambitious as possible with its programme for England.[93] The NFU's future generation forum has encouraged the government to provide state-backed loans and facilitate a network of farm mentors to ensure the scheme is a success.[94]

One additional policy to consider is the new freedom government has post-Brexit to design its young farmer payment scheme. At present, in England, farmers under 40 who are the main decision-maker can apply for a top-up payment of up to 17.5% of BPS entitlement. This payment is made for a maximum of five years; similar programmes exist in Scotland, Wales and Northern Ireland. With the phasing out of direct payments, it is unclear what will happen to young farmer payments. What influences younger generations to keep farming is complex but studies do show that payments positively affect motivation to stay by engendering sentiments like

belonging, responsibility and desire to improve productivity.[95] It is plausible that if payment rates and eligibility criteria were made more generous, some farms may see this as an incentive to hand overall control of the farm to younger generations open to using technology more quickly. With this in mind, we encourage the government to evaluate the effectiveness of young farmer payments against key outcomes like young people's rate of exit from farming, and consider whether increasing payments and/or reforming eligibility criteria could help transition farm management.

A new (more productive) dawn for British farming

The crossroads British farming has reached is an opportunity to do things differently: to farm more harmoniously with the environment; to prioritise animal welfare; to make agriculture more productive. The findings of this report – informed by the views of livestock farmers and other stakeholders from across the sector – suggest that precision technologies can help to make these a reality. However, given the relatively low base we are beginning from, there is some way to go to guarantee that livestock farmers across the country are adopting new technologies and practices and maximising their potential.

Effective policymaking can facilitate this transition and there are many promising developments already underway. We have argued that improving the agricultural funding system, knowledge exchange, data sharing, farm management and regulation can all contribute to driving technology adoption. Change will not happen overnight, but a Government committed to precision technologies as a core part of its vision for post-Brexit agriculture can help bring about a more productive dawn for British farming.

ENDNOTES

[1] House of Commons Environment, Food and Rural Affairs Committee (2021), Oral evidence: Environmental land management and the agricultural transition, HC 78.

[2] DEFRA (2020), The Path to Sustainable Farming: An Agricultural Transition Plan 2021 to 2024.

[3] https://www.theguardian.com/environment/2022/sep/30/how-truss-post-brexit-farming-policy-descended-into-chaos

[4] Institute for Government. (2022). Agriculture after Brexit: Replacing the CAP.

[5] HM Treasury (2022), *The Growth Plan 2022*.

[6] https://www.ukpol.co.uk/ranil-jayawardena-2022-speech-to-conservative-party-conference/

[7] https://www.fwi.co.uk/business/markets-and-trends/input-prices/uk-food-production-to-shrink-as-input-inflation-hits-24

[8] Dewulf, A., & Biesbroek, R. (2018), Nine lives of uncertainty in decision-making: strategies for dealing with uncertainty in environmental governance, Policy and Society, 37:4.

[9] World Resources Institute (2019), Creating a Sustainable Food Future.

[10] Thirtle, C. et al (2004), Explaining the Decline in UK Agricultural Productivity Growth. Journal of Agricultural Economics, 55:2.

[11] https://www.gov.uk/government/statistics/total-factor-productivity-for-england-by-farm-type

[12] The Andersons Centre and Associates (2018), The characteristics of high performing beef and sheep farms in Great Britain

[13] Andersons, (2015), The Best British Farmers: What gives them the edge?

[14] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1031917/fbs-businessincome-statsnotice-16dec20.pdf

[15] Agri-Food and Biosciences Institute (2018), Literature review: Key Drivers of Agricultural Productivity Growth; SRUC & SAC (2020), Boosting Productivity Growth in Scottish Agriculture; OECD (2015), Dynamics of dairy farm productivity growth.

[16] UK Government (2021), Net Zero Strategy: Build Back Greener.

[17] Allen, A. R., Skuce, R. A., & Byrne, A. W. (2018), Bovine Tuberculosis in Britain and Ireland – A Perfect Storm? the Confluence of Potential Ecological and Epidemiological Impediments to Controlling a Chronic Infectious Disease, Frontiers in Veterinary Science.

[18] https://www.gov.uk/government/statistics/incidence-of-tuberculosis-tb-in-cattle-in-great-britain/quarterly-tb-in-cattle-in-great-britain-statistics-notice-december-2021

[19] Mahendran, S. A. et al (2022), A survey of calf management practices and farmer perceptions of calf housing in UK dairy herds, Journal of Dairy Science 105:1

[20]ADAS (2015), Study to Model the Impact of Controlling Endemic Cattle Diseases and Conditions on National Cattle Productivity, Agricultural Performance and Greenhouse Gas Emissions.

[21] https://www.fwi.co.uk/business/business-management/agricultural-transition/labour-backs-nfu-calls-for-two-year-pause-to-bps-cuts

[22] https://www.fwi.co.uk/news/farm-policy/truss-and-sunak-set-out-their-plans-for-farming

[23] Campaign to Protect Rural England (2019), Uncertain harvest: does the loss of farms matter?

[24] Berckmans, D. (2017), General introduction to precision livestock farming, Animal Frontiers 7:1

[25] Berckmans, D. (2014), Precision livestock farming technologies for welfare management in intensive livestock systems, Revue Scientifique et Technique de l'OIE 33 :1

[26] Schillings, J., Bennett, R., & Rose, D. C. (2021) Exploring the Potential of Precision Livestock Farming Technologies to Help Address Farm Animal Welfare, Frontiers in Animal Science 2.

[27] Aquilani, C. et al (2022), Review: Precision Livestock Farming technologies in pasture-based livestock systems, Animal 16:1.

[28] Tullo, E., Finzi, A., & Guarino, M. (2019), Review: Environmental impact of livestock farming and Precision Livestock Farming as a mitigation strategy, Science of The Total Environment 650.

[29] Aquilani et al, Review: Precision Livestock Farming technologies in pasture-based livestock systems.

[30] Neethirajan, S., & Kemp, B. (2021), Digital Livestock Farming, Sensing and Bio-Sensing Research 32.

[31] Tullo et al, Review: Environmental impact of livestock farming and Precision Livestock Farming as a mitigation strategy.

[32] Wilkinson, J. & Garnsworthy, P. (2017), Impact of diet and fertility on greenhouse gas emissions and nitrogen efficiency of milk production, Livestock 22:3.

[33] AFBI, Key Drivers of Agricultural Productivity Growth.

[34] Key, N., McBride, W. & Mosheim, R. (2015), Decomposition of Total Productivity Change in the US Hog Industry, Journal of Agricultural and Applied Economics 40:1.

[35] OECD (2019), Innovation, Productivity and Sustainability in Food and Agriculture: Main Findings from Country Reviews and Policy Lessons.

[36] Aquilani et al, Review: Precision Livestock Farming technologies in pasture-based livestock systems.

[37] Schillings, et al, Exploring the Potential of Precision Livestock Farming Technologies to Help Address Farm Animal Welfare.

[38] Stevenson, P. (2017), Precision livestock farming: could it drive the livestock sector in the wrong direction? Compassion In World Farming.

[39] Lima, E. (2018), Drivers for precision livestock technology adoption: A study of factors associated with adoption of electronic identification technology by commercial sheep farmers in England and Wales, PLOS ONE 13:1

[40] DEFRA (2020), Farm Practices Survey October 2019 – General.

[41] Lima, Drivers for precision livestock technology adoption

[42] Berckmans, Precision livestock farming technologies for welfare management in intensive livestock systems.

[43] Stevenson, Precision livestock farming: could it drive the livestock sector in the wrong direction?

[44] Schillings, et al, Exploring the Potential of Precision Livestock Farming Technologies to Help Address Farm Animal Welfare.

[45] Jago, J et al (2013), Precision dairy farming in Australasia: Adoption, risks and opportunities, Animal Production Science 53:9; Yule, I. & Eastwood, C. (2011), Challenges and Opportunities

for Precision Dairy Farming in New Zealand, Proceedings of the 11th International Conference on Precision Agriculture.

[46] http://www.precisiondairy.com/proceedings/s1bewley2.pdf

[47] DEFRA (2020), Farm Practices Survey October 2019 – General.

[48] https://slate.com/technology/2015/06/max-plancks-principle-physics-and-constant-he-knew-how-to-change-his-mind.html

[49] OECD, Dynamics of dairy farm productivity growth.

[50] McDonald, R. et al (2013), Characteristics, intentions and expectations of new entrant dairy farmers entering the Irish dairy industry through the New Entrant Scheme, International Journal of Agricultural Management 2:4.

[51] McDonald, R. et al (2016), Factors Influencing New Entrant Dairy Farmer's Decision-making Process around Technology Adoption, The Journal of Agricultural Education and Extension 22:2.

[52] Andersons, The Best British Farmers: What gives them the edge?

[53] OECD, Dynamics of dairy farm productivity growth.

[54] OECD, Innovation, Productivity and Sustainability in Food and Agriculture; SRUC & SAC, Boosting Productivity Growth in Scottish Agriculture

[55] OECD, Dynamics of dairy farm productivity growth.

[56] Ibid.

[57] Sauer, J. & Latacz-Lohmann, U. (2014), Investment, technical change and efficiency: empirical evidence from German dairy production, European Review of Agricultural Economics 42:1.

[58] https://gov.wales/cattle-tags-when-will-bovine-electronic-identification-be-introduced

[59] Eastwood, C., Klerkx, L. & Nettle, R. (2017), Dynamics and distribution of public and private research and extension roles for technological innovation and diffusion: case studies of the implementation and adaptation of precision farming technologies, Journal of Rural Studies 49.

[60] Skevas, T., Skevas, I., & Kalaitzandonakes, N. (2022), The role of peer effects on farmers' decision to adopt unmanned aerial vehicles: evidence from Missouri, Applied Economics 54:12

[61] Chatzimichael, K., Genius, M., & Tzouvelekas, V. (2014), Informational cascades and technology adoption: Evidence from Greek and German organic growers, Food Policy 49.

[62] https://www.bankofengland.co.uk/-/media/boe/files/speech/2019/investment-and-uncertainty-the-value-of-waiting-for-news-speech-by-ben-broadbent

[63] Dixit, A., & Pindyck, R. (1994), Investment under Uncertainty.

[64] NFU (2015), NFU Spotlight on Farm Broadband and Mobile Networks.

[65] OECD, Innovation, Productivity and Sustainability in Food and Agriculture

[66] AFBI, Key Drivers of Agricultural Productivity Growth; SRUC & SAC, Boosting Productivity Growth in Scottish Agriculture; OECD, Dynamics of dairy farm productivity growth.

[67] https://www.theguardian.com/environment/2022/sep/30/how-truss-post-brexit-farming-policy-descended-into-chaos

[68] https://asmith.ucdavis.edu/news/new-zealands-farmers-dont-want-governments-money

[69] https://www.fwi.co.uk/business/prepare-farm-business-brexit

[70] OECD, Innovation, Productivity and Sustainability in Food and Agriculture.

[71] https://www.instituteforgovernment.org.uk/explainers/agriculture-subsidies-after-brexit#:~:text=In%20the%20medium%20term%2C%20the,continue%20to%20be%20based%20on

[72] https://www.gov.uk/guidance/farming-investment-fund

[73] https://defrafarming.blog.gov.uk/2022/02/22/farming-equipment-and-technology-fund-grants-issued/

[74] https://ritchie-d.co.uk/product/beef-monitor/

[75] https://www.gov.uk/government/statistics/farm-accounts-in-england

[76] United States Department of Agriculture (2018), Agricultural Research Investment and Policy reform in High-Income Countries. 1

[77] SRUC & SAC, Boosting Productivity Growth in Scottish Agriculture.

[78] https://www.agritechcentres.com/ciel

[79] https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/datasets/scienceengineeringandtechnologystatisticsreferencetables

[80] Eastwood et al, Dynamics and distribution of public and private research and extension roles for technological innovation and diffusion.

[81] https://www.gov.uk/government/publications/government-food-strategy/government-food-strategy

[82] Eastwood et al, Dynamics and distribution of public and private research and extension roles for technological innovation and diffusion.

[83] Sutherland, L.-A., & Marchand, F. (2021), On-farm demonstration: enabling peer-to-peer learning, The Journal of Agricultural Education and Extension 27:5.

[84] SRUC & SAC, Boosting Productivity Growth in Scottish Agriculture.

[85] DEFRA (2020), Farm Practices Survey October 2019 – General.

[86] https://www.scotsman.com/country-and-farming/apprenticeships-on-offer-for-tomorrows-young-farmers-3597561

[87] OECD, Innovation, Productivity and Sustainability in Food and Agriculture.

[88] https://www.icbf.com/?page_id=336

[89] https://www.gov.uk/government/statistics/farm-business-management-practices

[90] https://www.thescottishfarmer.co.uk/news/20036696.hugh-fraser-sets-nfus-livestock-plans/

[91] https://www.fginsight.com/news/cattle-next-to-move-to-multi-species-animal-movement-service-128230

[92] Lima, Drivers for precision livestock technology adoption

[93] SRUC Research (2020), Evaluation of the Young Entrants Support Scheme (YESS) Final Report.

[94] https://www.nfuonline.com/media-centre/releases/next-gen-forum-new-entrant-scheme-pr/

[95] May, D. et al (2019), Preventing young farmers from leaving the farm: Investigating the effectiveness of the young farmer payment using a behavioural approach, Land Use Policy 82.