Rural Policy Centre

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Raising the competitiveness of Scotland's agri-food industry

Research Report

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Executive Summary

The European Commission (EC) considers productivity to be the most reliable long term indicator of competitiveness (EC, 2010). The Scottish Government's declared aim of growing the output of the wider Scottish agri-food industry to £12.5bn by 2017 is intrinsically based on a growth in productivity (Scotland Food & Drink, 2010). An unproductive industry will have wider impacts on its position in export markets and, worse still, could lead to losses in market share to imports. Such industries consequently lose resources to other parts of the economy that make better use of them (i.e. add more value) and decline.

International comparisons of productivity growth are limited. Nevertheless, two authoritative studies indicate that growth in UK agricultural productivity since the 1980s has been lower than countries that were previously comparable. This report measures the productivity and efficiency of Scottish agriculture, and finds productivity growth has been slowing over the twenty years since 1989 and the rate of slow down has been increasing. This predominantly reflects a large fall in output growth, possibly due to structural changes after reform of the CAP, with little corresponding adjustment for inputs. Thus, labour (output per worker) and land (output per ha) productivity fell to negative levels in the post-2004 period.

A more mixed picture emerges at the farm level. Technical efficiency fell for general cropping and cereal farming types over the 1989-2009 period, whereas for specialist dairy and Less Favoured Area (LFA) cattle farms efficiency remained stable. However, there was quite dramatic downward turbulence in the rate of efficiency for the specialist sheep sector. The LFA cattle and sheep sector has slowly increased mean efficiencies over this time as the impact of specialisation towards cattle and the removal of sheep from these systems may be improving efficiencies.

A review of productivity studies identifies a number of reasons for decline in productivity growth, these are: falls in research and development funding; a shift in funding away from productivity towards wider social issues; the loss of advisory services focused on productivity gains; changes in industrial R&D; the negative consequences of subsidies, such as restricting access to new entrants and supporting avoidance of market risk; and increasing constraints on resources, predominantly through global economic and environmental change.

Consequently, there are a number of challenges for research and industry that should be explored to avert further falls in productivity and efficiency. These are:

- Further examination of Government data sets to understand resource use: many data are collected annually and present a long time series in which to explore the impact of drivers and forecast future impacts of policy interventions.
- Further research to understand the impact of knowledge transfer and exchange on the land use sector: this involves exploring the variety of transfer mechanisms which have been employed to understand how farmers receive, communicate and translate these into more efficient methods of food production.
- Analysis of the impact and choices made for promoting technology adoption: this involves an understanding of why some technologies, which seem to offer greater economic or environmental benefits, are not adopted by farmers or indeed an understanding of the impact of past technologies on raising productivity.
- An analysis of the role of other causal factors on productivity: a variety of these have been tested or postulated in other regional environments which could be applied

within the Scottish context. Examples are the development of human capital through education programmes, support for structural changes and capital investment, as well as regulatory and legal changes (such as the role of land ownership versus tenancy agreements) on raising productivity.

- the productivity of the main Scottish agri-food supply chains requires measurement to help identify opportunities for improvement and the role of particular actors in affecting efficient input and output usage.

- Exploring how industry can input further into research: there are financial incentives for investment into R&D and farmer co-operative structures could be encouraged further to invest in research or advice on best management practices for productivity.

- Targeting of subsides: subsidies tend to have had a negative effect on Scottish efficiency in the past, but, if allowed by WTO rules, could be targeted to further encourage the take up of new techniques or offer support for investment into capital heavy new technologies.

Adoption some of these measures may allow Scottish agriculture to reverse the decline in productivity growth and, the adoption of best practice measures from advice, could help to counteract some of the negative influence of increasing temperature fluctuations or the variability of a developing global economy.

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Chapter 1: Introduction

1.1. Introduction

The growing importance of food security issues in Western agricultural policy and an emphasis on reducing the negative environmental impact of the food sector have increased the need for understanding agricultural productivity growth. The European Commission (EC) considers productivity to be the most reliable long term indicator of competitiveness (EC, 2010). Better productivity is at the heart of the Scottish Government's declared aim of growing the output of the wider Scottish agri-food industry to £12.5 billion by 2017 (Scotland Food & Drink, 2010). An unproductive industry will have wider impacts on its position in export markets and, worse still, could lead to losses in market share to imports. Such industries consequently lose resources to other parts of the economy that make better use of them (i.e. add more value) and decline.

This report aims to explore the productivity of Scottish agriculture and how its competitiveness can be improved through lifting productivity at both the production and agri-food chain levels. The objectives are as follows:

1. To review available literature to gauge how Scottish (as part of the UK) productivity fares globally and to review productivity work in other countries (Chapter 2).

2. To present the main findings from a major report written by SAC that calculated the productivity of Scottish agriculture (Chapter 3).

3. To summarise the findings of another recent SAC report that compared the performance of the main farm types found in Scotland (Chapter 4).

4. To draw on the preceding chapters to identify how productivity growth can be improved and what challenges are ahead for productivity growth in the Scottish agri-food sector.

1.2 Productivity growth in context

Globally, agriculture's terms of trade have trended downwards since 1945 (Tyers and Anderson, 1986). Though farmers have generally faced an ongoing cost-price squeeze when measured over the long term, there are periods of respite thanks, for instance, to a helpful exchange rate or buoyant global commodity markets. The marked improvement in sheep prices in the past year or so provides a good example of a favourable improvement in a sector's terms of trade.

As farmers can do little to change the general level of prices and costs, to lift profitability they must raise their productivity by more than the deterioration in their terms of trade. Of course, farm subsidies play a key role in maintaining Scottish farm profitability. But with subsidies expected to decline in the long term owing to further CAP reform in 2013, Scottish agriculture will need to improve productivity to remain competitive.

Farmers can improve their productivity by:

- Changing their input-output mix (e.g. reducing cattle and increasing crops).
- Adopting new technologies (e.g. better seed varieties).
- Changing the size of their business.

Total Factor Productivity (TFP) is a measure of the output growth not attributable to the growth in inputs, i.e. intermediate inputs (e.g. fertiliser, feed), capital, labour and land. TFP is therefore the residual growth in output explained by technological change and the adoption of better production methods that improve efficiency. By implication, TFP identifies factors that influence the long term trend in output, rather than short run variations in production that can be explained by changes in weather, input levels and prices (Normile and Leetma, 2004).

Partial productivity measures (often termed technical efficiency) provide useful insights into competitiveness but should be used with care. Placing too much credence on measures like milk yield and lambing percentage is a trap that many farmers, consultants and researchers all too often fall into (Malcolm, 2004).

The next section presents an overview of changes in productivity at a global and competitor country level. This provides context for Chapters 3 and 4 which examine the productivity and resource use efficiency of farms in Scotland. The final chapter outlines areas for further investigation and the ways in which some of the issues raised in the previous chapters can be addressed.

Chapter 2: Productivity – an International View

2.1 Introduction

This chapter is based largely on a recent major report by Alston et al. (2010), which draws together much of the latest productivity work at farm level from around the world. The findings of a range of competitor countries are outlined. Particular attention is given to Australian work because of this country's keen use of productivity measurement in guiding their efforts to improve the competitiveness of their agricultural industry. First, however, the chapter focuses on work that attempts to measure the relative productivity growth of a range of countries.

2.2 International comparison studies

Fuglie (2010) used FAO data to estimate productivity growth rates for key countries, regions and the world overall between 1961 and 2006. He reached the following conclusions:

- Global agricultural productivity (TFP) has not slowed down in recent decades thanks to rapid productivity gains in, particularly, Brazil and China, plus a recovery in agricultural growth in former Soviet bloc countries.

- By comparison, growth in agricultural investment had slowed, meaning that the 2% annual growth in real global output was achieved by more efficient use of inputs. The wasteful use of inputs in the former Soviet Union prior to 1990 partly explains this efficiency improvement.

- Productivity rates have varied markedly between countries and regions. The old industrialised countries, including Britain, achieved only modest productivity growth (averaging just 0.9% between 2000 and 2007) as resources were withdrawn from agriculture. Brazil and China, by comparison, have sustained markedly higher productivity growth over the past three decades. Other developing countries, notably in sub-Saharan Africa, have experienced very low productivity growth reinforcing their poverty problems. Former Soviet countries, like Ukraine, have also recorded marked improvements in productivity in recent years.

- Fuglie (2010) believes that the recent (since 2005) substantial rise in agricultural output prices will attract more resource use into agriculture thereby boosting global agricultural output. This increased use of inputs will mask low productivity, growth especially in parts of the world (like Britain) where investment in agricultural research has markedly declined in recent decades. He also notes how agricultural productivity growth varies between commodities, highlighting how growth in maize yields has outpaced wheat yield growth because of private sector investment in R&D for the former crop.

However, Alston et al. (2010)[2] concluded that agricultural productivity growth has slowed down significantly in most of the world since 1990, with the exceptions of South America and China and Fuglie's findings should be used carefully until verified by further research. However, these authors share Fuglie's concerns about the negative impact of a slowdown in agricultural R&D on productivity growth.

[2] Alston et al. (2010) reviewed all authors' contributions to *The Shifting Patterns of Agricultural Production and Productivity Worldwide*, in writing chapter 15.

Thirtle and Holding (2003) included an international comparison of TFP growth. The comparison included ten EU countries plus America and covers the period 1973 to 2001 for most countries. In 1973 America was more efficient than all the EU countries except Holland and Belgium. The UK was grouped in the "high growth club" along with Denmark, France, Holland, Belgium and America based on its relatively high level of TFP and high growth rate at the beginning of the period. From 1984, however, UK growth slipped well behind that of the other high growth countries. Between 1984 and 2001 the UK averaged just 0.9% per annum as compared to the French and Danish rates of 2.2% and 2.0% respectively. Consequently the UK was notable in moving from the "high growth club" to the "low growth club" in a European context.

The international comparison applies to the overall productivity of agriculture in the UK. Other parts of the study point to UK livestock performance being the main culprit behind the marked decline in UK agricultural productivity. CAP reforms of the early 1990's may be a factor in the poor productivity performance of UK stock farmers, given the incentives to farm to maximise subsidy income (e.g. extensification and enhanced stock headage premia).

Alston et al. (2010) also highlighted that the relative decline in UK performance coincided with reductions in public R&D in the 1980s plus a change in extension provision (in England and Wales)[3]. The former reduces the pace of technological change, the latter the effectiveness with which technological change is transferred to producers. The reduction in public sector research is clearly reflected in both wheat and barley yields. UK wheat yields have risen by 1% annually since 1984, which is about half the rate in the early part of the study period. This rate is well below France and Germany. The relative performance of UK barley yields is even worse.

The study goes on to suggest that UK research needs to refocus to halt the relative decline in UK farm performance. Multinationals like Syngenta and Monsanto are now the key players in agricultural research where the emphasis is now on biotechnology and molecular biology rather than traditional plant breeding. The UK agricultural research effort would, according to the study's authors, be better served by concentrating on adaptive rather than basic R&D. That is, research that exploits the potential of major international research developments.

2.3 Productivity measures in competitor countries[4]

2.3.1 Australia

The Australians place much emphasis on the measurement of productivity to better understand the performance of their agricultural and food industries. Two sources of productivity measures are used:

- The Australian Bureau of Statistics (ABS) uses national income data to produce a productivity measure based on value added[5] approach that covers all sectors of the Australian "market" economy.
- The Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES) measure covers broadacre agriculture (cropping, mixed crop-livestock, beef and sheep farm types) and is a gross output based measure.

[3] Scottish farming's efficiency has fared better than UK growth as explained in Chapter 3. However, Barnes (2010) could not measure whether this advantage was at least in part caused by higher government support for extension in Scotland.

[4] Unless stated, this section summarises information presented in Alston et al. (2010).

[5] Value added measures of TFP are more partial than those based on gross output, therefore are considered less exacting. However, value added measures are easier to calculate and allow comparison between sectors of an economy.

Productivity growth is critical for Australian farmers because of the long term deterioration in their "terms of trade"[6] (i.e., the so called cost-price squeeze). In short, unless productivity (more efficient use of inputs) outstrips a worsening terms of trade, farm incomes fall. The willingness of the Australian Government to provide subsidies to support farm incomes has been limited, so farms with poor productivity growth have typically left the industry over time.

The ABS measure reveals that Australian agriculture (fisheries and forestry) is a relatively high performer compared to other sectors of the economy (around 2.5 times higher than the overall economy in the 1986-2006 period). Furthermore, based on the ABS measure there is no evidence of a recent slowdown in Australian agricultural productivity.

According to ABARES, declining terms of trade more than offset gains in TFP in the 1953-1990 period, but since then the terms of trade has declined by less than 1% annually and has generally been outstripped by productivity gains resulting in better farm incomes. Performance has differed between farm types, however. Table 2.1 shows the strong performance of crop farms compared to livestock (especially sheep) farms, though the figures conceal the poor performance of cropping farms since 2000.

Table 2.1: Average annual input, output and TFP growth (1977/78 to 2007/08)

Farm type	*Input growth %*	*Output growth %*	*TFP growth %*
Cropping	*0.2*	*0.8*	*1.9*
Mixed	*-1.6*	*2.1*	*1.4*
Beef	*0.2*	*-0.1*	*1.5*
Sheep	*-1.7*	*1.6*	*0.3*
*Dairy**	*3.9*	*5.1*	*1.2*

*Note: *to 2006/07.*
Source: ABARE 2009, Australian lamb 09.1, Canberra. ABARE 2010, Productivity growth: trends, drivers and opportunities for broadacre and dairy industries. (Nossal and Sheng, 2010)

Nossal and Sheng (2010) suggest the following reasons for the changing fortunes of the various farm types over the 30 year period:

- Cropping farms did well in the 1980s and 1990s because of advances in seeds, fertiliser and chemicals, plus a switch toward min-till systems and more diverse crop rotations. Limited advances in livestock technologies plus, possibly, the shorter production cycle of crops perhaps made it easier to demonstrate the benefits of new technologies to crop farmers resulting in higher adoption rates. Bigger machinery allied to min-till techniques also allowed crop farmers to markedly increase labour productivity.

- Drought has been a major cause of low productivity on crop farms since 2000. Less moisture has curtailed the growing of some crops, which has resulted in crop rotations becoming less efficient in terms of labour and machinery.

- Western Australia has experienced the best productivity growth because of a move toward crop farming, large farms and fewer problems with drought than experienced in eastern states.

[6] Terms of trade is the ratio of an index of prices received by farmers compared to an index of prices paid by farmers. Generally, the terms of trade for farm products globally have trended downward since WW2, until very recently.

- Meanwhile sheep farming has benefited from the industry switching focus from wool to meat production, the latter benefiting from more intensive production methods. The big fall in national flock has also lifted productivity as lower performing sheep, farms and farmers have left the industry. With wool production often on the most marginal farmland, continued drought will have been a factor behind the low productivity of wool farming.

However, the long term growth in the productivity of Australian broadacre agriculture has slowed since the mid 1990's regardless of droughts. Recent research (Sheng et al., 2011) indicates that a decline in public investment in agricultural R&D since the late 1970s may account for much of this slow down in productivity growth[7]. The researchers also suggest that factors reducing innovation adoption (farmers age, education), less farm sales limiting structural change and the impact of drought making farmers more risk averse, have also contributed to lower productivity growth. Interestingly, recent Australian work (Sheng et al., 2011) suggests that bigger farm size is not directly responsible for higher productivity growth. Rather, larger farms are better able to exploit new technologies.

To sum up, Australian research points to investment in R&D and improving the take up of new ideas as central to driving future productivity growth in their agricultural industry. Mullen (2010) calculates an internal return of 15-40% annually to public sector R&D funded in recent decades largely by levies on production.

2.3.2 New Zealand

Until recently, the New Zealanders have only used the value added approach based on ABS data to calculate TFP. The overall productivity (TFP) of New Zealand agriculture between 1972 and 1984 was 1.5% annually, but since 1984 has averaged 2.5% annually.

A range of partial productivity measures also point to dramatic changes in performance since the mid 1980s. Land productivity has improved by 85% since 1983/84, mainly because the area under livestock and arable dropped from 14m ha to 12m ha in the 20 years following subsidy removal. Over the same period, livestock productivity also rose dramatically even though livestock wintered dropped from 100m to 94m stock units (ewe equivalents), while dairy cow yields rose by 30%. Further indicators of productivity are in Table 2.2.

Table 2.2: Stock units[8] and productivity indicators – New Zealand

		1982/83	*2003/04*	*Change %*
Sheep	*stock unit*	*64,474*	*37,010*	*-42.6*
Beef	*stock unit*	*22,018*	*21,593*	*-1.9*
Dairy	*stock unit*	*19,658*	*32,365*	*64.6*
Total	*stock unit*	*106,150*	*90,968*	*-14.3*
Milk solids per cow	*kg*	*231*	*305*	*32.3*
Lambing rate	*%*	*96*	*113*	*17.9*
Lamb weight	*kg/hd*	*13*	*17*	*27.7*
Mutton weight	*kg/hd*	*19*	*24*	*26.3*
Beef weight	*kg/hd*	*223*	*257*	*15.2*

Source: Agriculture in New Zealand, NZ MAF (2006)

[7] This research indicated that Australian investment in agricultural R&D grew strongly in the 1950s and 1960s, drifting down from about 4-5% of GDP annually between 1978 and 1986 to about 3% in recent years (which is slightly above other developed countries at 2.6%).

[8] A stock unit (su) is a measure used to compare the nutrition requirements of different grazing animals (e.g. 1su = one 55kg ewe producing 1 lamb, a dairy cow = 7su).

Labour productivity has almost doubled in the 20 years to 2003/04. In 1982/83 the labour force peaked at 127,000 full time equivalents, but was just 100,000 in 2004/05. The productivity improvement in New Zealand was driven by the need to regain profitability. The main explanations for this improvement are:

- Removal of low performing farmers;
- A move toward bigger businesses helped by exit of some farmers;
- A change in the balance of farm types (reduction in sheep and increase in dairying);
- A refocusing of R&D and technology transfer toward industry needs.

2.3.3 United States

US agricultural production has increased remarkably in the past 100 years, especially between 1949 and 1990. The large increase in production was associated with a big increase in the quantity of material inputs (e.g., fertiliser), a very large decrease in labour and little or no change in land and capital inputs.

However, between 1990 and 2002, productivity growth slowed substantially, halving compared to the 1949-1990 period, with the slowdown particularly marked in the northern plains, southeast and northeast regions.

Declining productivity may be a reflection of overall lower spending on agricultural R&D since the late 1970s, or at least a cut in the share of R&D spent on production enhancing work. For the four major crops grown in the US, yields grew at a much slower rate in the 1990-2006 period. The US will suffer a widening competitiveness gap unless other competing countries suffer a similar slowdown in productivity.

2.3.4 Selected other countries

A number of studies tend to find Brazilian productivity for agriculture to have grown by around 20% between the mid-1980s to late 1990s (Rada et al., 2009; Barros, 1999; da Silva et al., 2000). This latter study argued the productivity growth emerged from Embrapa's[9] contribution to technological changes, rural migration and trade liberalisation, improving the availability of material inputs at lower prices. Rada et al. (2009) identified the lower performing states and argued that policy interventions should concentrate on a regional basis to raise national level productivity.

China seems to have experienced a significant leap in output and associated productivity measures from 1979 to the mid-1980s. This was predominantly led by government reforms on grain self-sufficiency (Lin, 1992). Since this period however several studies have pointed to either a decrease in the rates of growth (Carter et al., 1999) or a reversal in trends from the mid-1990s (Tong and Fulginiti (2003). However, this may be a question of data quality and Carter et al. (1999) find differences in farm level data compared to aggregate data. These authors found regional variations in efficiency which radically reduced estimates of growth rate. Jin et al. (2010) conclude that much of China's productivity growth reflects the adaption and adoption of technologies from other countries. They remain open-minded as to whether future Chinese productivity growth will be sustained by domestically produced technologies and institutional reforms.

Evenson et al. (1999) found high levels of agricultural productivity growth in India from the 1950s to the mid-1980s, which they attributed to public agricultural research and extension;

[9] Embrapa is the Brazilian Agricultural Research Corporation that aims "to provide feasible solutions for the sustainable development of Brazilian agribusiness through knowledge and technology generation and transfer".

as well as expansion of irrigated area and rural infrastructure and improvement in human capital. Mahadevan (2003) examined Indian productivity growth over the period 1970 to 2000, finding little observable evidence of gains to India's agricultural performance after economic reforms to open up its markets. This is echoed by Praduman and Surabhi (2006), who found that productivity has fallen since the 1980s.

Government policy has strongly influenced Argentinean agricultural productivity according to Lence (2010). A big reduction in the taxation of farming in the 1990s boosted productivity growth as farmers increased use of fertiliser and pesticides, adopted no-till cultivation (aided by GM seed technology), converted land from extensive beef production to crops and intensified remaining cattle production (including dairying). Yet international studies indicate that Argentinean farmers, especially livestock farmers, have plenty of scope for further improvement. However, Lence notes fears that an overly free market approach may have resulted in changes, especially the high reliance on a single crop (soya), that are unsustainable. Since 2001, successive Argentine governments' have become more interventionist, but in a manner that may have harmed productivity growth without improving the environment.

The productivity of Russian and Ukrainian agriculture over the past 20 years has also been largely shaped by government policy according to Swinnen et al. (2010). The poor productivity of these ex-communist countries worsened following the fall of the Berlin Wall in 1989, as output collapsed. Economic crisis in these countries in the late 1990s resulted in market liberalisation policies that led to more efficient allocation of resources. Allied to increased investment in the food industry improving vertical integration, establishing a more competitive policy environment has improved productivity. However, it took more than 15 years for labour and land productivity to recover to pre-reform levels.

2.4 Conclusions

- Based on this international review, investment in agricultural R&D focused on production and its dissemination to farmers, drives productivity growth. The uptake of new ideas by farmers depends on; the methods of technology transfer used, human capital (farmer age, education), farm size and the regulatory structure (competition).

- International comparisons of productivity growth are limited. Nevertheless, two studies indicate that UK agricultural productivity has been low relative to most competitor countries since the 1980s. By comparison, productivity has grown rapidly in progressive developing countries like Brazil.

- The review identified close links between the fall in productivity with a number of factors principally driven by reductions in R&D funding for agricultural production and corresponding falls in support for advisory services. However, lower spending on R&D and extension per se does not necessarily result in lower productivity as demonstrated by the New Zealand experience. There, deregulation forced a remodelling of R&D and information dissemination to provide more "bang for the bucks". In short, R&D became more applied and led by industry needs rather than researcher wants.

- Accordingly, some support for the uptake of new ideas needs to be explored, in terms of how technology and knowledge is transferred. Development needs also to be focused on human capital, in terms of how the industry supports (or dissuades) new entrants and how education and knowledge about agricultural techniques is encouraged. In addition, further studies show a relationship with farm size and how farming has intensified in the periods of high productivity growth and, indeed, how regulatory structures have changed which engender, or indeed constrain production potential.

- Data quality is an important aspect of measuring agricultural productivity and indeed some commentators have suggested the residual in output to input growth may be attributable to measurement errors.

- However, the UK is not alone in worrying about declining productivity. Both the US and Australia have identified declining productivity as a major issue affecting the capacity of their industries to compete. Based on a review of literature, the Australians make very good use of productivity measurement to help identify problems and thereby strategies for improving future productivity and competitiveness. How they use their farm income survey (equivalent to the Farm Accounts Surveys conducted in the UK) is especially notable.

Chapter 3: Total Factor Productivity Index for Scottish Agriculture

3.1 Introduction

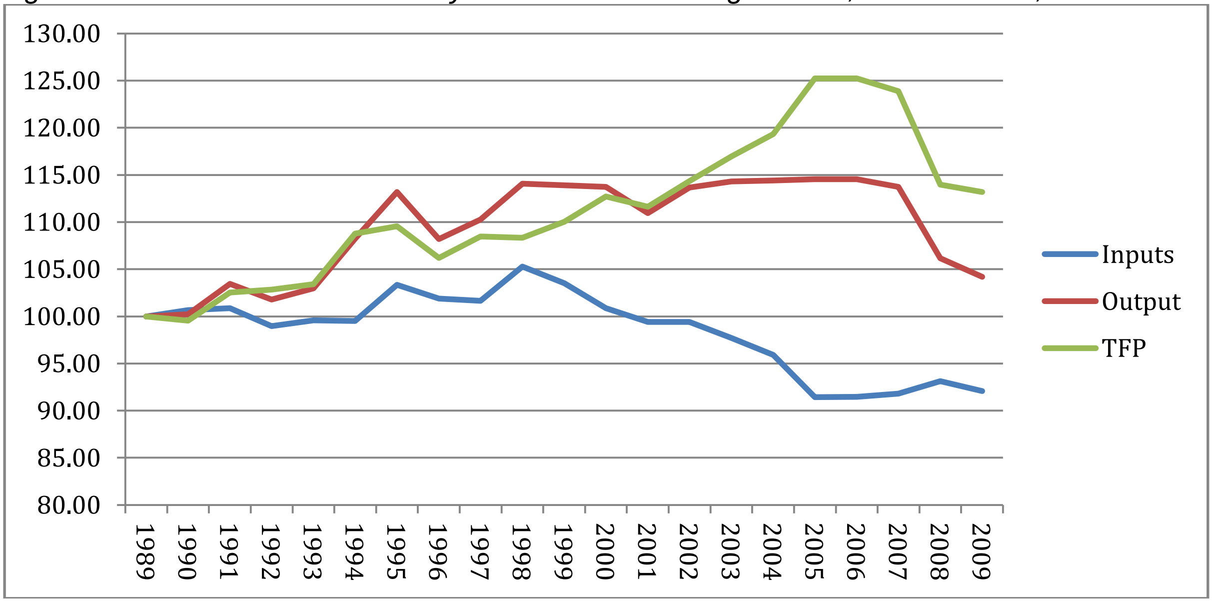
Productivity can be measured partially (e.g. output per labour input), or 'totally' (i.e. accounting for all inputs and outputs). We can develop these indicators using the aggregate account of Scottish agriculture, which is published on a yearly basis, and gives an overview of how Scottish agriculture is using its resources for major commodities.

Most UK indicators produced by Government only measure labour productivity, partly due to the fact that labour productivity is relatively simpler to measure than total fact productivity (TFP). Labour productivity relies on fewer assumptions and requires less comprehensive data. Most work on TFP measurement in the UK food sector has been conducted outside the Government (Rayner et. al., 1986; Thirtle and Bottomley, 1992; Barnes, 2002; Thirtle et al., 2004; Barnes and McVittie, 2006). Accordingly, this chapter offers a TFP index for Scottish agriculture. Whilst an index has been presented for the UK (see Thirtle et al. 2003), most nations within the UK have their own processes for agricultural policy making (an example of which is the difference in administering the Single Farm Payment (SFP) (Defra, 2005; SEERAD, 2005; DARD, 2004). Accordingly, a wholly UK based index is somewhat irrelevant given these devolved policies.

3.2 Total factor productivity index

The full methodology for constructing the series is detailed in Barnes (2006), who constructs a series from 1973 to 2004. However, a significant issue is the treatment of the SFP within the output series. Up to 2004 these were included in the commodity information of the Economic Report for Scottish Agriculture, and with removal of support away from production there is a significant drop in commodity output in 2005. Consequently, a decision had to be made regarding the adjustment for subsidies. Fortunately, the Scottish Agriculture Output, Input and Income Statistics (Scottish Government, 2009) present a series from 2000 of both commodity values with and without subsidies. It would be ideal to remove all subsidies from output to provide a consistent series, but these data only go back as far as 2000. Consequently, we take the average share of subsidies to output, relevant to main Scottish commodities over the 2000/2002 period (the period in which the subsidy payment is based) and inflate commodity values from 2005 to 2009 to account for the share of subsidy. This reflects the historic basis on which the SFP is based in Scotland. Figure 3.1 shows the results on inputs, outputs and TFP (taken as the ratio of output to input indexes), over the period 1989 to 2009.

Figure 3.1: Total Factor Productivity Index for Scottish Agriculture, 1989 to 2009, 1989=100



Clearly there is a downward effect on output since decoupling. Part of this may be due to the imputation process (outlined above), but the withdrawal of livestock, which accounts for around 55% of the output share, is having a downward impact on this index. The rates of growth are presented below as compound rates[10].

Table 3.1: Input, Output and Total Factor Productivity 1989-2009, average compound growth rates

	89/99	*00/04*	*05/09*	*89/09*
Input	*-0.22%*	*-0.99%*	*0.13%*	*-0.61%*
Output	*1.08%*	*0.12%*	*-1.87%*	*0.20%*
TFP	*1.30%*	*1.12%*	*-2.00%*	*0.81%*

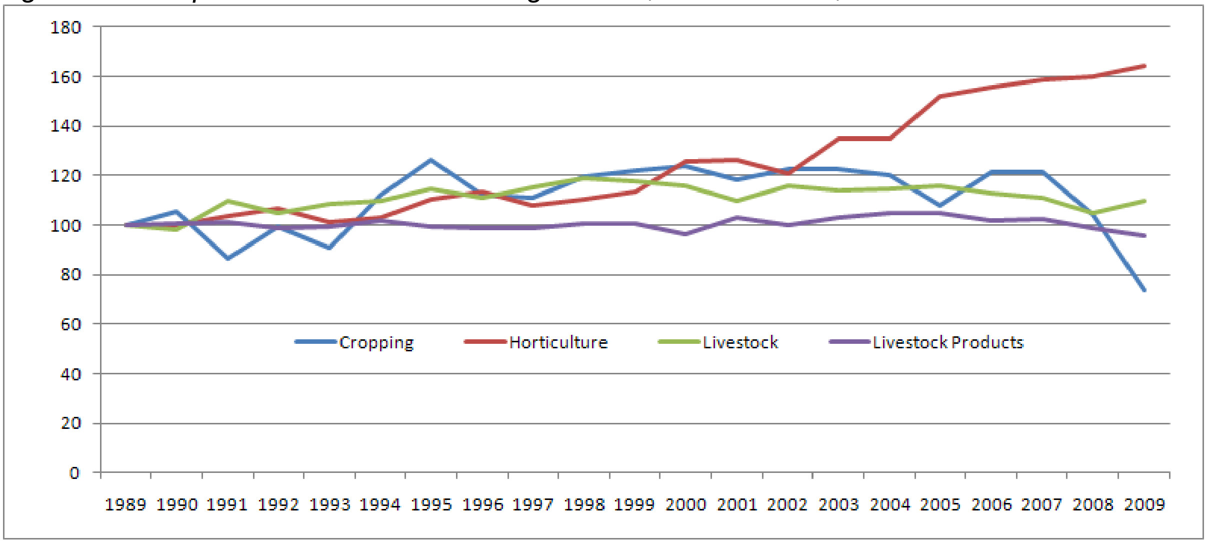
Up to 2004 the input series seems to decline. This is fine as the output series grows over the 1989 to 2000 period by over 1% per annum. We calculate TFP as the ratio of input to output to inputs, hence any fall in inputs with a corresponding rise in outputs leads to positive TFP growth. Thus, up to 2000 Scottish agriculture grew at a rate of 1.3% per annum. This fell to 1.12% in the 2000 to 2004 period which was driven by large falls in output (following the Agenda 2000 CAP reforms and the Foot and Mouth Disease outbreak). Finally for the post-decoupling period we find that output fell dramatically by nearly 1.9% per annum. In addition inputs grew over this period slightly by 0.13% per annum, perhaps due to restructuring. Overall this leads to a large fall in TFP of 2% per annum over the 2005 to 2009 period.

[10] We take the compound annual growth rate (CAGR). This smoothes the annual gain over time as volatility in the series could render the arithmetic mean irrelevant.

3.2.1 Changes in Outputs

Figure 3.2 shows the changes in output of the main commodity groups over the 1990 to 2009 period, generally showing a growth over this period. The highest growth is horticulture which averages over 2% per annum.

Figure 3.2: Output Indexes for Scottish Agriculture, 1989 to 2009, 1989=100



The real falls however are in the crops sector and whilst cereals have grown over this period, the values of oilseed rape and potatoes shows a decline which rapidly increases in the post-decoupling period. Livestock also followed a similar pattern though these are falling at lower rates, and this has had an influence on livestock products also.

Table 3.2: Main output commodities, 1989 to 2009, average compound growth rates

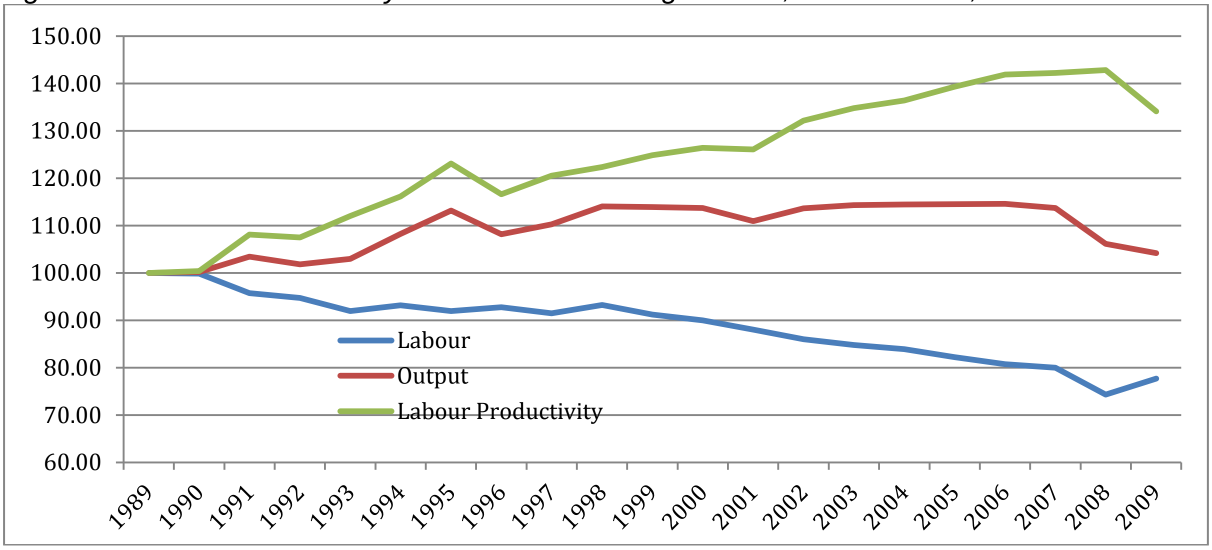
	1989-2000	*2000-04*	*2005-2009*	*1989-2009*
Crops	*1.8%*	*-0.6%*	*-7.3%*	*-1.4%*
Horticulture	*2.1%*	*1.7%*	*2.0%*	*2.4%*
Livestock	*1.4%*	*-0.3%*	*-1.4%*	*0.4%*
Livestock Products	*-0.4%*	*2.1%*	*-2.3%*	*-0.2%*

3.2.2 Changes in Inputs

The indexes of output and labour are presented in Figure 3.3, with the calculation of labour productivity[11] showing quite divergent paths. Output growth is flanked by the large increases in labour productivity (taken as the index of output to labour). Notably, unlike previous series this is not unduly affected immediately by decoupling in 2005. However labour seems to revert upwards, after a continual decline, in 2008, this is in conjunction with a fall in output since the 2005 period and ultimately leads to a dip in productivity for the recent years of the series.

[11] The labour index is constructed as the number of farmer and family (unpaid) and regular, casual and seasonal (paid) members. These are multiplied by average annual hours worked and the index is constructed using the costs of unpaid and paid labour as a weighted share.

Figure 3.3: Labour Productivity Index for Scottish Agriculture, 1989 to 2009, 1989=100



Labour seems to have fallen over the three periods outlined in Table 3.3. This rate accelerates from the turn of the century onwards to around 1.4% per annum, and softens slightly in the final post-decoupling period but is still greater than 1% per annum. These changes have had a corresponding increase on labour productivity. Whilst this was around 2% per annum, it gradually falls until the annual rate of growth is negative is the post-decoupling period.

Table 3.3: Labour productivity series, 1989 to 2009, average compound growth rates

	89/99	*00/04*	*05/09*	*89/09*
Labour	*-0.88%*	*-1.39%*	*-1.13%*	*-1.20%*
Output	*1.08%*	*0.12%*	*-1.87%*	*0.20%*
Labour Productivity	*1.97%*	*1.54%*	*-0.75%*	*1.41%*

Figure 3.4 shows the indexes of land[12], output and land productivity, taken as the ratio of the index of output to the index of land. Land quantity recently increased, since 2005, which infers a rise in eligible land since this period[13].

[12] The land index is constructed from total agricultural area, weighted by the changes in the value for net rent (which is imputed on owner occupied land).
[13] The method of data collection changed in 2009 and land was collected as part of the single application form rather than the census form. This led to a fall of -0.6% in area between 2008 and 2009.

Figure 3.4: Land Productivity Index for Scottish Agriculture, 1989 to 2009, 1989=100

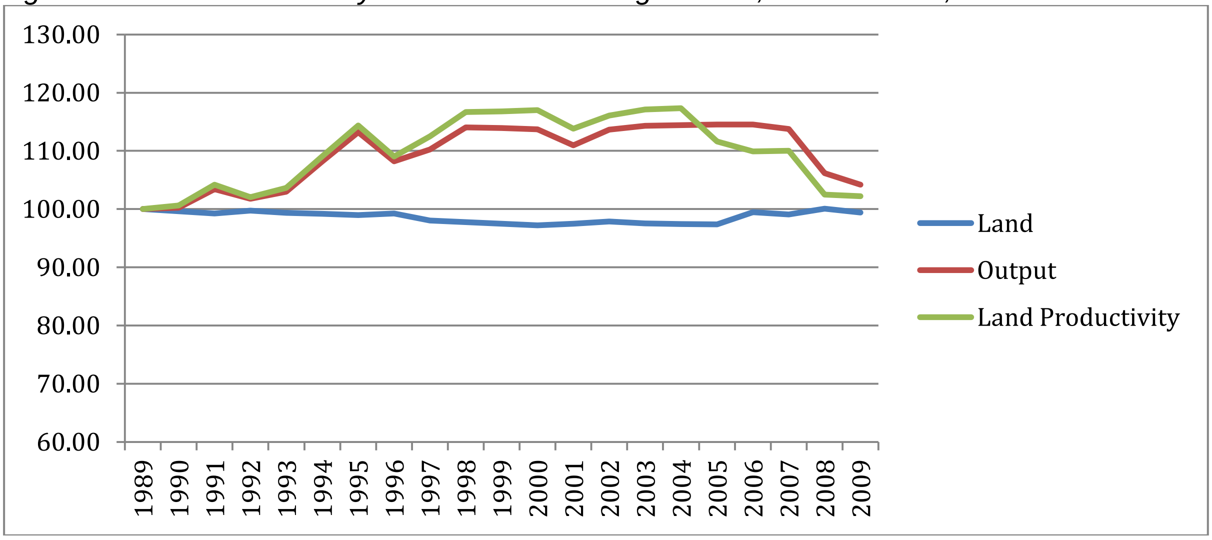


Table 3.4 shows that given the rise in land quantities and the falls recorded in total output that in the 2005 to the 2009 period land productivity fell by over 2% per annum. Nevertheless, before this period land productivity grew by 1.3% per annum up to 1999, but then fell quite remarkably by around 0.1% up to 2004.

Table 3.4: Land productivity series, 1989 to 2009, average compound growth rates

	89/99	*00/04*	*05/09*	*89/09*
Land	*-0.24%*	*0.05%*	*0.42%*	*-0.03%*
Output	*1.08%*	*0.12%*	*-1.87%*	*0.20%*
Land Productivity	*1.32%*	*0.08%*	*-2.28%*	*0.22%*

Other indicators of materials inputs are collected and contribute to the total factor productivity series, however for brevity and interest we examine two inputs which have a strong link with environmental performance and construct productivity indexes, namely fuel and fertiliser usage. Table 3.5 shows the annual average growth rates for these two indicators over selected periods.

Fuel and oil usage has increased by around 3.5% on average over the whole period. The commodity price of fuel has risen substantially over the 2005 to 2009 period but we use the appropriate Defra deflator to negate these price rises and find that usage increased by an average of nearly 2% per annum in the post-decoupling period. As output has had no corresponding rise over this time then productivity of fuel use has fallen to -3.7% per annum.

Fertilisers tell a different story as they show a minimal level of growth in the former period with a slight decline up to 2004. This falls quite spectacularly in the post-decoupling period, principally following the falls recorded in both cropping and livestock outputs over the time period. These falls in usage have led to quite significant rises in fertiliser productivity in the post-decoupling period of around 7-8% growth per annum.

Table 3.5: Energy and nutrient productivity series, 1989 to 2009, average compound growth rates

	89/99	*00/04*	*05/09*	*89/09*
Fuel and Oil	*3.7%*	*-1.5%*	*1.8%*	*3.5%*
Fuel and Oil Productivity	*-2.5%*	*1.7%*	*-3.7%*	*-3.2%*
Fertiliser	*0.1%*	*-0.5%*	*-8.8%*	*-2.4%*
Fertiliser Productivity	*0.9%*	*0.7%*	*7.6%*	*2.7%*

3.3 Summary

- The Scottish Government have stated a firm commitment to support a 'prosperous and sustainable growth' for the agricultural industry and has clearly asserted that TPF is a key indicator in measuring this progress. Accordingly, this paper has presented a TFP growth index for Scottish agriculture over the period 1989 to 2009.

- Output seems to have fallen over the period, with clear falls in post-decoupling agriculture, predominantly driven by non-cereal based crops.

- TFP has grown at an average of 0.8% per annum over the period 1989 to 2009. Higher rates of growth were found for the earlier part of the series but after 2004 these rates fell into negative levels. This is predominantly a result of the fall in the rate of output growth, whereas input usage accelerated.

- Labour productivity has grown by an average of 1.4% per annum and land productivity by 0.22%. However, both fall to negative levels after 2004. Hence it seems that promotion of a sustainable and prosperous agriculture may prove problematic for the Scottish Government given this industry's heritage of negative growth rates since the 1980s. Thus it has first to pull its own agriculture out of the negative trend in productivity recorded here to begin its course towards sustainable production.

- One issue for the assessment is the adjustment of outputs for the SFP to obtain a consistent series, though we note very little break in the series between 2004 and 2005 and are reasonably confident that the adjustment in output values has had little overall effect on measuring rates of growth.

Chapter 4: Comparative Farm Level Performance

4.1 Introduction

Technical efficiency is a measure of how resources are being used. We use an approach known as stochastic production frontiers, which takes a sample of farms of a particular type from the Farm Account Survey (FAS) data and estimates their relative efficiencies. This approach removes some of the variance that may occur due to noise. In this case such factors as weather and disease are somewhat negated under this method. The most efficient farms represent the best practice frontier, i.e. they have the best use of resources and the highest level of efficiency. Once identified then other farms can be measured relative to this frontier and hence each farm gets a score from between 0 and 1. The higher the score the closer this farm is to the frontier[14].

The figures that follow represent the mean technical efficiency score of each farm type in the FAS over the period 1989 to 2009. Mean scores are presented for three periods, namely 1989 to 1999, 2000 to 2004 and 2005 to 2009. The latter two periods are of interest to give some picture of how decoupling and the SFP have affected efficiency at the farm level, as opposed to at the aggregate level in the TFP series above. The results are summarised in the following section.

4.2 Technical efficiency of Scottish farm types

For predominantly cropping systems, which are typified by general cropping and cereals farming types mean technical efficiencies (TE) have fallen over the whole 20-year period. Cereal farms decline from a mean of 0.83 in 1989 to 0.66 in 2009. Clearly from these averages there is a dramatic fall in mean TE levels from the 2000 period onwards, and hence the changes due to decoupling in 2005 cannot be fully attributed as the cause of this fall. A more worrying trend is found in general cropping farms which fell from a mean of 0.61 in 1989 to 0.37 in 2009. The figure clearly shows this trend is downward (see Figure 4.1).

Predominantly livestock systems can be classified as either specialist (dairying, lowland and LFA specialist cattle and LFA specialist sheep) or mixed (LFA and lowland cattle & sheep). For the specialist farms the results are a relatively steady progress in terms of TE (dairy, LFA cattle) but quite dramatic downward turbulence for the specialist sheep sector. Both dairy and LFA cattle have relatively high means for their TE. For the former, mean TE increases in the last 10 years from 0.67 in the 2000/04 period to 0.71 in the post decoupling period, for the latter there is a minimal fall, though this is not significant, and effectively means that average TE has not changed over the period. This may reflect the longer biophysical cycles that these farms operate under for any change to occur. LFA specialist sheep farms, on the other hand show a downward cycle, although notably this seems to fluctuate, with rises in the mid-1990s, and falls and rises in the early period of this decade. However, a notable decrease occurs from 2004 onwards. Though mean efficiencies only fall slightly in this period it may still be evidence of the restructuring which is occurring in the hill and upland areas of Scotland.

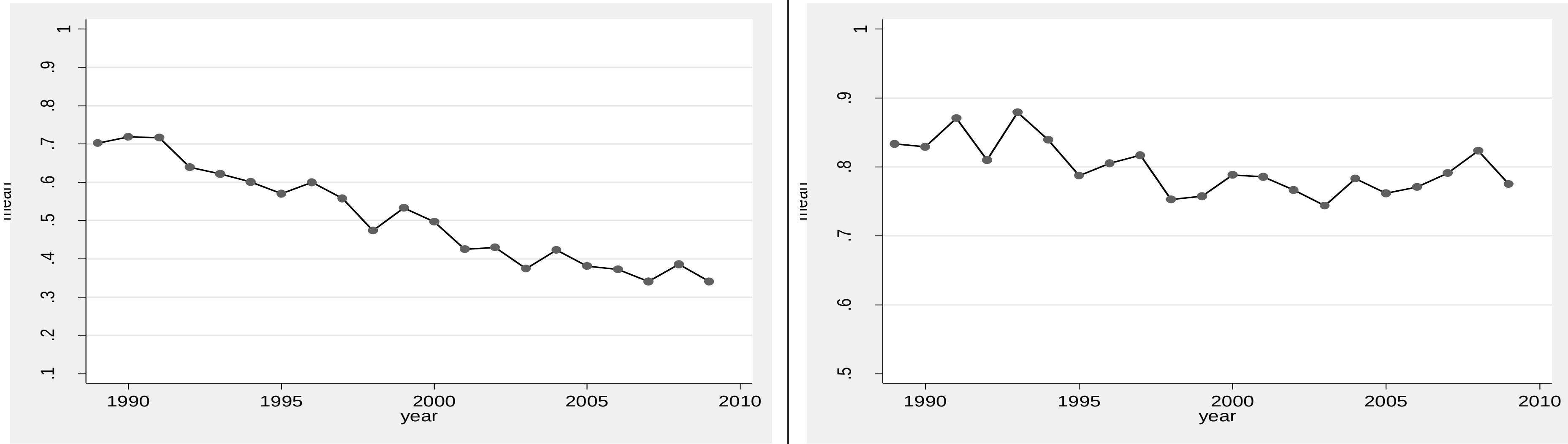
The Cattle and Sheep farming systems again show some interesting trends. The LFA sector has slowly increased mean efficiencies over this time as the impact of specialisation towards cattle and the removal of sheep from these systems may be improving efficiencies. The Lowland sector should be viewed with caution as only low numbers are collected within the FAS. As such the high levels of fluctuations may be due to sampling issues rather than any other factors. Finally, the mixed farming systems have a relatively smooth and upward trend over this time and demonstrate some of the highest mean efficiencies across the sector.

[14] More explanation is available in Barnes et al. (2010).

Again, some specialisation may be occurring in these systems, which has led to improvements in efficiency.

Figure 4.1: Mean technical efficiency scores for Scottish Farm types, 1989 to 2009

General Cropping Farms	*Cereals Farms*

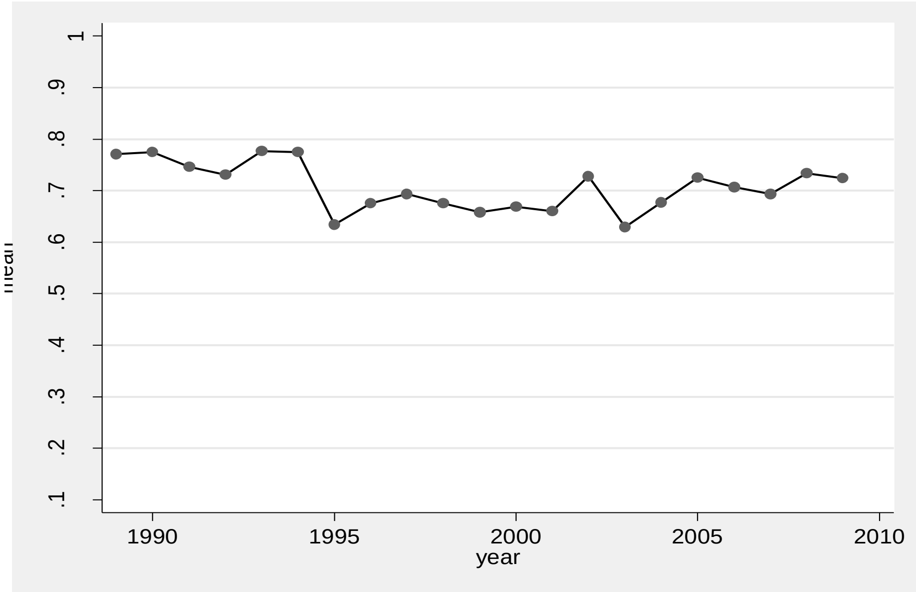
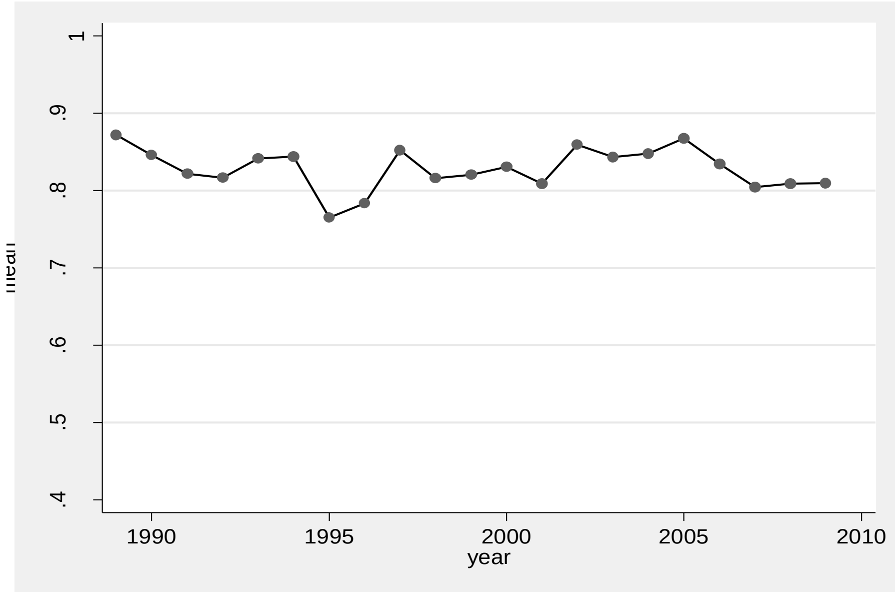


General Cropping Farms

Mean	*0.517*
1989-99	*0.612*
2000-04	*0.435*
2005-09	*0.373*

Cereals Farms

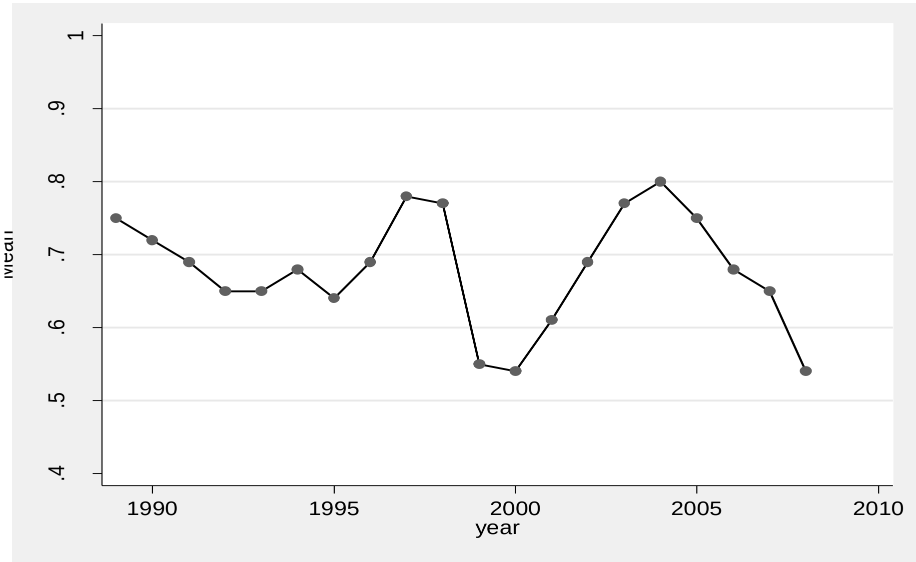
Mean	*0.745*
1989-99	*0.834*
2000-04	*0.698*
2005-09	*0.662*

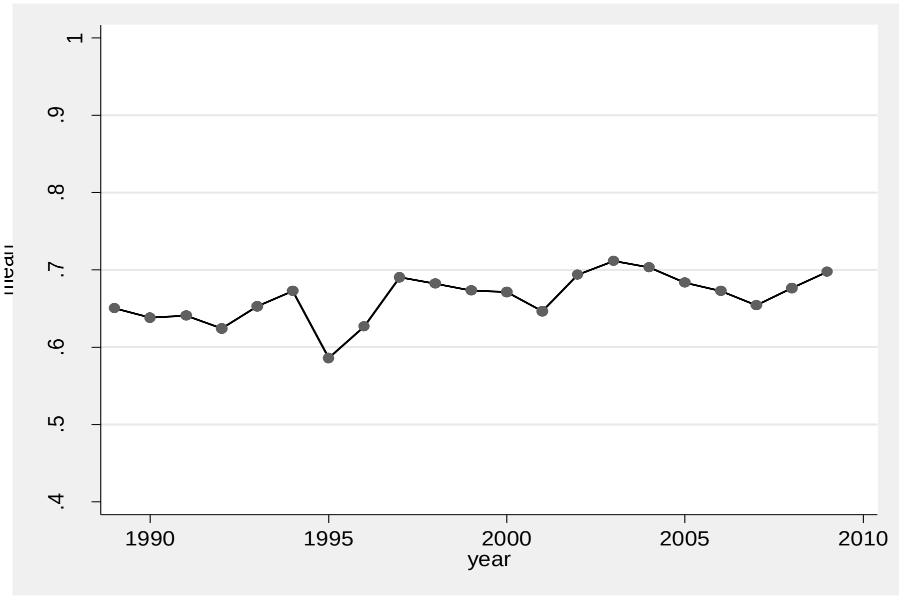
Dairy Farms	*LFA Specialist Cattle Farms*
	

Mean	*0.711*
1989-99	*0.722*
2000-04	*0.673*
2005-09	*0.710*

Mean	*0.828*
1989-99	*0.824*
2000-04	*0.836*
2005-09	*0.830*

LFA Specialist Sheep Farms	*LFA Cattle and Sheep Farms*



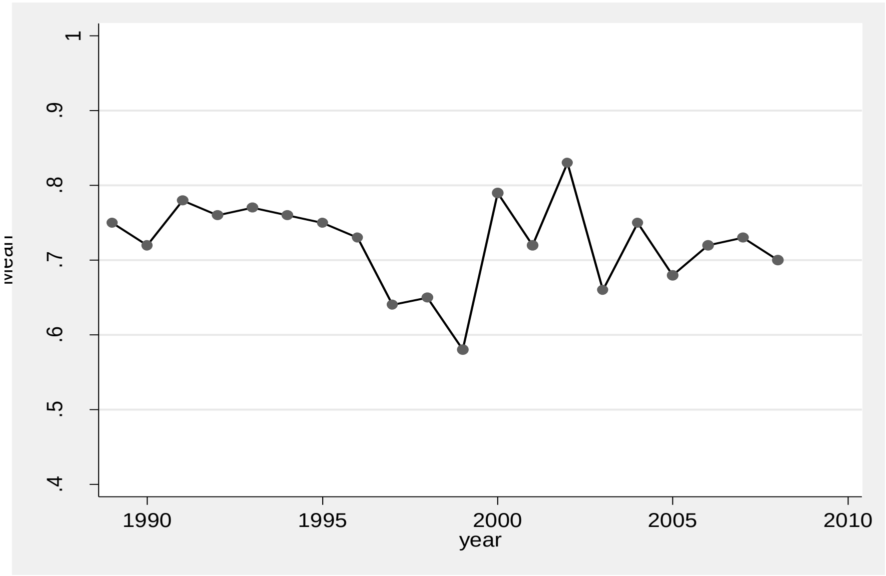
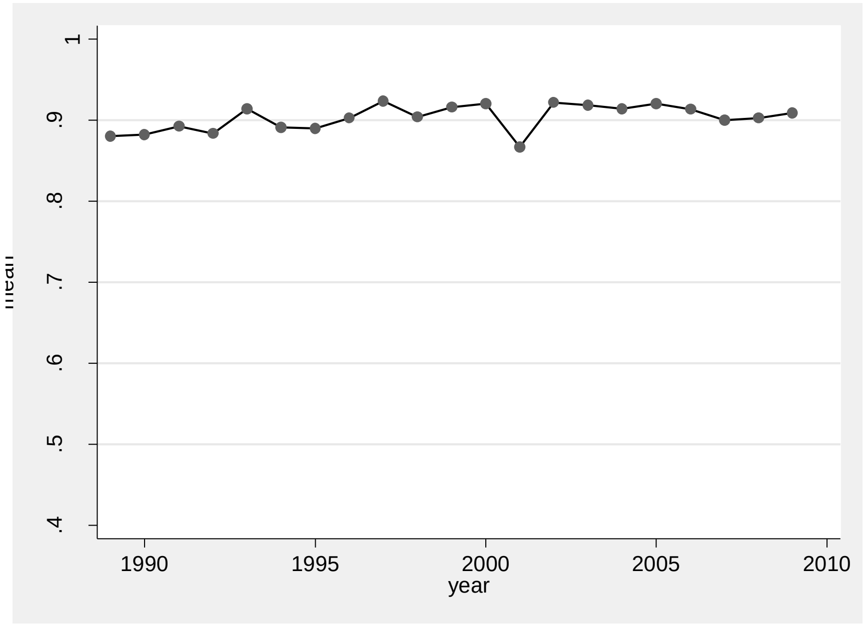


LFA Specialist Sheep Farms

Mean	*0.675*
1989-99	*0.688*
2000-04	*0.682*
2005-09	*0.655*

LFA Cattle and Sheep Farms

Mean	*0.662*
1989-99	*0.650*
2000-04	*0.679*
2005-09	*0.681*

*Lowland Cattle and Sheep Farms**	*Mixed Farms*
	

Mean	*0.725*
1989-99	*0.717*
2000-04	*0.750*
2005-09	*0.708*

Mean	*0.903*
1989-99	*0.899*
2000-04	*0.907*
2005-09	*0.910*

**Low numbers of observations*

Table 4.1: Partial Results from Translog, with Inefficiency Effects

	Cereals		Gen Cropping		Dairy		LFA Cattle &Sheep		Mixed	
Variables	β	Sig	β	Sig	β	Sig	β	Sig	β	Sig
Materials	0.456	***	0.436	***	0.602	***	0.466	***	0.481	***
Energy	0.114	***	0.129	***	0.057	***	0.138	***	0.118	***
Labour	0.025	***	0.120	***	0.003	***	0.030	**	0.040	**
Land	0.342	***	0.205	***	0.364	***	0.257	***	0.318	***
Capital	0.101	***	0.104	***	0.020	***	0.111	***	0.067	***
Time	0.071	***	0.085	***	0.049	***	0.035	***	0.031	***
$Time^2$	-0.001	***	-0.001	***	-0.001	***	-0.001	***	-0.001	*
RTS	1.037		0.994		1.047		1.003		1.024	
Gearing	-0.004	-	0.001	*	0.000	-	0.000	-		
Subsidies	0.071	***	0.011	-	0.166	***	0.020	***	0.010	-
Specialisation	0.042	-	-0.127	***	-0.021	***	-0.026	***		
Rent/Ha	-0.118	***	-0.041	*	-0.108	***	-0.095	***	-0.117	-
Cg/Area	-0.004	-	0.012	-	0.019	**	0.011	-	-0.004	-
Age	0.073	*	0.080	*	0.051	**	0.079	***	0.301	-
FFI/GM	-0.090	***			-0.123	***	-0.090	***		-
MacSharry	0.034	-	-0.017	-	-0.053	*	-0.005	-	-0.036	*
SFP	-0.016	-	-0.013	-	-0.051	*	0.076	**	0.026	*
ESA	-0.024	-	0.082	***	-0.006	-	-0.225	**	0.178	-
FMD					0.032	-	0.082	***	0.167	**
BSE							0.180	**	-0.171	-
GLU/HA					-0.236	***	-0.288	***	-0.385	-
TIME	0.018	-	0.038	***	-0.003	-	-0.019	***	-0.003	***

(*** sig at 0.001, ** sig at 0.01, * sig at 0.05)

Table 4.1 shows the impact of inefficiency effects within the estimation of efficiency. Effectively, information from the FAS can be used to indicate which factors are driving inefficiencies in the system, thus to understand their positive impact on efficiencies the signs must be reversed. The first half of Table 4.1 indicates the influence of each input on output and clearly for all farm types 'Materials', which is composed of most variable physical inputs into the system, is the most important. This is especially the case for dairying, which relies heavily on feed, fertiliser and other livestock expenses. Secondly, land is an important input into the system for most of the systems. For a number of systems, total labour hours, which is the sum of all hours worked on the farm, is only a small contributor to overall output. Similarly, of interest may be the role of energy, comprised of electricity and fuel and oil inputs into the system. For most farm types this are most substantial than labour in producing output.

The 'Time' variables indicate how the frontier has moved over the whole period. For all farm types these are positive which means the frontier has moved forward, principally through the adoption of more advanced techniques and technologies. The squared time trend indicates the rate at which the frontier has moved, and this is slightly negative, indicating the rate of progress in the frontier has slowed down slightly.

The 'RTS' value indicates returns to scale and is the sum of the linear input coefficients. Notably these are slightly above or near to 1 which indicates that farms are operating at an optimal scale, aside from general cropping which has a score of slightly less than 1. This indicates decreasing returns to scale, i.e. farms are too big, though again this is marginal.

The final part of Table 4.1 some of the variables available for understanding the drivers of inefficiency and they vary in success when fitting against the various farm types. Notably the 'Subsidies' variable, which is the ratio of subsidies to gross margin is all positive, meaning that they have a strong negative effect on efficiencies. For example for cereals farms a 1% increase in the subsidy level will lead to a 7.1% fall in efficiency. Rent per hectare is used as proxy for indicating quality of land, and these are all negative, i.e. an increase in land quality (though rent per ha) is related to increases in efficiency. The 'Age' variable is positive indicating that as farmers get older their efficiency levels reduce, which tends to follow that younger farms are more risk takers and adopters of new technologies. Another indicator relating to of the farmer is the farm family income to gross margin indicator. This represents the relationship between family income and agricultural income. This is negative for a number of farms and indicates that the higher the family income then we would expect more efficiency.

The grazing livestock units per ha (GLU/ha) indicate that, for the livestock farms, greater intensity leads to greater efficiencies. The 'Time' variable within the explanation of inefficiency indicates how the average farm has moved relative to the frontier over time and, where significant, general cropping farms have moved away from the frontier, whereas both LFA cattle and sheep and mixed farms have moved closer. This is an important policy message as we would, from a resource usage aspect, require farms to become more efficient. What is emerging is that for some sectors the average farm is drifting away from the frontier, i.e. there is a growing disparity between the 'leaders', who are dictating the technological progress of that sector and the followers, who are lagging further behind.

A number of policy indicators have been used to indicate changes in the CAP (MacSharry and SFP) or the impact of various shocks (Foot and Mouth Disease [FMD]; BSE) on the industry. The impact is somewhat inconclusive. For the cropping sectors this seems to be insignificant for both reforms, whereas for dairying these have both had positive impacts on efficiency. For LFA cattle and sheep, only the 2005 reforms have had a small negative impact, and for mixed farms, the recent reforms were also negative, but the MacSharry reforms seem to have had a positive impact.

Consequently, there is a paucity of evidence for the impact of recent reforms on agricultural efficiency, though Barnes et al. (2010) did find a positive effect of recent reforms on English farming types. It is therefore difficult to estimate the possible impact of future CAP reform on the UK productivity and efficiency[15].

4.3 Summary

- Mean technical efficiencies of cropping farms (cereals and general cropping) have fallen over the period 1989 to 2009.

- Dairying, specialist cattle and LFA cattle and sheep farming systems have maintained their efficiencies, though specialist sheep farms have experienced a fall in efficiency levels.

- Mixed farming types have high mean levels of technical efficiency and these have been maintained throughout the period.

- Key drivers of efficiency seem to be farms which are more intensive and have better quality of land, a higher family farm income to gross margins, lower subsidies to gross margins, and younger farmers.

- Policy impacts are somewhat muted, but for some sectors (e.g. dairying), recent CAP reform has had a positive impact, whereas for others, such as mixed and LFA cattle and sheep farms, policy reform has had a negative impact.

[15] A view on the possible impacts of future CAP reform on productivity can be found at: http://www.aes.ac.uk/_pdfs/_pages/12_92.pdf.

Chapter 5: Raising the productivity of the Scottish agri-food sector[16]

Productivity is the cornerstone of competitiveness and is, by implication, an important driver for the future sustainability of Scottish agriculture. Unfortunately, international studies suggest that UK and Scottish productivity growth has lagged behind that of our main international competitors over the last 20 years. Moreover, there is a worrying (productivity) gap between our best and average farmers.

Poor productivity growth at the farm level has serious implications for the Scottish Government's declared growth plans for Scotland's wider agri-food industry. Drivers that have been identified in previous reviews and those which are particularly relevant for Scotland are outlined below:-

- *R&D funding trends:* The majority of studies in developed countries have linked their falls in productivity to a corresponding fall in research and development budgets in the 1980s and 1990s. There is certainly strong evidence to suggest that this has an influence and also offers some return to Government in terms of an investment. However, most of these studies argue for an increase in investment *per se*, and do not offer any indication of where funds should be allocated.

- *R&D funding patterns:* Further, there has been an undeniable shift away from productivity enhancing research towards public good work (Barnes, 2002; Thirtle and Holding, 2003). Only recently has work been conducted on examining whether the two goals of productivity and the public good can be reconciled (e.g. the concept of 'win-win' technologies). Moreover, perhaps for meeting the multiple goals of the Scottish Government, other indices, such as those compiled for water quality by SEPA, should be considered.

- *Industrial R&D funding*: the private sector and, in particular, the role of the levy boards have a strong influence in productivity growth as their work could be considered mostly 'near market' in nature. It is debateable, however, as to how well the private sector and levy boards assess the potential benefits of their investment on productivity.

- *The role of subsidies*: we find a strong negative effect of subsidies on farmer efficiency, i.e. those farms with a higher proportion of subsidy to output tend to perform less well. Subsidies, and entitlement to subsidies, tend to favour incumbent older generation farmers and protect producers from more adverse market risk. Hence the incentive for innovation-seeking behaviours may be dampened and also affect restructuring efforts.

- *The role of extension activity:* Thirtle and Holding (2003) argue that the loss of public funding for extension services in England has contributed to observed falls in productivity growth. Barnes et al. (2010) found higher performance in the efficiency of Scottish agriculture compared to English and Welsh agriculture and a factor in this may be the relative roles and funding of advisory work. In addition, how knowledge is exchanged and the role of significant rural actors, such as vets or other farmers, are quite significant in dictating the rate at which newer, more efficient techniques are adopted and these should be explored further.

- *Growing resource and environmental constraints:* Rutton (2002) outlined a number of studies which point to increasing pressures on the quantity and quality of input resources, which include significant reductions in soil fertility, and loss of abundance

[16] We are grateful to Julian Bell and Professor John Oldham (SAC) for some of the points made in this chapter.

in water resources. Further, increasing pressures on the agricultural system and a cause of growing variability of production will be a changing temperature. Climate change research is becoming an increasingly important dimension to understanding how productivity will be affected.

To address these issues there are a number areas which need to be explored by both researchers and industry.

- *Measuring productivity and efficiency:* This report has provided measures of productivity using Scottish data over a long time period to understand growth. Accurate measurement and monitoring of efficiency and productivity is required to understand productivity growth itself. Developed economies offer a good, robust set of data series which reflect agricultural activity on the ground. Many data sets are collected annually and present a long time series in which to explore the impact of drivers and to forecast future impacts of policy interventions. Productivity and efficiency measurement techniques are continually developing and it is important to integrate these within estimates to inform industry and Government on meeting set targets.

- *Measuring the impact of research:* Malcolm (2004) argues, if applied R&D is not correctly measured, it can lead to the roll out of ideas that take the industry in the wrong direction. Consequently, applied agricultural R&D projects could have built into them a common method for estimating the productivity benefits for the industry that should result from the project. A tool could be developed for providing a methodology to do this that has potential widespread application.

- *Measuring the impact of extension:* Improving understanding of the reasons why some farms perform better than others and using that understanding to promote more widespread beneficial actions. Barnes et al. (2010) have conducted work at the UK and EU level comparing performance and identifying farmers who have either consistently performed well (to use as examples of good practice) or have been in the lower bracket of performance. This work can be used to understand why some farmers perform better than others (Barnes et al., 2010). This EU and UK work could be easily translated to the Scottish context and provide a function for understanding how farmers improve or indeed lower their performance over time.

- *Measuring farmer response to innovation and extension:* Support for understanding the impact of knowledge transfer and exchange on the land use sector. The translation of research findings into productivity growth changes is a complicated process. This involves exploring the variety of transfer mechanisms which have been employed to improve our knowledge of how farmers understand, communicate and translate these into more efficient methods of food production. This also requires a focus on knowledge systems and their impact on performance and how to engender behavioural change[17]. At the same time, there should be a review of the success of current methods of technology transfer, e.g. one-to-one farm consultancy (incl. use of whole farm reviews), monitor farms, knowledge transfer events and publications. Such a review should also check on how well the latest ideas and techniques are understood by the frontline consultants interfacing with farmers.

[17] For further information contact: Alan.Renwick@sac.ac.uk.

- *Analysing technology adoption:* This involves an understanding of why some technologies, which seem to offer greater economic or environmental benefits, are not adopted by farmers, or indeed what the impact of past technologies have been on raising productivity. A large amount of research work within Scotland is aimed at improving productivity and translating this to the agri-food industries (e.g. improving production, cutting costs, reducing pollution). Work has also been undertaken on the correct measurement of impacts (e.g. Thomson et al., 2010). Extending this work to potential technologies, would provide a decision-making schema for the adoption of future technologies to achieve productivity growth.

- *Explore the options for increasing industry input into research*: Some of the gaps in R&D funding from the government could be made up through industry, or by joint industry-public sector initiatives. The levy boards have a particular part to play as they run applied research programmes with an emphasis on translating research findings into practice. However, a key area to be developed is the role and engagement of the farmer. On this point, tax credits are currently available for small companies to invest in R&D. More detail is perhaps needed on how farm and agricultural supply businesses can benefit directly from this. Another aspect is the role of farmer organisations and particularly co-operatives which, in some countries are highly organised and provide support for similarly market orientated research. Machinery and purchasing rings are commonplace in Scotland and perhaps advisory or financial incentives may encourage these to grow to allow capacity to fund future research, development or advisory schemes.

- *Extend productivity measurement to whole food supply chains:* Further work could extend productivity measures to the food supply chain[18]. Successful agri-food supply chains require a whole chain efficiency analysis to assess how well input suppliers, farmers, processors and retailers work together. This is especially important given the need for greater sustainability within the supply chain, as evidenced by recent initiatives such as the LEAN thinking campaign[19].

- *Explore the targeting of subsidies:* The reform of the CAP in 2013 may present a number of opportunities for the farming sector which allow greater capture of efficiency gains. In particular, the targeting of subsidies towards encouraging innovative behaviour, perhaps through extending the options available in the Scottish Rural Development Plan for training and education, or through support for cost sharing of expensive technologies on farm may be encouraged. Though, this would require some examination of the WTO agreements to see what is permissible.

- *Examine the role of other causal factors on productivity:* A small literature exists on the other factors which affect productivity and a variety of these have been tested or postulated in other regional environments which could be applied within the Scottish context. These include the development of human capital through education programmes and support for structural changes. In addition, the impact on productivity of regulatory and legal changes, such as the role of land ownership versus tenancy agreements, is a particularly crucial one for Scottish technological investment.

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[18] For further information contact: Andrew.Barnes@sac.ac.uk.
[19] See for example: http://www.igd.com/index.asp?id=1&fid=5&sid=45&tid=186.

References

Alston, J., Babcock, B., and Pardey, P. (Eds.) (2010). *The Shifting Patterns of Agricultural Production and Productivity Worldwide*. Midwest Agribusiness Trade and Research Information Center (MATRIC).

Barros, A. L. M. (1999). *"Capital, Productividade e Crescimento da Agricultura: O Brasil de 1970 a 1995."* Universidade de Sao Paulo, Esalq, Piracicaba.

Barnes, A.P., Revoredo-Giha, C., Sauer, J. Elliott, J. and Jones, G. (2010). A report on technical efficiency at the farm level 1989 to 2008. Final Report to Defra, London.

Carter, C. A., Chen, J. and Chu, B. (1999). *Agricultural Productivity Growth in China: Farm Level versus National Measurement*. Agriculture and Resource Economics Working Papers, Department of Agricultural and Resource Economics, UCD, UC Davis. Available online at: http://escholarship.org/uc/item/51j0k8kv#page-1

da Silva Dias, G. L., and Amaral, C. M. (2000). *Brasil: Uma Decada em Transicao*. Edited by R. Baumann. Rio de Janeiro: Editora Campus.

European Commission (2010). *European Competitiveness Report 2009*. EU, Brussels.

Evenson, R. E. Pray, C. E. and Rosegrant, M. W. (1998). *Agricultural research and productivity growth in India*. International Food Policy Research Institute, Research Report 109.

Fuglie, K. (2010). Total Factor Productivity in Global Agricultural Economy: Evidence from the FAO. In: Alston, J., Babcock, B., and Pardey, P. (eds.) (2010). *The Shifting Patterns of Agricultural Production and Productivity Worldwide*. Midwest Agribusiness Trade and Research Information Center (MATRIC).

Jin, S, Huang, J. and Rozelle, S. (2010). Agricultural productivity in China. In: Alston,J, Babcock,B, and Pardey,P (eds.) (2010). *The Shifting Patterns of Agricultural Production and Productivity Worldwide*. Midwest Agribusiness Trade and Research Information Center (MATRIC).

Lin, Justin Yifu. (1992). "Rural Reforms and Agricultural Growth in China." *American Economic Review*, 82, pp. 34-51.

Lence S. H. (2010). The agricultural sector in Argentina: major trends and recent developments. In: Alston, J., Babcock, B., and Pardey, P. (eds.) (2010). *The Shifting Patterns of Agricultural Production and Productivity Worldwide*. Midwest Agribusiness Trade and Research Information Center (MATRIC).

Mahadevan, R. (2003). "Productivity growth in indian agriculture: the role of globalization and economic reform." *Asia-Pacific Development Journal* 10:2, pp. 57-72.

Malcolm,B. (2004). Where's the Economics? The Core Discipline of Farm Management has gone missing! *Australian Journal of Agricultural and Resource Economics*, 48:3, pp. 395-417.

Mullen, J. D., (2010). Trends in investment in agricultural R&D in Australia and its potential contribution to productivity. *Australian Agribusiness Review,18, pp. 18-29*

Normile, M. A., and Leetma, S. E. (2004). *US-EU food and agriculture comparisons.* Economic Research Service, US Department of Agriculture. Washington DC.

Nossal, K,. Sheng, Y. (2010). *Productivity growth: trends, drivers and opportunities for broadacre and dairy industries. Australian Commodities*, 17 .1, pp.216-230.

Paul, C. J. M., Johnston, J. E. and Frengley, G. A. G. (2000). Efficiency in New Zealand Sheep and Beef Farming: The Impacts of Regulatory Reform, *Review of Economics and Statistics*, 82:2, pp. 325-337.

Praduman, K. and Surabhi, M. (2006). Agricultural Productivity Trends in India: Sustainability Issues. Agricultural Economics Research Review 19, pp. 71-88.

Rada, N. E., Buccola, S. T. and Fuglie, K. O. (2009). Brazil's Rising Agricultural Productivity and World Competitiveness. *Paper prepared for presentation at the Agricultural & Applied Economics Association 2009 AAEA & ACCI Joint Annual Meeting,* Milwaukee, Wisconsin, July 26-29, 2009.

Rae, A. N., Nixon, C. and Lattimore, R. G. (2003). Adjustment to Agricultural Policy Reform - Issues and Lessons from the New Zealand Experience. *Paper presented at the Policy Reform and Adjustment Workshop,* October 23-25, 2003, Imperial College London, Wye Campus.

Rutton, V.W. (2002). Productivity Growth in World Agriculture: Sources and Constraints. *Journal of Economic Perspectives. 16: 4, 161–184*

Scotland Food and Drink (2010). Fresh Thinking: Industry Strategy. SFD, Edinburgh. Available at:- http://www.scotlandfoodanddrink.org/media/17978/industry%20strategy%20refresh%20doc.pdf

Scottish Government (2007). *The Government Economic Strategy*. Scottish Government, Edinburgh.

Sheng, Y., Zhao, S., and Nossal, K. (2011). *Productivity and farm size in Australian agriculture: reinvestigating the returns to scale.* Final Report to ABARES (project: 43025).

Swinnen, J. F. M, Van Herck, K. and Vranken, L. (2010). Shifting patterns of agricultural production and productivity in the former Soviet Union and Central and Eastern Europe. In: Alston, J., Babcock, B., and Pardey, P. (eds.) (2010). *The Shifting Patterns of Agricultural Production and Productivity Worldwide*. Midwest Agribusiness Trade and Research Information Center (MATRIC).

Thirtle, C. and Holding, J.. (2003). *Productivity in UK agriculture: causes and constraints.* Report to Defra.

Tong, H. and Fulginiti, L. E. (2003). Chinese Regional Agricultural Productivity in the 1990's. *Paper presented at AAEA meeting*, Long Beach, California, July 2002. Available online at: http://129.3.20.41/eps/othr/papers/0502/0502012.pdf

Tyers, R and Anderson, K. (1986). *Distortions in world food markets: a quantitative assessment.* World Development Report, World Bank, Washington.

Zhao, S, Sheng, Y and Mullen, JD (2010). *Has growth in productivity in Australian broadacre agriculture slowed?.* Contributed paper, 54th Conference of the Australian Agricultural and Resource Economics Society, February 10-12, 2010, Adelaide.