Boosting Productivity Growth in Scottish Agriculture

A report for RESAS

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Glossary

Allocative efficiency: the rate at which costs are minimised to create revenues.

Technical Efficiency: the ratio of physical output to physical input.

Economic efficiency: a composite of technical and allocative efficiency and thus provides a farm level analogue to productivity.

Partial Productivity: a measure of productivity at a specific unit level, usually land or labour, per unit of output.

Total Factor Productivity (TFP): the ratio of an output index to an input index which measures the growth in output not attributable to growth in inputs. It is explained mostly by technological change and the adoption of better production methods that improve efficiency, though variances are also attributable to weather, disease, markets and other impacts.

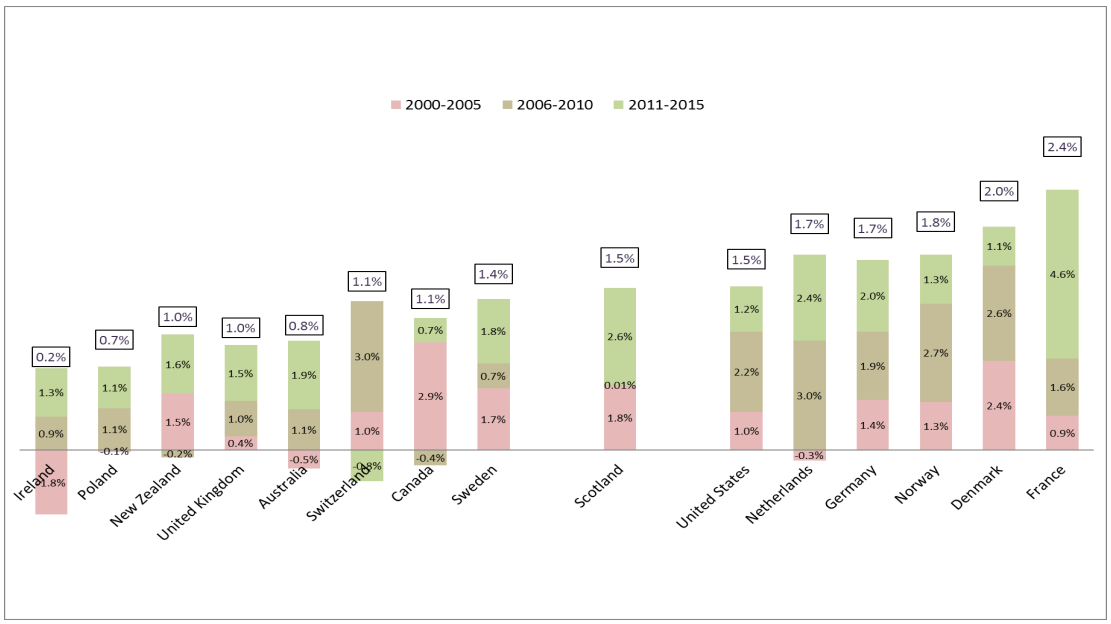
Executive Summary

Agricultural productivity is a key measure of sustainable growth. Productivity measures the growth in output relative to input and is explained mostly by technological change and the adoption of better production methods that improve efficiency. However, in addition to fluctuations in global market prices, agricultural productivity is also highly affected by variances in weather conditions and outbreaks of crop and livestock diseases. Consequently, reducing the rate of inputs to maintain or grow output should support a more sustainable and resilient agricultural sector as this reflects the ability to accommodate some of these perturbations.

In Scotland there are further challenges to support productivity growth due to climatic and biophysical disadvantage. However, this is also attributable to inappropriate management, low levels of technology uptake and lack of willingness to adopt techniques and systems which may be more efficient and resource saving. At an aggregate level Scottish productivity growth has shown positive, yet erratic, annual growth since 2000.

When compared to comparator high-income countries, and using a variety of data sources, Scotland seems to perform as a middle ranking country when annual average growth rates are measured[1] (Fig E1)

Figure E1. Average Annual Growth rates for selected countries in Total Factor Productivity across time periods, 2000-2015



[1]These reflect estimates from two different data sources and should be viewed with caution.

Disaggregating performance at a sectoral level using the Farm Business survey we find wide disparities between farm types. Table E1 shows the average annual growth rates for each type studied over selected periods which illustrate the variance in performance.

Table E1. Average Annual Rates of Growth for each farm type using Farm Business Survey data

	Cereals	LFA Cattle and Sheep	General Cropping	LFA Sheep	LFA Cattle	Dairy
2000-2005	-0.2%	-0.2%	-0.7%	0.4%	0.1%	-0.1%
2006-2010	-1.4%	0.9%	1.0%	0.6%	0.1%	1.3%
2011-2017	1.2%	-0.3%	0.7%	-0.1%	-0.8%	-2.1%

There were wide variances in performance, with a number of farms operating at around half the efficiency found for the best performers within the sector. This infers that, in addition to disadvantages faced by these farm types, there are a range of behaviours and decision-making, as well as adoption of technologies and practices, that affect performance. In order to improve productivity farmers can*: i) adopt new technologies, ii) change the size of their businesses, and/or iii) change the input-output mix*.

To support these changes there are three main types of measures which are identified in this report:

i) *policy interventions;* such as support for changing the business and provision of advice, education and research engagement for change;

ii) *technological interventions*; such as adoption of new technologies or techniques, or applying alternative approaches to uplift productivity; and

iii) *management interventions;* which include farmer decision making and farm planning, to switch the mix of inputs and outputs, or increase scale of the enterprise.

A range of interventions were reviewed to assess their applicability to Scotland. These are shown in table E2 with an initial assessment of the costs and the effect on productivity. In summary, multiple options exist which range from movement towards more market-based mechanisms, increasing funding for the innovation system to focus on productivity enhancing research, as well as new technologies and targeted Government support. Direct funding of farmers needs to follow current WTO green box rules, i.e. productivity may only be a co-benefit but not the direct aim of the intervention, such as demonstrated in the recent Countryside Productivity Small Grant Scheme in England.

The effect of an intervention on farming productivity is context specific. Moreover, disentangling poor land and climate from poor or bad management is difficult. The evaluations used here to identify applicable productivity measures have emphasised the context specific nature of their application. Accordingly, unpicking effects directly on productivity is complicated by these factors. Consequently, there are limits and caveats to the interventions outlined below which could be effective at raising productivity growth given the nuances of Scottish agriculture. Moreover, there may be unintended consequences to a productivity seeking policy which, as evidenced through previous policies has led to harmful levels of intensification, biodiversity loss and the consequent ‘lock-in’ of farmers on a productivity-debt cycle.

The last few decades have raised the profile of co-benefits which focuses on raising levels of natural capital whilst also supporting productivity growth. Such approaches include integrated pest management and minimum tillage approaches which are the growing focus of European policy makers.

Understanding the ambitions of Scottish agricultural policy and clarifying these visions for the future would allow more targeted and cost-effective interventions in boosting productivity growth for the coming decades. Ultimately, therefore, the problem for Scottish agriculture is how to intervene and how to prioritise the reasons for Government intervention into this sector. This is more prevalent now as wider social goals are demanded of agriculture, as well as pressures on maintaining competitiveness in a post-Brexit landscape.

Table E2. Summary tables of approaches available to uplift productivity for Scottish agriculture

Productivity driver	**Policy Instrument**	**Justification**	**Is it feasible for Scotland?**	**Estimated scale of public expense**	**Estimated scale of productivity benefit for industry**
Market forces	Reduction in Direct payments	Most studies find a negative relationship between support payments and productivity. Reduced direct support may stimulate an uplift in productivity.	Complete removal of direct payments is not suggested for Scotland given the limited scope for marked productivity improvement across much of the country (88% of Scottish land is Less Favoured Area). For example, where subsidies are removed, on average, in the period 2017-2018, LFA sheep farms in Scotland would make a loss of £27,400 (Scottish Government, 2019). Direct payments are WTO green box eligible. Improved response to market signals is critical to lifting productivity in heavily supported sectors. The impacts of more reliance on market mechanisms would depend on the level at which area payments are set. Farmers would be more exposed to market fluctuations and would therefore need improved risk management practices.	Cost Saving	High in productive areas.
	Lowering area support to reduce asset values, helping to engineer a reallocation of resources (into larger individual units)	Research has shown that large farms are better adopters of new technologies because of the scale needed for many new technologies, suggesting that amalgamation helps	Any benefits of improved productivity would have to be set against the potential "middling out" of Scottish agriculture and its social consequences, which may be politically unattractive. For example, impacts on crofting areas. Also, a recent examination of Scottish agriculture by business size suggests that in terms of an average Scottish farm (by farm type) is misleading. That is, a small proportion of Scottish farms occupy a relatively large share of the area farmed and account for most of the Scottish farm output.		

		lift productivity.			
R&D	Increased funding into research that facilitates better productivity	Knowledge is a public good. Improved targeting of funding to support commercial and pre-competitive applied research and development would lead to longer term productivity improvements	Government funding of productivity related R&D effectively ended in the 1980's as it was deemed "near market" and was the responsibility of industry and producer levy funding. Recent research by the USDA suggests that the change adversely affected UK productivity growth. Recognition of the failure of the 1980's funding model was the rationale for the UK Government investing £150m via the 2013 Agri-Tech Strategy which established four Agri-Tech Centres. Significant demands for meeting climate targets may support applied research that delivers private and environmental benefits ('win-win').	Marginal Increase / Refocus in R&D Budget	High across the sector.
Education of next farming generation	Increase applied, practical & targeted productivity through Further Education / apprenticeship / work-based learning schemes.	Support for skills-based training for school/college leavers focuses on applied skills for productivity growth.	Some countries have highly regarded apprenticeship schemes which relate to improving labour productivity. The shared apprenticeship schemes in the North East of Scotland illustrate what can be achieved. Within Scotland the mandate for work based and skills-based training in rural sectors could be better targeted at particular farming systems and types.	Raise / reallocate education budget towards rural productivity	High. Dependant on ease of entry into farming industry
	Increase applied and practical productivity training and knowledge through	Offering applied skills based training at HNC, HND and Degree level to provide competencies in agricultural related topics would lead to	More practical elements within Scottish HE provisions for agriculture, engineering and horticulture. Support for advancement of more technical advanced courses could engage a wider spectrum of students to focus on productivity interventions, such as precision farming and spatial data analysis.	Raise funding for FE and HE sector	Medium – but offers long-term impacts.

	Further and Higher Education programmes.	medium term-productivity improvements through training of the next generation of scientists, farmers and consultants			
Farmer training	Introduce a lifelong learning / CPD support scheme	A fund which incentivises a demand driven approach to knowledge should lead to more uptake of approaches which raise productivity, given the needs based criteria.	Whilst compliance training (e.g. chemical spraying), is currently driven by a legal requirement there are opportunities for increasing engagement in training through innovative financing. This could also be acceptable under WTO Green Box rules.	High - Dependant on eligibility.	Medium – but offers long-term impacts.
Technology transfer	Support for an Extension service	Raising awareness of contemporary knowledge and technologies would improve longer-term farmer planning and encourage increased productivity. Needs framed in global challenges relating to climate change and food security	Under the SRDP the Farm Advisory Service does help provide farmers with advice that lifts productivity (e.g. web based resources and tools, support for new entrants). Support for productivity as a co-benefit to reducing GhG's or enhancing biodiversity may be a further route justified under WTO to increase farm advice provision. Improved translation of research and development findings (e.g. through Strategic Research Programmes by SEFARI institutes / Agri-tech, etc.) through extension should be achievable.	High	Medium - dependant on how advice is adopted
	Monitor farms	Monitor farms are based on the concept of peer-to-peer learning and demonstration which have been found to	Qualitative evaluations have inferred greater social support and opportunities for engaging in novel practices. These are widely used in Scotland for 20 years and funded via a combination of producer levy funding and SRDP CAP funding.	Low	Medium - dependant on level of participation

		be a more cost-effective route to transfer for participants.	Can help to facilitate adoption of best practice - application of techniques and technologies observed at Monitor farm events.		
	Smart farms	Public support for Smart farms for trialling future technologies allows economies of scale and capacity issues to be overcome and feasibility of application at farm level.	A number of countries adopt Smart Farms. Scotland's remote regions require digital engagement. SRUC's Kirkton upland farm has explored options for adoption of sensing technologies as well as plans for Barony for Dairying. This could be extended to other farm types and regions through engagement with industry and HEI sector.	Low Cost (usually with private partnerships)	Medium - dependant on level of participation
	Privately funded demonstration farms	Aim to demonstrate best or next practice in a strictly commercial setting. Similarly justified through peer-to-peer learning.	Demonstration farms in Ireland and New Zealand are relatively new and untested with respect to the link to improve productivity. They are generally funded through commercial interests. Agri-EPI satellite farm network (UK-wide including Scotland) have been established to test and demonstrate new technologies.	No Cost	Medium - dependant on level of participation
Financing	Grants	Support for adoption of new technologies and practices requiring expensive equipment. This mitigates some of the risk incurred around long pay back times.	Recent UK history demonstrates that productivity can be improved through grants. However, whether this applies to Scotland's current situation and is eligible under WTO rules is debatable. Grants would probably have to focus on productivity as an additional benefit, such as animal health and support for eco-systems (as Defra's Countryside Productivity Small Grant Scheme does)	Depends on level of capital grant.	High - allows replacement of older machinery and land improvements
		Support supply chains to adopt new technologies and adoption of practices. This would allow	Scotland already intervenes through 'Knowledge Transfer and Innovation Fund' schemes. This gives part or whole support funding. Shared private/public funding mechanisms offer a reduction in public expenditure but also lead to more adoption through industry engagement and design.	Low (usually shared with private sector)	High

		better horizontal integration and lead to reductions in waste and, hence per unit efficiency.	The Rural Innovation Support Service is an example of a support mechanism to facilitate collaborative innovation investigations and adoptions. Expansion of this scheme may allow greater co-ordination along the supply chain with, ultimately improvements in productivity. In addition, the application process is rigorous to demonstrate value of project, targets, phasing and monitoring.		
	Risk Management – Forward Contracts	Allow farmers to manage price received over an extended period, bringing some certainty to income levels. Improves resilience of business and viewed as a key business strength by banking sector. Benefits of greater access to credit and investment resulting in business productivity improvements.	Clear and transparent pricing mechanisms required based on futures markets – UK exit of EU likely to impact on futures markets due to market changes.	Potentially high (dependant on severity of market fluctuations)	Medium – awareness of secure price may lead to improved investment
	Loans	Loans incur more responsibility within the recipient and requires payback. The higher governance level may create more willingness to succeed within the applicant.	Other countries utilise this approach (e.g. Australia's Farm Investment Loans) Scotland has some experience within the recent SRDP for New Entrants and Young Farmers however there is no evaluation of its effectiveness. Expansion of loans to other sectors may allow more self-selection of projects for funding from a demand led perspective.	Depends on level of capital grant.	High - allows replacement of older machinery and land improvements

National programmes	National recording of livestock tracking Disease control and eradication	Livestock traceability allows efficiency benefits by controlling/reporting disease incidence within the national flock or herd. Scotland is a leader in national animal health programmes.	In Scotland schemes for Sheep, Cattle and Pigs are in place. Engagement will be a management tool for improving efficiency (exploiting EID digital technology). Bovine EID may provide useful management tools for farmers upon adoptions Extension to the industry allows improving farm performance and supply chain management to minimise waste.	High	Medium – additional benefit if it influences decisions
Regulatory Changes	Land Ownership and Rights	Changing ownership and use of land provides opportunities for current businesses to expand. Joint Venture Farming Government backed retirement schemes	In some countries (e.g. Ireland) opportunities for exploring tax-relief systems have engendered more land to be available for short to medium term lets. This comes at a cost to revenues but may create uplifts in productivity. Benefit to new entrants – potentially raising productivity through new entrants taking on land made available by older farmers, without a successor, who may be under-utilising land. Lack of on-farm retirement housing barrier to succession on Scottish farms. Planning exemptions for new development for retirement housing for farmers previously used by some Planning Authorities in Scotland.	High - loss of tax revenues	Medium – dependant on land available and number of innovative new entrants
	Genetic engineering	Adaptive routes to sustainable management may need to be highly technological. This should not preclude other routes, e.g. managing natural capital to uplift productivity.	Currently unfeasible under present day regulation but Scotland has world leading animal science research. New synthetic biology technologies like gene editing may lead to opportunities to better target productivity in the coming decades.	Medium	Unknown – in field testing is limited due to legal restrictions

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1.0 Introduction

Agricultural policy intervention has, for a number of decades, focused on raising the level of productivity within the industry. This is a means to minimise the environmental impact, and support competitiveness and economic growth within the industry. Productivity indicates the rate at which inputs are converted to outputs and reflects the level of technology adoption and best practice within the industry. This ultimately indicates resilience to changes in market conditions or fluctuations in weather.

Productivity can be measured as a full or partial indicator. Partial productivity is measured through output per ha of land or per labour unit. These partial indicators are useful to reflect the relative change in capital, labour or land use over time. On the other hand, Total factor productivity (TFP), is a single metric which combines all measurable inputs and outputs, as well as prices and costs, to provide a fuller measure of change over time (Fuglie, 2012).

Scottish agriculture is faced with varying levels of biophysical and climatic challenges. Around 88% of agricultural land in Scotland is classified as Less Favoured Area and conducted in some of the most remote rural areas within Europe. Faced with these barriers, both the costs of production are higher, and yields are reduced from naturally occurring weather and land related constraints. Accordingly, these areas, whilst not productive themselves, do have examples of best practice that could inform a wider social and environmental agenda.

The purpose of this report is two-fold:

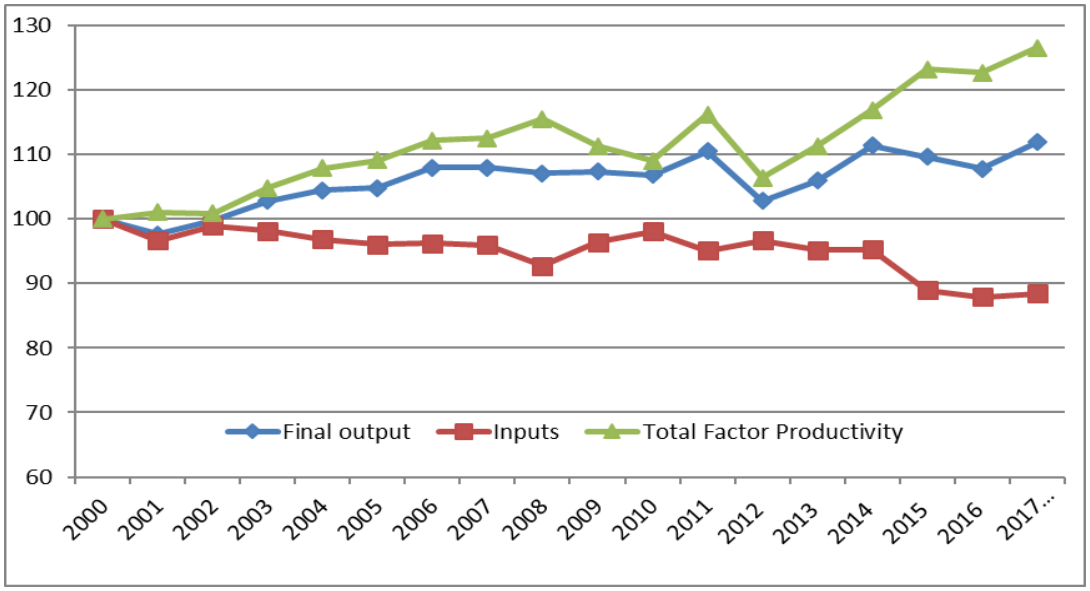
i) to understand the current efficiency of Scottish agricultural sectors, and

ii) to outline key interventions that could be used to support productivity growth in Scottish agriculture.

2.0 Productivity growth in Scottish agriculture

Figure 1 shows the rate of growth in total factor productivity for agriculture in Scotland, as measured by RESAS.

Figure 1. Total Factor Productivity of Scottish Agriculture (2000=100)



Source: ERSA (2017)

On average, the growth in TFP over the whole period equates to 1.5% per annum, driven by a fall in inputs 0f 0.7% per annum, and a similar lift in output growth of 0.7% per annum. Table 1 shows the average rates of growth in TFP over selected periods.

Table 1. Average Rates of Annual Growth

Period	Average Annual Growth Rate
2000-2005	1.75%
2006-2010	0.04%
2011-2015	2.28%

This table shows significant perturbations in annual rates of growth. Whilst still positive, the period 2006 to 2010 covers restructuring of the industry immediately after the introduction of decoupled support for most sectors[2]. Weather and market pressures are also evident in the 2009/10-2012/3 period but since that time TFP has grown on average at a rate of 1.6% per annum. This is driven by a range of factors, including changes in climate but also changing scale of the enterprises and loss of investment into research, development and extension.

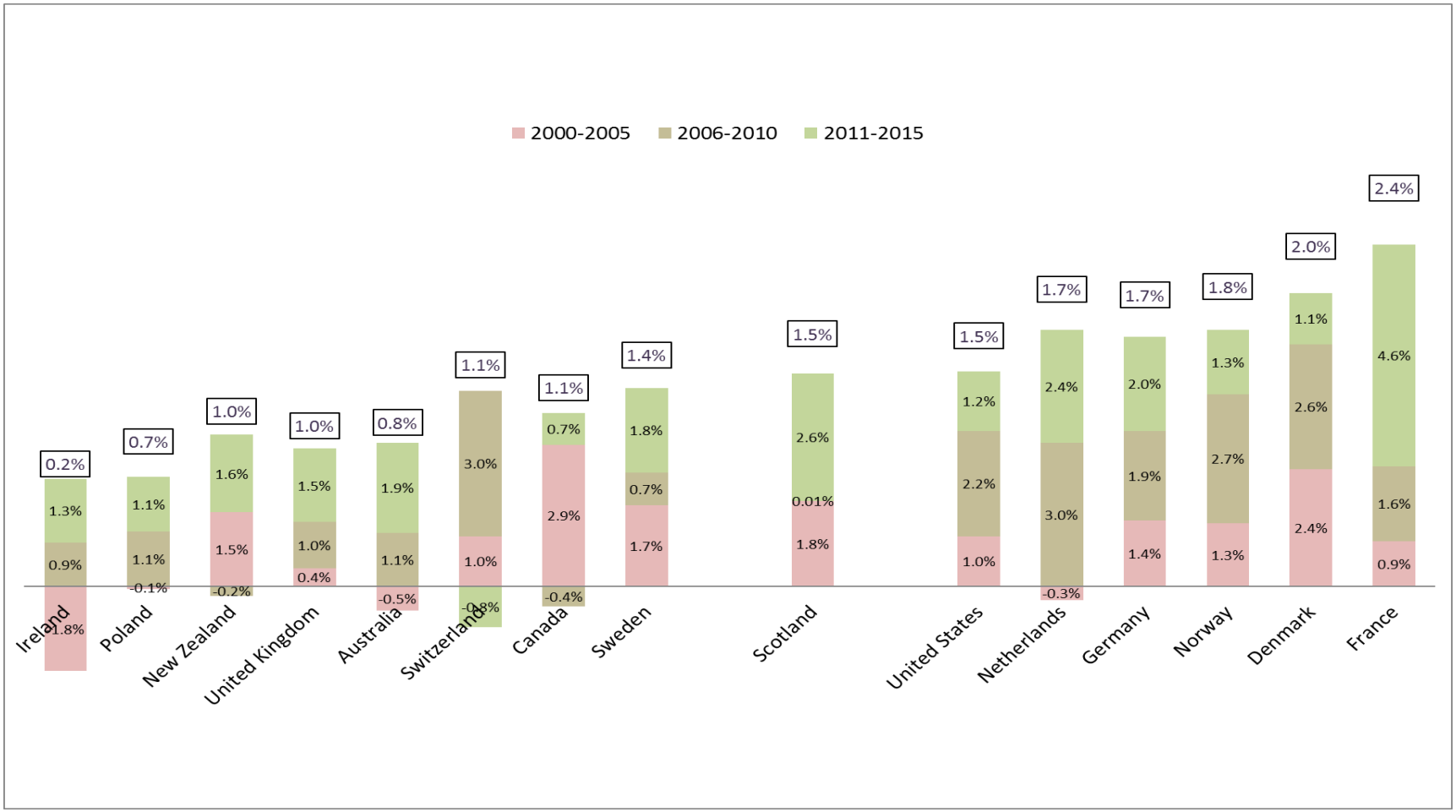
Comparative Analysis of TFP

Fuglie (2012) produced an ambitious agenda for collating TFP indices using a variety of data to compare countries. This has been further extended by USDA and provides a common metric for understanding growth rates. Figure 2 shows the annual average growth rates for selected comparator countries over the same periods (aside from the latter period which only extends to 2015). Scotland is only represented at the UK level so consequently we used the data collected under the Economic Report for Scottish Agriculture to compare growth rates. This must be used with caution, as USDA's and Scottish Government's methodologies and data resolution are different. Nevertheless, they do allow some comparison of trends in growth over discrete periods.

Overall rates of annual growth are shown in the boxes above the bars and show an increase from 0.4% for Ireland to 2.5% for France. More importantly it shows Scotland as a middle growth country. However, this mostly emerges from growth in the post-2010 period and shows minimal growth in the 2006-2010 period. Moreover, by splitting into time periods it reveals the great diversity in growth over these discrete periods. For most countries their highest growth period has been in the post-2010 period. This effectively relates to stable growth within the global economy.

[2] The Beef sector remained coupled to production with the Scottish Beef Calf Scheme

Figure 2. TFP Average Annual Growth rates for selected countries and time periods, 2000-2015



Source: Author's composition based on USDA (2017) and ERSA (2017)

Efficiency of Scottish Agricultural Farms

Whereas TFP offers a national level measure of growth, a small number of studies have focused on the efficiency of individual farms within Scotland. These studies tend to use micro level farm business data to estimate the ranges of inefficiency across a sector. Barnes *et al.* (2010) compared efficiency performance between different UK and EU regions. The report found that Scotland performed well against the UK average with high average technical efficiencies for lowland grazing and dairy farms.

More recently Barnes (2017) extended the series from 1989 to 2016 and focused on resource efficiency for a range of sectors in Scotland. Apportioning these by time period, to reflect policy changes over the period, he found differences in the mean efficiency of the sectors explored but also wide variances in the efficiency levels within each sector. The greatest variances were for livestock farms in Less Favoured Areas which he attributed to the challenges in production faced by these producers in these areas.

Drivers of Productivity growth

The studies mentioned above also examined a range of explanatory factors for understanding divergence in performance between enterprises. Barnes (2017) found for Scotland:

- The effect of subsidy on efficiencies vary between farm type, with positive impacts in cereals and mixed farming but negative for most other sectors.
- The higher the level of specialist education the more likely they are to be technically efficient.
- Older farmers in livestock farms tended to be more efficient than younger farmers, which may be a proxy for experience. However, for some farms this variable was insignificant.
- Changeover of business (proxied through identifying a successor) has a positive effect on mixed farming but was not significant for other sectors.
- The level of productive land is positively related to technical efficiency for a number of farms, whereas increasing LFA area has a negative area.
- Altitude had a negative influence on the efficiency of sheep farms. Hence, there are limits to how much change could be expected from farms with these biophysical constraints.
- CAP Policy reforms were tested and found to have a mixed effect on the sectors. The MacSharry reforms in 1993 had no significant effect on efficiency in cereals but a negative effect on general cropping. Moreover, the reforms had a positive impact on LFA farms. Similarly, decoupling through the Fischler reforms (in 2003) had no significant effect for most farm types, aside from dairy where it was positive and for mixed farms where it had a negative effect.

3.0. Economic efficiency of Scottish agricultural sectors

In order to measure the current efficiency of Scottish agriculture we apply the farm business survey data to assess the '*economic efficiency'* of each of the main farm sectors. The farm business survey data collects individual data on farm businesses over a number of time periods. This gives information on the inputs, which were grouped into materials (reflecting crop and livestock variable inputs), capital (which is reflective of investment in buildings and

machinery), labour inputs (including at the minimum standard agricultural wage rate for the costs of family inputs), and land area and rental values. From these we can estimate technical efficiency (the rate of physical output to physical input) and allocative efficiency (the rate at which costs are minimized to create revenues). When multiplied together this gives an indicator named '*economic efficiency'.* This provides an analogue to TFP but allows us to measure at a sectoral level. The table below show the growth rates for cropping and livestock types[3].

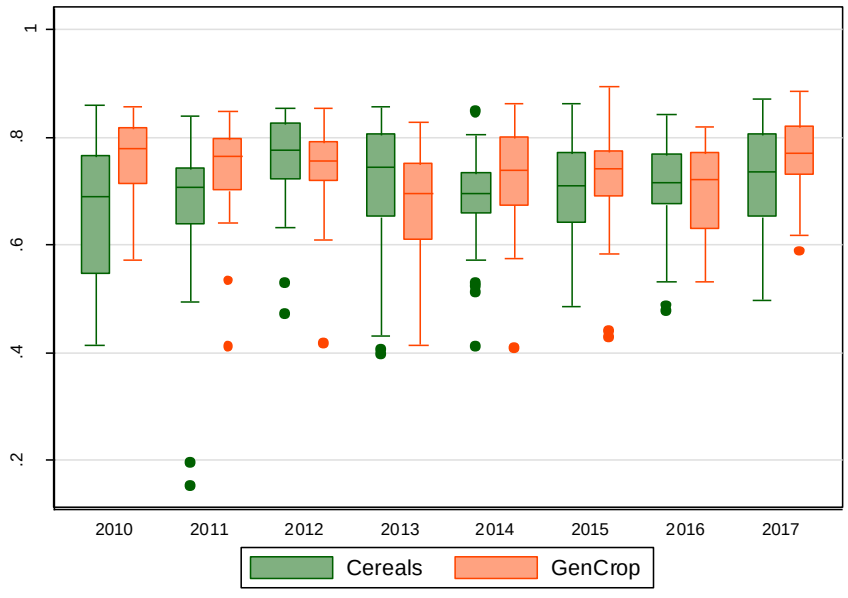
Table 2. Average Annual Rates of Growth for each farm type using Farm Business Survey data

	Cereals	LFA Cattle and Sheep	General Cropping	LFA Sheep	LFA Cattle	Dairy
2000-2005	-0.2%	-0.2%	-0.7%	0.4%	0.1%	-0.1%
2006-2010	-1.4%	0.9%	1.0%	0.6%	0.1%	1.3%
2011-2017	1.2%	-0.3%	0.7%	-0.1%	-0.8%	-2.1%

A diversity of performance is observed across these farm types and time periods with low or negative annual rates of change identified in most sectors. These generally show vulnerabilities to market conditions, including exchange rate fluctuations, as well as uncertainty from weather and policy changes. Taking this sectoral approach, although from a small sample of the farming population, dampens some of the growth rates identified in the aggregate TFP measure.

Examining at individual farm business level also identifies the range of performance observed in the results. The figures below are box plots which show the median and the range of efficiency observed over time periods, with efficiency closer to 1 indicating higher levels of efficiency.

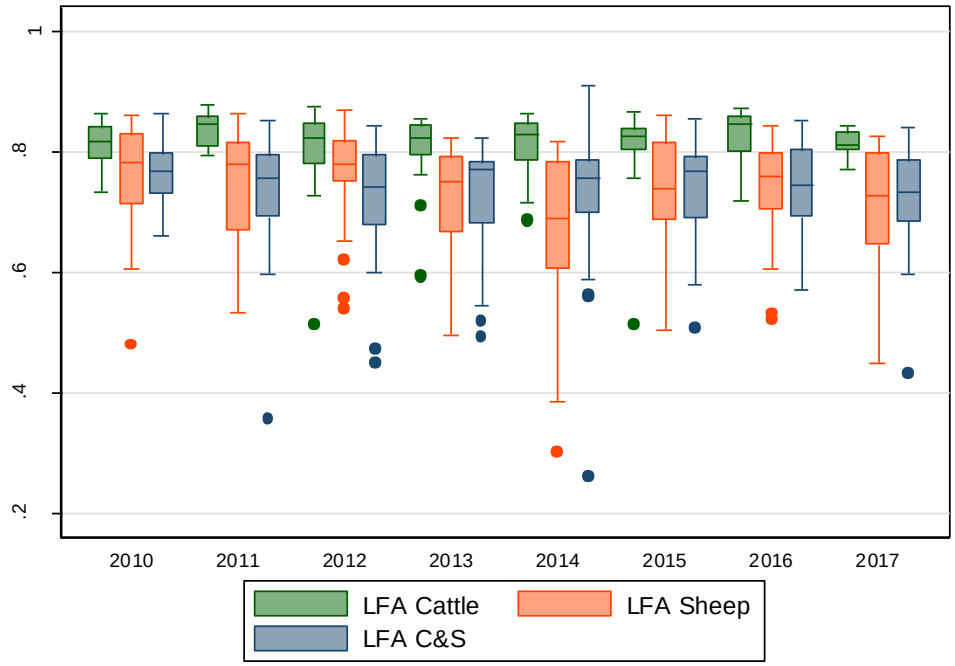
Figure 3. Box plot of Economic Efficiencies for mostly cropping farm types, 2010-2017



[3] These are measured as a Fischer Index to match the calculation of aggregate TFP within the Economic Report on Scottish Agriculture.

The variances show the range of performance within Cereals and General Cropping farms, with Cereals showing the most volatility, potentially due to their specialisation within specific crops and vulnerability to global market prices and weather variances.

Figure 4. Box plot of Economic Efficiencies for mostly LFA livestock farm types, 2010-2017



Large variances are also observed for the LFA Sheep farming systems, which again show disturbances from weather but also policy reform, as these sectors are heavily reliant on subsidy systems.

Summary

- Scottish productivity is generally positive and ranks well against comparator countries. Though some caution is needed over measurement and data issues between countries.
- Nevertheless, TFP is positive and has tended to increase at a higher rate from 2010 onward.
- Sectorally, these rates are less positive which reveals the divergence of performance both across farm types but also within farm types.
- All sectors reveal turbulence over time. More pertinently, the distribution of efficiencies for these farms tend to show a number with low efficiency levels. This indicates there are low performing farms in all main farming sectors in Scotland.

The next section examines the instruments that could raise productivity rates. It outlines examples of the efficacy in which some farms may be able to raise their performance to best practice.

4.0. Key measures and policies to boost productivity growth in Scottish Agriculture

Farmers can improve their productivity by: i) adopting new technologies, ii) changing the size of their businesses, or iii) changing the input-output mix.

This highlights the role of both micro level drivers, e.g. business ability and the will to change, along with a macro-economic environment, which encourages change. For brevity, these can be seen as:

- *policy interventions*, such as support for change and provision of advice, education and research engagement for change;
- *technological* interventions, such as adoption of new technologies or techniques, or applying alternative approaches to uplift productivity;
- *management interventions*, which include farmer decision making and farm planning in terms of the ability to switch the mix of inputs and outputs, or increase in scale; and
- *adoption of best practice*, which would minimise the range of performance by farmer adoption of current practices and approaches that would increase economic or technical efficiency.

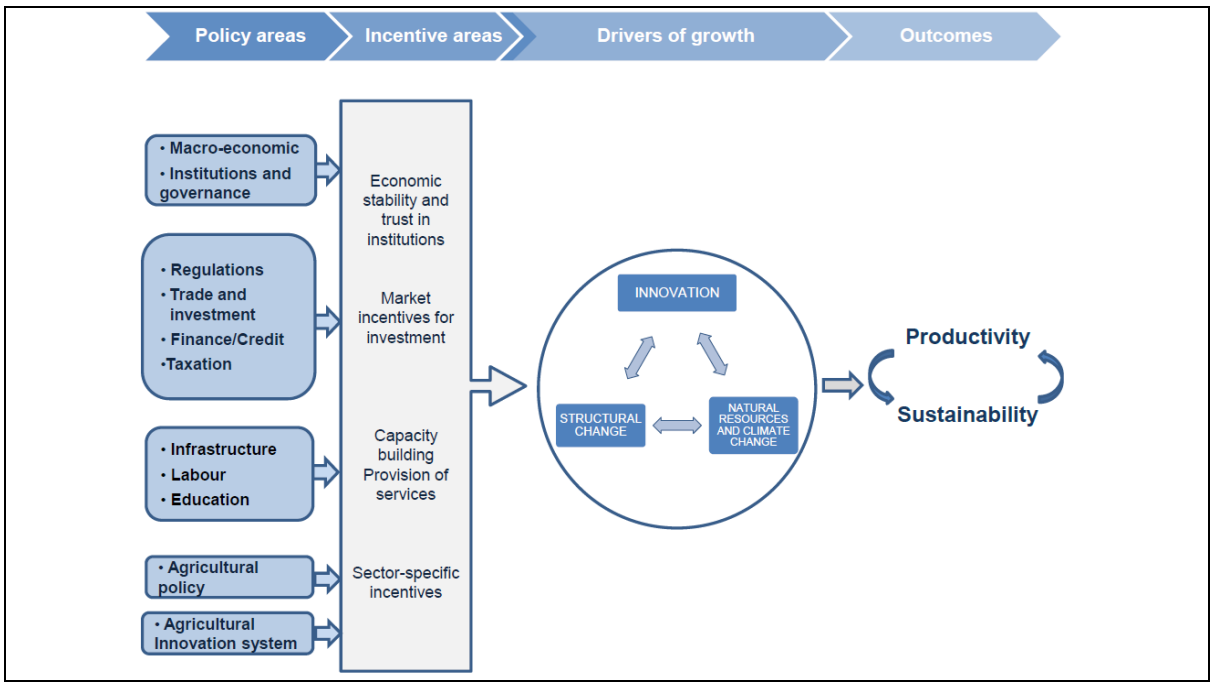
Policy Interventions and their effect on raising productivity

The OECD (2015) provided a conceptual model for understanding the routes for how 'policy' affects productivity growth (Fig 5). It presents the range of macro-economic tools, which would have a favourable influence on productivity growth. Fiscal tools are also pertinent as this may lead to increased investment in high cost technologies, support the development of land to improve capital assets and provide the basis for more positive risk-taking behaviour.

Similarly, infrastructure has been found to improve productivity, through support of networks for advice and supply of machinery and materials. Also, pertinent, and explored previously in studies, is the role of agricultural policy and subsidy support. Finally, within each country the agricultural innovation system (public advice, research, farmer skills and creation of industry led research) are different. These have been found to have varying degrees of influence within agricultural productivity.

Accordingly, sector specific policies have an influence, but also interventions which affect the wider economy, such as the labour market or infrastructural support, will also indirectly lead to raising productivity in the agricultural sector. Those interventions that have had some degree of investigation are demonstration and advice, the role of subsidies and regulation and directed grants or financial loans.

Figure 5. How policy influences productivity and sustainability



Source: OECD (2015)

Research and Development

Government funding of research and development (R&D) has underpinned productivity growth for over half a century. Assessments of the economic costs and benefits finds high rates of return and provide a strong justification for continued support. Indeed, reductions in funding from applied, or 'near-market', research in the UK led to a loss in productivity growth rates in the 1990s. Nevertheless, other countries which experienced similar cuts, such as the Netherlands, managed to sustain their productivity growth levels. Hence, whilst funding R&D is an important driver of productivity growth, the strategic focus and the institutions around R&D are just as important. Increasing commercial funding and joint partnership initiatives have, it has been argued, increased the market focus of applied research and thus increased greater uptake of technologies and techniques. This may be the fundamental driver behind the UK Government's £150 million Agri-Tech strategy which provides capital for encouraging private sector initiatives in crop health, livestock, benchmarking and metrics, as well as precision agriculture. Accordingly, increasing rates of investment may be justified with respect to the return on productivity but needs to be strategically focused towards commercialised outcomes to enable growth.

Demonstration and Advice

A common finding in applied productivity studies is that engagement with farmer advisory networks and information sharing groups tends to have a positive effect on productivity. There are different components of advisory engagement. Current interventions in Scotland include the Farm Advisory Service, sector specific interventions such as the Beef Efficiency Scheme and the Cereals/Potatoes in Practice events and monitor and demonstration farms.

Farm Advisory Service

Evaluations of the role of advice on productivity can be traced back to work in the US in the 1970s, finding high rates of return from public investment in applied advice. Thirtle et al., (2003) argued that the privatization of extension by the UK government in the 1980s and,

consequently the loss of 'free' advice to farmers was a key reason for the UK's poor productivity growth for the past 30 years.

The Farm Advisory Service is a component of the Scottish Rural Development Programme, with the aim of offering free advice and a range of specialist services around farming production, conservation and woodland management as well as training for advisors. In its third year, a full evaluation of the effects on the agricultural economy has not been conducted as yet, but a recent annual report stated:

> '*It is clear that those who take up the advice find it to be of a high quality and really worthwhile to their business. This is supported by our experience of farmers who we have approached to take part in case studies. We have found real advocates, keen to share their good experiences with peer farmers.*'

A number of reviews have argued that investment in extension and provision of information is a public good when targeted at low-income group farmers and this has led to uplifts in productivity and profitability. However, these studies tend to be rather general with limited context to Scotland. Another criticism of these studies is that they rely on long historic time frames and do not accommodate the full influences of agricultural policy change.

A recent study of Scottish advisory networks has highlighted that there tends to be a proportion of farmers – around 20% - with the potential for a greater need for advice who are not currently accessing advisory services (Prager et al, 2015). Initiatives to reach these farmers would be beneficial in ensuring that farmers are managing their businesses productively regarding, e.g. fertiliser inputs, adhering to Cross Compliance rules and limiting waste. Advice on diversification opportunities that could improve productivity, including legally permitted development initiatives, was also highlighted by these authors.

Farmer Discussion Groups

There is a relative wealth of evaluation on farmer discussion groups. In Ireland both dairy and beef farming have been widely studied (Hennessy and Heanue, 2012). Evaluation of the Beef Technology Adoption Programme (BTAP) in Ireland may be analogous to the Beef Efficiency Scheme. The aim is to improve innovation levels in cattle farmers. A financial payment is offered for completing programme tasks. However, Läpple and Hennessy (2015a) indicated that farmers that joined a discussion group programme after the introduction of a financial incentive showed no significant improvement in economic performance. This contrasts with the dairy discussion groups where there was a perceived uplift in performance. They argued this effect may be context specific and suggested that further work on the means for intervention, i.e. the advice offered and farmers targeted, requires a more nuanced study.

Support for Farmer Learning

Improving the educational attainment of the farming population will lift the productivity of the industry. Likewise, the participation in education of not only the next generation of farmers but also the "continuous improvement" of the current farming population, whatever their age will be beneficial. Some EU countries strongly incentivize education and training by linking support and grants to completing a formal qualification or apprenticeships.

Recent work in New Zealand suggests that farmers vary in their capacity to take up new ideas and technologies. Their ability to learn, or "absorptive capacity", is influenced by personal factors like age, education and networks, plus economic drivers, such as farm type, profitability, cash flow and balance sheet strength. A more immediate solution is to change the way ideas are communicated to match the learning ability of the farmer. A recent major

New Zealand project, the Red Meat Profit Partnership (RMPP), has segmented farmers based on how they learn so that the best extension method can be deployed.

Cost is a factor in the adoption of new technology and new ways of working. Yet Scottish farmers receive free or low-cost knowledge transfer programmes, i.e. Farm Advisory Service. An alternative or complement to this may be to change the funding mechanism by giving the farmer a "fund" to spend on the training and advice they value. Such demand driven schemes are exemplified by the lifelong learning scheme available to all Singaporeans, a scheme considered central to the country's high productivity. Significantly, the original Land Management Options scheme which closed in 2016 included a fund for training element, so Scotland has some experience with such funding.

Monitor and Demonstration Farms

The reduction in the funding of near market research and extension by the UK government was most stark in England, where these became the domain of producer levy-based R&D and ADAS the main provider of advice was effectively privatised. The network of Experimental Husbandry Farms (EHFs) that turned research and development (R&D) into best practice were also closed.

Though Scotland did not close its "college farms" (equivalents to EHFs), their focus did change as funding shifted away to 'public good' outcomes. Notably, the Irish Republic maintained an R&D-extension model (under Teagasc) close to the post-war England and Wales model with the focus still largely on driving industry productivity.

Three alternative demonstration models have emerged over the last 30 years to help promote best practice.

1. The monitor farm model using real commercial farms for trialling and disseminating best practice arose after the New Zealand government privatised its R&D-extension model in the 1980's. The model was brought to Scotland in the 1990's. A qualitative evaluation of 18 Scottish Monitor Farms in 2014 (Malcolm Watson Consulting, 2014) found that:

    - The Monitor Farm Projects have been successful in introducing improved farming practice and improved farm enterprise for those who participated;
    - The Monitor Farm model is effective in driving changes in farming practice amongst active participants;
    - 93% (17) Monitor Farmers stated that their project helped improve productivity and 85% (15) reported that they had reduced costs through more efficient use of key inputs.

    The report concluded that participation in Monitor Farm projects results in a reduction in costs and improvements in productivity amongst active farmers. These changes are likely to contribute to improved profitability, which will assist in sustaining farm enterprises and farm businesses. However, this evaluation was qualitative and did not attempt to measure productivity or profitability improvement on participating farms, before and after their involvement. The problem of enabling a full evaluation of quantifiable success has been partially addressed in the current monitor farm programme, by getting all participating farmers to formally benchmark their businesses.

2. Demonstration farms are run by employed managers and staff on commercial grounds, their remit is to apply best (or next best) practice to achieve high profitability. The only demonstration farm currently in Scotland is in Deeside, Aberdeenshire, with more of a focus on wildlife conservation. In New Zealand, the South Island Dairy Development Centre runs two dairy farms. In addition, Tullamore Farm was recently established by

the Irish Farmers Journal to demonstrate best practice in a commercial setting. Irish processor Dawn Meats set up Newford Farm in 2015 to blueprint suckler beef production.

3. Smart farms, which do not currently exist in Scotland, are typically less commercial, focusing more on cutting edge technology controlled by researchers and teachers. The University of New England's smart farm in Australia is financed by the Australian Government to trial and disseminate sustainable practices on commercial farms and is close to the monitor farm model. An extension of the farm scale models considered above is the economy wide project in Tasmania to exploit digital and communication technology. The Sense-T project being developed aims to draw together farm, weather and environmental data in real time to improve the sustainability and competitiveness of Tasmanian agriculture.

Closer to home, the UK Agri-Tech Strategy (funded by the Department of Business, Energy and Industrial Strategy) established four joint public-private initiative 'Agri-Tech' centres. Of these, the Agri-Epi centre has developed a 'satellite farm' network which are real farms used as a 'test bed' for technological development in precision agriculture, measuring variances in production to raise productivity and efficiency in the sector. At the farm level, SRUC's Kirkton mountain farm in Crianlariach also has a current project looking at capturing environmental data that will aid farmer decision-making. Few studies have focused on the evaluation of demonstration farms in developed country contexts. In developing countries, these have been found to raise income and productivity, though the benefits may be more diffuse within high income farming systems.

Reduction in direct support

Most studies find a negative relationship between subsidies and productivity. Generally, the higher the farm level subsidy received leads to lower efficiency or productivity. In a meta-analysis of studies, Minviel and Latruffe (2017) found that the effect was mostly negative. They argued that subsidies may reduce farmers' effort and change their attitude to risk-taking; on the other hand, subsidies may help farmers overcome financial constraints that impede efficient restructuring or modernization, and thus may increase technical efficiency by improving the farm's productive capacity through replacement investment or net investment in advanced technologies. Moreover, subsidies tend to create barriers to entry to farming for new entrants who may have more innovative approaches.

The usual example of subsidy removal and effects on productivity is New Zealand, which reduced farm level support substantially in the 1980's and, after some structural adjustment saw a growth in TFP. Though this has dampened since 2000 (see Figure 1), removal of direct payments would be expected to hit the valuation of assets like land, as well as rebasing land rental values and livestock prices (e.g., store cattle prices) at lower levels. Similarly, Australia has had a period of deregulation and removal of support throughout the 80's and 90's. While the numbers of farms and farmers fell, it is mostly inefficient or smaller farmers which exit the industry and output is generally maintained by a more intensive farm base. However, these are context dependent as they reflect wider changes in the economic environment and the baseline sizes of these farms.

The effect of subsidies is context and time dependent. Within the CAP, the focus on output growth in the 1970's and early 1980's was overly successful. Farms grew bigger and staple cereals and livestock products were over-supplied. Since that time, a growing social and environmental dimension has emerged within the CAP and this may have diffused the impact on productivity growth or may coincide with plateauing of yields and farm size observed from the 1990's onwards.

Removal or reduction in direct support for farmers in Scotland would lead to significant restructuring in the industry. There are currently high levels of inequality when farming incomes are considered alone and the removal of support would lead to a number of consequences for farming households. Specifically, these households would withdraw from agricultural production and extend non-agricultural activity, or sell up land to other businesses. The full effect of removal is dependent on the management and ownership structure of the farm, as tenanted farmers will be more vulnerable than owner-occupied farmers. In order to reorient towards post-support some farms may focus onto commercial outcomes through intensification and expansion. Moreover, removal of support may lead to reduced pathways for regulating activities and behaviours which may be environmentally hazardous. Therefore, whilst difficult to unpick the response of removal of support this would lead to an overall uplift in industry productivity at a high social and environmental cost. This will occur unequally across the regions with the more remote regions – those upland farming systems – experiencing higher levels of restructuring.

Capital grants and loans

Generous capital grants were a key element of the 1947 Agriculture Act. This act boosted productivity mainly by lifting stocking rates through land development and modernisation and acquisition of new production equipment enabling technological development and economies of scale. However, studies within other economic sectors find both positive and negative relationships between investment support and productivity. Principally this is driven by the effect on risk perception to encourage investment behaviour and boost production efficiency. A negative effect was found in that capital grants may lead to 'crowding-out' of innovative capacity, where investments would have occurred anyway with less restrictions on what to invest in.

In agriculture, capital grants are WTO (green box) eligible, but only if used for environmental or animal welfare reasons. Hence, if capital grants were to be introduced, they must be targeted at supporting services but not productivity raising *per se*, such as preservation of natural capital, replacement of off-farm with on-farm inputs, and support diagnostics for animal welfare, e.g. blood tests, and smart technologies, such as GPS to better match fertilizer use to crop needs. While most grants cover upfront capital spending, perhaps a more useful use of grants is to reduce trading costs. For instance, the use of faecal egg counts (dung tests) to reduce wormer resistance is considered too expensive by many farmers and a hurdle to the use of this technology to improve animal welfare and boost productivity.

The grant aiding of projects aimed at improving co-operation and supply chain efficiency is also popular. The current SRDP includes a number of schemes that target improvement of "chain productivity". The UK government offered £20m through its Industrial Challenge Fund to revolutionise food production and lower its environmental impact. New Zealand's Primary Growth Partnership involved large-scale projects aimed at improving the competitiveness of their primary industries.

Finally, it should be highlighted that the tax system already incentivizes capital investment with allowances for plant and machinery being particularly notable. Commercial woodland is also treated very favourably by the current tax regime so it is important to design a grant scheme that is consistent with the tax system.

Capital Loans

There is a growing debate around the role of loans for capital. A study of Dutch agriculture examined the capital structure, namely the level of debt within the farming business, and

found that higher debt levels had a positive effect on productivity growth. The effect of a loan compared to a grant may encourage entrepreneurial capacity of the farmer in that it is necessary to use funding efficiently, since the loan must be paid back. Hence, the ancillary work around preparing investment plans, estimating full spend and return times may support a more business management led approach when compared to a grant. However, we would expect that a loan is still only eligible under WTO green box rules. Hence, activities requiring investment which support natural capital and not productivity may be the chief target of these loans.

The Scottish RDP has experience of loans to new entrants; however they involved a high level of administration and had questionable success. Any capital loan scheme would have to understand the large transaction of running such schemes, and factor these ancillary costs into any assessment of effectiveness.

Support for New Entrants

Farming is generally typified by high barriers to entry and support for new entrants has emerged as a viable intervention within farming policy in developed countries. The main arguments for supporting new entrants are that it allows more innovative thinking and provide fresh perspectives on farming and related diversification as they draw on networks and experience outside of agriculture. This could lead to more sustainable farming systems. A recent European Innovation Partnership discussion paper highlighted that new entrants have higher ICT skills and this may lead to higher agricultural productivity as information is accessed and decision-making tools identified and used, compared to traditional older farmers.

Schemes aimed at structural adjustment are WTO (green box) eligible and the current Scottish RDP does include initiatives aimed at getting new farmers into the industry. In Scotland young farmers (<41 years) can receive additional support through an uplift in Basic Payment Scheme (BPS) rates on the first 90 ha. This is conditional on them demonstrating a legal 51% share of farm business and a 25% share of farm capital as a means to give them a meaningful role in farm business' decision making.

In addition, Government-backed retirement schemes have been popular in other countries. One barrier to farm succession in Scotland is a lack of retiral housing on the farm; until parents move out of the farmhouse, they can be reluctant to retire. Easing planning restrictions to allow more retirement housing on the farm (perhaps conditional on early/timely retirement) could speed up the transition. Until recently, local councils in parts of Scotland (e.g. West Lothian Council) had made providing housing for retiring farmers one of the exceptions to new development in the countryside but this exception has now been removed.

Equity Farming

Limited evidence is available to assess the effect of 'Equity farming' or 'equity partnerships', which is a notable recent model that has been applied in Welsh dairy farming. This is defined as 'a joint business venture between two or more individuals who have come together to pool their capital and often their skills to enable the partners to obtain revenue and growth from their farm investment.'

Changing Tax Laws

For new entrants or expanding agricultural businesses, access to land is a major constraint. Often land is only available on short-term leases (<1yr) which sharply curtails the ability of

the farmer to raise finance and to justify investment in the land and capital equipment. This issue has been exacerbated by recent changes to land tenure legislation in Scotland, which have led to a withdrawal or reduction in the length of land leases offered by landowners of land available for rent. In the Republic of Ireland tax-relief was used to encourage longer term leasing. Income tax reliefs for longer leases were increased by 50% on:

- On 5 to 7-year leases tax relief on up to €18,000 p.a.
- On 7 to 10-year leases tax relief on up to €22,500 p.a.
- On leases over 15 years tax relief on up to €40,000 p.a.

This incurred a significant cost of €9.2m in 2014, prior to their introduction, and €13.9m in 2015. This led to an increase in long-term letting of agricultural land, with lets of over 5 years increasing by a third in 2015 alone. In the same year, 27% of tenants surveyed stated that they had started a new long-term lease.

Similar changes to the tax system could incentivise a similar shift within Scotland, encouraging the shift of land management from older farmers and farming investors who own the land to active and often younger farmers.

National Programmes for Disease Monitoring

Livestock farming is a significant economic tranche of Scottish agriculture. The management of disease within livestock is fundamentally important to sustaining productivity. Decreases in output reduction from poor animal health range from 12-75%, or in some cases loss of animals and subsequent costs of disposal and re-stocking. National programmes of disease control and eradication provide support for productivity through prevention and minimisation of these costs. Within Scotland schemes for livestock traceability are available for Sheep, Cattle and Pigs and these have the additional benefit of providing metrics for benchmarks and exploiting the technology around monitoring of livestock health and early warning of health issues. Moreover, further development of these schemes allows for leaner supply chain management and therefore reduces wastage offering increased efficiencies. Support for these schemes consequently has the effect of maintaining productivity but also, if enabled comprehensively, may help to raise productivity.

Technological Interventions for raising productivity

Implementing Established Technologies

It is important to stress that in Scotland there is generally a low uptake of current, mainstream technologies and techniques. For Scottish livestock farms, the better use of well-established feeding, breeding, health, marketing and budgeting practices should lift productivity and profitability on most farms, e.g. low uptake of sexed semen in dairy, sheep and beef sectors, limited rotational grazing practices, progeny tested sires and benchmarking and budgeting skills.

Arable Technologies

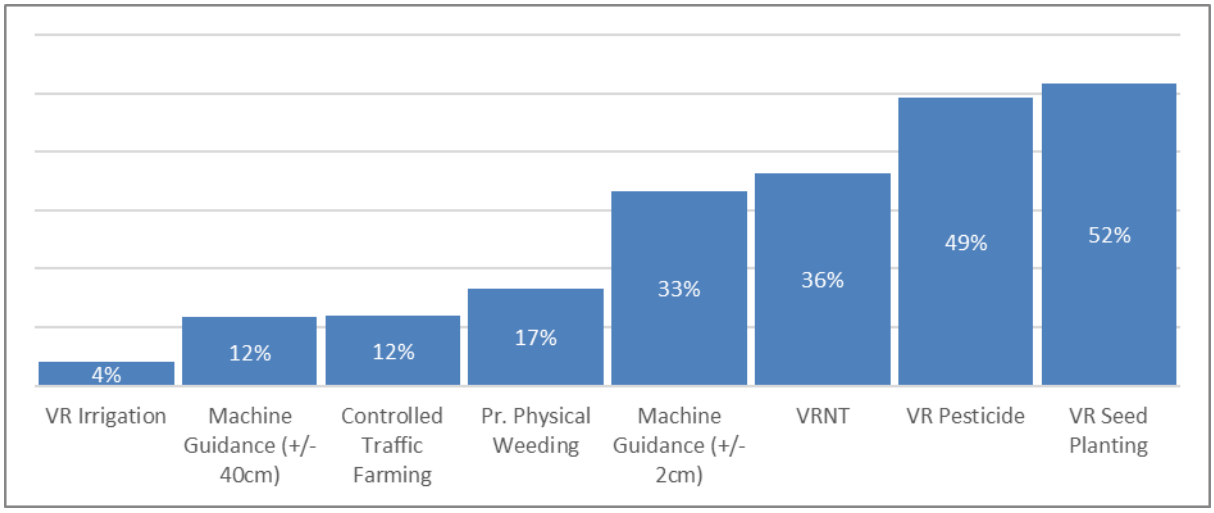
One of the main technologies to have potential to affect agricultural production in developed countries is the concept of SMART farming and interconnectivity of machinery with data gathering and analysis for decision making. Precision Agricultural Technologies (PATs) represent a suite of technologies and approaches that reduce variability at the field or herd level. This provides a holistic system approach to managing spatial and temporal variability

to increase profitability, optimize yield and quality, and reduce costs and environmental impact.

A SRUC survey of 239 cereals and potato producers in Eastern Scotland in 2017 identified the main PATs which were currently adopted and were intended to be adopted within their farming systems. The bulk of adoption is on machine guidance and variable rate systems. Both have been found, in multiple farm studies, to reduce fuel use and management time if used optimally. However, issues have been identified around the appropriate level of training of farmers to operate PATs needed to raise returns and productivity to noticeable levels (Barnes et al., 2018). In order to accommodate these training needs institutions such as Harper Adams University offer a professional course on precision agriculture aimed for farmers, co-sponsored by the National Farmers Union.

The intentions of farmers to uptake various PATs were ranked in terms of likelihood of adoption in 5-10 years' time.

Figure 6. Precision Agricultural Technologies: intentions to adopt in 5-10 years' time, percentage frequency



Source: Barnes and Eory (2017)

When ranked in terms of likelihood of adoption in 5-10 years' time, around half the farmers indicated they would adopt variable rate pesticide and seed planting technology.

Nutrient Management and Soil Nutrient Mapping

A key issue emerges around the testing and correction of soil pH. Changes in the prices of lime, and the subsequent costs of spreading machinery have now limited the amount of re-liming of land within Scotland. This approach has given promising results for yield but also has been found to have additional benefits in managing GhG emissions. The drop in liming activity in Scotland is a major cause for concern since correcting soil pH remains one of the most cost-effective management strategies available to growers. A focus on costs without an appreciation of benefits is felt to be one reason for some farmers cutting back their lime applications. This could also be a mechanism within Nutrient Management Planning (NMP), which is currently a voluntary initiative. Adopting NMPs will ultimately have a long-term effect on productivity as the level of input used to would decrease as soil organic matter and carbon are stabilised.

Improved Soil Management

Improving soil structure and organic matter can improve resilience of yields in time of drought and flood. There is still a tendency to over cultivate within Eastern Arable farms and farm trials have shown reduced cultivations can save money and improve yields. In some countries, moving to minimum or non-tillage systems brings further productivity improvements. Whilst there is ongoing work at the James Hutton Institute and on Monitor Farms, conclusions cannot be drawn as to the effect on productivity in Scotland. Reducing cultivation has important benefits in terms of reducing compaction and increasing water infiltration. This leads to greater retention of rainfall in a dry season and reduced water logging in a wet season; both benefitting crop yields and resilience in uncertain climatic environment. Poor soil structure can be equally damaging in grasslands as it is in arable production. Where soil structure is particularly poor it can halve the productivity of grassland to as little as 6-7t Dry Matter (DM) /ha from 9-14t DM/ha on sites with good soil structure (Jones, R., 2013). The quality of the pasture can also suffer leading to lower growth rates in grazing livestock. The use of PAT has an important role in reducing machinery traffic at a field level through accurate placement of tramlines and through the adoption of controlled traffic farming where machinery is restricted to specific areas.

Changing cereal yields and varietal uptake

A steady rise in crop yields had been an engine of productivity growth in Scotland. However, there is evidence of a plateau emerging in cereal yields (see Kightly et al., 2011). Crop trials are showing yield growth in staple Scottish crops but there seems to be a disjunct between trials and the observed yields on farm. A number of reasons can be identified but the more profitable innovative farmers are showing evidence of crop yield growth, whereas the majority are, at the average, not revealing clear evidence of this. Issues may be biophysical or technological: traits breeders are looking for have moved away from solely yield growth to encompass other traits, such as drought or water tolerance, lodging risk or variance in performance and end user requirements. Whilst supporting resilience these factors may not impact as directly as yield growth on productivity indicators.

The Scotch whisky distilling sector has introduced specific end use requirements for barley, which differ significantly from those of the wider brewing industry across the EU. Scotch whisky distillers now specify spring barley varieties that are non-expressive of compounds that can lead to the production of Glycosidic nitrile (non-GN) compounds (a potential carcinogen) during the distilling process. This is not an issue for brewing markets. Whilst barley breeders are now incorporating non-GN traits within their European breeding programme, the lower market size of Scotch whisky (~1.0mt pa) compared to EU brewing barley use (~10mt) naturally leads to less investment in this trait compared to brewing only varieties. As a result, the yield performance of distilling barley varieties has fallen behind those of brewing only varieties in UK trials impairing yield growth on farm in Scotland. On the other hand, this has led to a segmentation of the malting barley market in Europe with distilling barley production now largely restricted to Scotland and parts of England. Therefore, the premium for Scottish distilling barley varieties has risen (~10%) over that of English brewing varieties. Therefore, in terms of value generated per ha then Scottish barley growers have not necessarily fallen behind in financial output terms.

Livestock Technologies

Electronic Identification (EID)

Electronic Identification of sheep has been found to have a significant saving (of around 40% on farm trial sites) in labour use. EID kits including crates, so called wands for data collection, and data loggers have an initial high investment but have been found to payback over 5-10 years. An estimate on an actual hill farm, compared to test sites have still found to reduce labour use by a quarter (Morgan-Davies et al., 2018). Moreover, if EID were used in conjunction with training then some uplift in productivity would be expected in sheep farms in Scotland.

Estimated Breeding Values (EBVs) and pedigree recording

A series of studies in the Scottish context have found an average gain of around £3 per animal between a control animal versus a selected animal. There is a lead-in time for these technologies as all animals in a flock would need to be recorded and as rams with indexed values and EBVs are brought into the flock, there would be an expected uplift in productivity. Naturally, this could provide some support against the depressed values for sheep in the market and the high reliance on subsidy of most hill sheep farms.

According to the AHDB, selecting the right genetics within a sire can increase the profitability of a 50 cow suckler herd by £1,500 to £2,000 per annum. Moreover, a recent evaluation of the genetic gains of EBVs in the dairy sector argued for an estimated increase in value of around £0.5bn in the economic value of dairy stock purely from selective breeding using EBVs.

Robotic Milkers

Since their introduction in the 1990's, there has been steady growth in the number of farms adopting robotic milking within Europe. Rodenberg (2002) identified the ability to scale dairy enterprises as the main benefit of robotic milkers. Hence, estimates of economic or productivity benefits, for the US and Canada, were higher but dependent on the baseline size of the herd and the potential for growth. The need for trained staff to support and use the milkers at an optimal level was also identified.

Management changes to raise productivity

Widen the range of planted crops

Scotland has a very narrow climatic window to establish and harvest cereal and other crops and this tends to lead to higher machinery costs due to the high seasonal demand for combines and planting kit. Moreover, the scale and shape of fields in Scotland limit working operation time and efficiency. Accordingly, there are limits to how much Scottish agricultural productivity can compare with, say the South East of England or, further afield such as Ukraine. An option to manage this is to widen the range of crops planted, which would diffuse some of the intensity of the workload. Again, climatic conditions limit this range, but some growers are now exploring maturing differences in these crops. For instance, barley varieties such as Golden Promise and wheat varieties such as Cordiale can mature earlier, leading to lower labour and machinery costs by spreading workload.

Alternative input usage

Systems work looking at introducing a precision livestock farming approach to improve technical and economic performance in hill sheep farms showed that a precision livestock farming approach (PLF) approach has the potential to increase net margin per ewe per year by £3, compared to a more conventional management. This is mostly due to labour savings.

A targeted approach to sheep management using precision livestock farming showed that targeted worming of lambs meant a decrease of 40% in wormer input, without compromising lamb growth (Morgan-Davies, et al. 2017).

Changing business size

Australian research concludes that large farms are better adopters because of the scale needed for many new technologies, suggesting that amalgamation helps lift productivity. However, the benefits of improved productivity would have to be set against the potential "middling out" of Scottish agriculture and its social consequences, which may be politically unattractive. Also, while lowering area support to reduce asset values to help engineer a reallocation of resources (into bigger units) helps expanders, it might reduce the incentive of some farmers to exit the industry.

A recent examination of Scottish agriculture by business size suggests that talking in terms of an average Scottish farm (by farm type) is misleading. That is, a small proportion of Scottish farms occupy a relatively large share of the area farmed and account for most of the Scottish farm output. In addition, the scale of operation is quite diverse in Scottish agriculture. The table below shows that roughly only 9% of holdings are more than 200 ha. Consequently, it would be assumed that these farms are large enough to cover economies of scale, are more likely to have leverage to invest in new technologies, and potentially the absorptive capacity to engage in input mixes.

Table 3. Size Categories and Distribution of Farms in Scotland

Size Categories	0-<2	2-<5	5-<10	10-<20	20-<50	50-<100	100-<200	200 +
%tage of Farms	21%	20%	12%	10%	11%	9%	8%	9%

Source: ERSA (2019)

Collaborative farming agreements (e.g. Joint Venture Farming)

Collaborative farming can be defined as; "*two or more farmers working together in a formal arrangement for the mutual benefit of all those involved in the arrangement*" (Teagasc, 2019). These arrangements can bring economic benefits from increased scale, sharing of skills and experience and social benefits through reducing isolation. Informal collaboration in farming is relatively commonplace but to achieve the largest mutual benefit greater integration is required which requires suitable contract or partnership agreements.

A joint venture can be some form of co-operation, formed in a legal manner, between two or more parties to form a business relationship, other than as landlord and tenant (SAC Consulting, 2018). The principal forms of agreement in use in Scotland are; Contract Farming, Share farming and Joint Ventures.

Joint Ventures could be of particular benefit to new entrants to the industry and increase productivity through utilising land - by making it available to new entrants and others - which may be owned by older farmers who do not have a successor identified and who are looking to decrease their management and/or farming activity without selling their land. Nearly a quarter of respondents (597) to a SRUC/JHI Scottish Farmer Intentions Survey conducted in 2018 agreed that they would be interested in participating in a joint farming venture such as share farming. Increasing awareness in the industry of the principles and business distinctions of shared farming ventures could have the potential to increase the number of those interested in exploring share farming venture business models.

'Food Valley' in the Netherlands – established in 2004 at Wageningen – facilitates the collaboration in proximity of food manufacturers and research institutes in the development of knowledge and innovation on food production. Co-operation between parties in the agri-food regional cluster has attracted start-ups and choice of location for food sector companies of various sizes. The success of this initiative highlights that increasing collaboration between research and development and industry can facilitate a strong agri-food sector in the economy.

Collaboration could be encouraged by favouring joint business applications for agricultural support and potentially by offering tax relief for the formation of joint ventures. Co-operatives are a specific form of collaboration typically involving larger numbers of producers. According to SAOS, "*Co-operation involves farmers, growers, other rural businesses and communities working together to achieve a commercial objective, which they cannot achieve independently and individually. Through co-operation, members help themselves, pro-actively taking responsibility for generating value and sustainable services in which they have a common purpose."* (SAOS, 2019).

There are several agricultural co-operatives in operation in Scotland across areas of the industry including livestock marketing, machinery rings, milk suppliers and groups of growers. Co-operatives provide the advantages of strengthened bargaining power, enhanced management of the supply chain and the benefits of economies of scale, whilst enabling reduced transaction costs and market risks. It has been observed that where sectors of the industry receive less subsidy, there is an increased number of co-operatives.

There may be opportunities in relation to future changes to direct subsidy payments to review the benefits of co-operatives and the implementation of policy initiatives to further develop co-operatives in the industry. This could include policy support for increasing human capital amongst those involved in the development of co-operatives and attracting young farmers as possible co-operative board members in the future (Bijman et al, 2012).

An existing agricultural co-operative in Scotland, the Borders Machinery Ring (BMR), based at Earlston in the Scottish Borders is a co-operative owned by a membership of currently around 1,000. The co-operative provides a range of services including contracting/machinery hire, labour, training, farm supplies, utilities comparisons and information on renewable energy opportunities. The BMR's Member Value Statement for 2018 highlighted member savings of around £150,000 per year on fuel and up to £38,700/year through use of a weekly invoicing and automatic payments system, providing efficiency gains to members' businesses (BMR, 2019).

Policy interventions in the form of capital grants to Scottish co-operatives could help to further develop the services offered and start-up of co-operatives in other areas of the country. Scottish Government funding has been provided to BMR for candidates and business mentors for a pre-apprenticeship scheme in 2019 to address recruitment of young people in the rural sector. Such a scheme has been in operation by Ringlink (Scotland) Ltd based in the North East for the past five years. Follow-up of the career direction of students of the course could evaluate the value in funding for courses in other regions of the country.

Risk Management

Crop insurance policies in the United States provide government subsidised premiums for various types of crop insurance. The US Agricultural Act of 2014 provided for new entrant farmers a further 10 per percent premium reduction on insurance (National Crop Insurance Services, 2019). A study into the impacts of crop insurance on productivity (Embaye et al, 2017) on Kansas farms found mixed effects on productivity, highlighting that crop insurance can result in reduced innovation or adoption of new technologies and therefore reduced

levels of competitiveness. The Scottish Government has provided funding for previous incidences of severe weather in Scotland as reactive policies. There may be scope to investigate government funded crop insurance policies for future impacts such as climate change and changing land use patterns in Scotland. It would be useful to consider the socially optimal use of such insurance policies in relation to productivity improvements of government funded schemes.

However, it is unlikely the UK and Scotland can deploy crop insurance to the same extent as the US for a number of scale issues. Crop production in the US is of such a large scale globally that the condition and yield of US crops in response to weather event can have a major effect of the global pricing of many commodities particularly; wheat, maize and soya. For this reason, US farmers on a national scale often enjoy a 'natural hedge' where poor crop conditions and lower output can quickly lead to partial compensatory effect from higher prices. In Scotland and the UK, local yield effects can be significant on local price levels but are of trivial importance on a global stage. Also given the small scale of the UK and Scottish agricultural market for any insurance products, unit costs are likely to be higher. These issues are likely to raises the cost of income insurance in the UK relative to the US and making it a less attractive private or policy instrument to deploy here. That said opportunities remain for producers to identify specific weather risks and seek appropriate weather insurance rather than crop insurance. For example, bread wheat milling quality achieved on an individual farm is very closely related to the level of rainfall in the second week of August (in East Anglia). Farmers can therefore buy weather insurance to pay out if weekly rainfall on their farm exceeds a set level (~25mm) in that time period commensurate with their potential scale of loss (e.g. loss of £20/t bread wheat premium on 9t/ha = £180/ha).

In Scotland, similar opportunities may be identified such as the level of rainfall in June, a key month for forage production on beef and dairy farms. Insuring against such production risks is increasingly important as the level of investment and productivity on a farm rises as there is more at stake. Rising investment in productivity improvements needs accompanied by steps to manage and reduce business risk. The use of forward contracts allows farmers to manage the price they receive over an extended period, brings some certainty to income levels and frees-up management time to focus on improving the physical management and productivity of their enterprises. Forward contracts have been widely used by cereal and potato farmers for many years and more recently have become more widespread in the dairy sector. Improving income certainty through forward contracting improves the resilience of the business and is recognised as a key business strength by the banking sector. In this way farmers practicing a coherent risk management strategy can benefit from greater access to credit which in turn can unlock investment spurring further productivity improvement. This would be reliant on clear and transparent forward pricing mechanisms based on futures markets, which in turn are likely to be impacted by market changes when the UK exits the EU.

Changing the input-output mix.

Subsidies could be accused of leading to retention of unsustainable production enterprises on farm. Several sectors within Scotland are closer to the market than others and thus subject to more market forces. Subsidies buffer some of the vulnerabilities in production. The experience of New Zealand highlights how the market mechanism drove productivity growth through dramatically changing the input-output (enterprise) mix of land use since the mid-1980's. Effectively, the best land has shifted from sheep into dairy and poor land into forestry (though some of this area was subsequently felled to go into dairying).

Horticulture, pigs and poultry units have historically been ignored by subsidy systems in Europe but are growing components on some farms to support anaerobic digestion on farm.

Switching the enterprise to a more mixed operation may offer opportunities for recycling inputs, as in the case of classic mixed arable and livestock farms were only excess intermediates such as hay or straw are traded out with the farm.

However, the constraints of some farming enterprises, such as hill and upland enterprises limit the on-farm diversification that is available and may seek alternatives such as renewable or agro-forestry. These would not impact productivity but effectively highlight that a policy in pursuit of productivity may not be fully realised in certain systems of beef and sheep sectors. There are further questions around the removal of support and the significant social and economic restructuring that could emerge from this.

Additional Approaches

Gene editing

Gene editing is included with technologies regulated by the same legislation as genetically modified organisms (GMO's). The technology can only presently be used for research and is therefore fairly untested in European systems. Gene editing targets a particular location on the genome. While this does change genetic material, this precise targeting is distinct from the genetic modification technologies developed in the 1990's. Potential uses of the technology include crops that better withstand pests, that have enhanced nutritional value, and that are able to grow on marginal lands, and targeting viruses which currently hamper current livestock productivity. Within developed countries gene editing may provide a route to lower inputs, as they would improve drought tolerance and pesticide use, plus find ways for producing protein from current marginal lands.

5.0. Further Issues around Productivity Enhancing Work

The effect of intervention on farming productivity is context specific. Moreover, disentangling poor land and climate from poor or bad management is difficult. The evaluations used here to assess productivity effects have emphasised the context, or sectoral, specific nature of their work and unpicking effects directly on productivity is complicated by these factors. Consequently, there are limits and caveats to the interventions that may be applied, and which will be effective at raising productivity growth given the nuances of Scottish agriculture.

Level of Intervention to raise Productivity

Some approaches to raising TFP are radical. In particular, structural change and/or removal of subsidies will have the effect of increasing farm sizes and potentially offer leverage for entrepreneurial investment. This has subsequent consequences for how Scotland manages large tracts of land which are currently under extensive production, the so called 'hard-hill' systems of upland sheep, which remain unproductive.

Others are more within the realm of *nudging* farmer behaviour towards best practice through the adoption of technology, techniques and practices which are proven to be beneficial. However, there are arguments that some farmers are adopting technologies which do not fit their system or provide return on their investment. Combined with this, the lack of training and support for current 'high tech' solutions are pertinent and an avenue for ensuring that farmers who do purchase high cost equipment are provided with suitable training as needed to operate new machinery at optimal levels. In addition, it is noticeable that services are growing within the rural economy to support decision-making. An example of this is 'Soil Essentials', which provides analytical capacity to cropping farmer's data collection and provides several services for reducing in-field variance. Another service, FarMax, provides

web-based grass and feed budgeting and a forecasting tool developed in New Zealand and now being introduced to farmers in the UK and Scotland. Tools that can help farmers make increased use of grass can significantly improve productivity and lower costs.

Promotion of 'Win-Wins'

An alternative route is to seek support through promotion of the natural capital of the system and take so called agro-ecological routes to maintain yield, e.g. through integrated pest management, or through the introduction of livestock into arable systems. Mixed cropping and forage crops are beneficial for invertebrate and birdlife, which support productivity through pollination and pest control services. This is also good, if responsibly managed, for soil health and ultimately provides a win-win for the environment and productivity. It also contributes to the current debate around the 'social contract of farming', and public re-engagement with food, rejecting the negative consequences of intensive farming. Moreover, recognition of responsible behaviours within supply chains and suitable reward for these practices would also be an example where the private sector could support productivity gains. Public support for initiatives that reduce environmental impact can avoid WTO constraints with the potential to positively impact technical efficiency e.g. Beef Efficiency Scheme.

Private Sector Initiatives

Farming does sit within a chain and productivity is affected through input suppliers and the traits sought through breeding. For instance, grass breeders have selected for extremely successful i.e. high yielding, high energy grasses. However, they are also less resilient, leading to more seed purchases. In addition, aligning retailers' and other supply chain actors' beliefs and motivations may play a large part in offering a private sector solution to raising productivity as these may offer more price stability (through forward contracts) or access to information services and even loans for purchasing of more efficient and appropriate equipment.

Support services play a role in encouraging productivity and other countries have exemplars of engagement, which can inform current advisory extension and analysis services. Notable though is the role of impartial advice compared to commercially driven advice. Work by SRUC in nutrient management and integrated pest management, has found the influence of commercial agronomists to lead to oversupply of agro-chemicals in Scottish systems. The public sector has a role in rebalancing this advice.

Unintended Consequences

Finally, it must be emphasised that seeking routes to higher productivity can lead to unintended consequences. Historically, intensification and boosting yields through plant breeding, agrochemical application and high mechanisation led to a range of ecological and social consequences. At the farm level, it has led to higher debt levels. There may have been a misalignment between what best fits the farm and what is promoted as good for the farm by commercial interests. Furthermore, there is danger of government failure, which in the past has intervened to support farming productivity and led to perverse outcomes. More specifically, government intervention can lead to 'crowding out' of private sector interventions and to dampening entrepreneurial behaviour within the farming population.

Social Licence to Farm

In response to criticism towards growing perceptions of industrialised farming methods the farming population and related lobby groups have been promoting the social license to farm. This evolved within Canada, New Zealand and Australia, where public funding of agriculture is low. Licence to farm generally refers to the level of public trust within the farming industry

and is related to the amount of belief that the values of the public are echoed by practices in the industry. Thus, licence to farm needs greater engagement and awareness raising by the farming industry to the consumer. This 'social contribution' of farming is a non-tangible barrier which may limit or at least direct the potential for productivity growth within the sector. Intensification, whilst positive for productivity, is generally viewed negatively by the public. Arguments for a social licence to farm are consequently about the "continuous improvement" of the current farming systems in terms of their social and environmental goals.

6.0 Summary

- Agricultural productivity is a key measure of sustainable growth. Total Factor Productivity measures the growth in outputs relative to inputs and is explained mostly by technological change and the adoption of better production methods that improve efficiency.
- Reducing the rate of inputs to maintain or grow outputs should support a more sustainable and resilient agricultural sector as it reflects the ability of the sector to accommodate some perturbations from weather, disease and market shocks.
- In Scotland, there are challenges to support productivity growth due to climatic and biophysical disadvantage. However, this is also attributable to inappropriate management, low levels of technology uptake and lack of willingness to adopt techniques and systems which may be more efficient and resource saving.
- At an aggregate level, Scottish productivity growth has shown positive yet erratic annual growth since 2000. When compared to comparator high-income countries using a variety of data sources Scotland seems to perform as a middle ranking country when annual average growth rates are measured.
- Disaggregating performance at a sectoral level using the Farm Business survey we find wide disparities between farm types. Moreover, within farm types there were wide variances in performance, with a number of farmers performing at less than half efficiency of the best performers within the sector.
- Multiple options exist for engaging in raising productivity. These range from movement towards more market-based mechanisms with subsequent social and structural effects, increasing funding for the innovation system to focus on productivity enhancing research and new technologies and targeted support, which carry a further burden on public expenditure.
- Direct funding must follow current WTO green box rules where raising productivity may only be a co-benefit but not the direct aim of the intervention, such as demonstrated in the recent Countryside Productivity Small Grant Scheme in England.
- The effect of interventions on farming productivity is context specific. The evaluations used here to assess productivity effects have emphasised the context, or sectoral, specific nature of past studies. Unpicking the effect on productivity is complicated by these factors.
- Consequently, there are limits and caveats to the interventions that may be applied, and which will be effective at raising productivity growth given the nuances of Scottish agriculture. Moreover, there may be unintended consequences to a productivity seeking policy which, as evidenced through previous policies, has led to harmful levels of intensification, biodiversity loss and the consequent 'lock-in' of farmers on a productivity-debt cycle.

- Ultimately, the problem for Scottish agriculture is how to intervene and how to prioritise the reasons for intervention. Wider social goals are demanded of agriculture, as well as pressures on competitiveness in a post-Brexit landscape.
- Understanding the ambitions of Scottish agricultural policy and clarifying these visions for the future would allow more targeted and cost-effective interventions in boosting productivity growth for the coming decades.

7.0 Recommendations

Wider social goals are demanded of Scottish agriculture, as well as pressures on competitiveness in a post-Brexit landscape. Understanding the ambitions of Scottish agricultural policy and clarifying these visions for the future would allow more targeted and cost-effective interventions for boosting productivity growth in the coming decades.

The interventions presented here are all examples that have been employed in developed agricultural economic systems. Accordingly, the options outlined above may be feasible for Scottish agriculture but may be less politically palatable or desirable in terms of the significant social and environmental costs which may occur from their implementation.

Effectively, due to the need to comply with WTO constraints, the subsidy system has been specifically designed to not increase productivity. Hence, if subsidies were to continue, they need to be redesigned holistically to ensure that they are at least neutral or not negative to productivity growth. The growing research and policy interest into 'win-win' technologies may fit here with support for technologies and techniques which enhance natural capital and raise productivity as a secondary objective.

There may also be "productivity loop holes" that remain in WTO rules that could be exploited. Specifically, such schemes could focus on:

- Support for structural change through encouraging retiring older farmers and support for new entrants. Some of these schemes already exist and may be extended further.
- Support for training. The role of education and knowledge generation, peer-to-peer learning and support for encouraging innovation are fundamental to supporting productivity growth
- Specific schemes focused on productivity. The example of the English Countryside Productivity Schemes could be explored for a Scottish equivalent. These offer competitive grants for capital purchases, adding value and improving farm productivity.

Wider still there may be a range of other fiscal / regulatory measures the government can take that could be adjusted to support productivity growth, though clearly some are currently outwith Scottish Government control:

- Tax incentives for joint and collaborative ventures to encourage more investment for efficiency
- Greater flexibility in the forms of land tenure and support for longer term leases, again to encourage longer term planning and land management
- Inheritance tax relief has been a major factor in raising the value of land above its productivity value, and consequently some land is currently not managed optimally for efficiency but for financial reasons. Changes in tax relief may encourage more oppourtunities for efficient farmers to manage increased land.

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