Department for Environment Food & Rural Affairs

Characteristics of high performing grazing livestock farms in England

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1 Contents

1 Contents 1
2 Executive Summary 2
3 Introduction 3
3.1 Purpose 5
3.2 Definitions 5
3.3 Data and Methods 5
4 Results 7
4.1 Breakdown of variation in performance 7
4.2 Farm characteristics related to farming performance 9
4.2.1 Business Decisions 10
4.2.2 Farm characteristics 21
5 Conclusions 24
6 Appendix A 27
6.1 Breakdown of variation in performance 27
6.2 Farm characteristics related to farming performance 28
6.2.1 Fixed effects structure 28
6.2.2 Random effects structure 31
7 Appendix B 32
7.1 Spatial distribution of farm business output/input ratio 34
7.2 Relationship between farm type and performance 35
7.3 Relationship between year and performance 36
7.4 Model diagnostic plots 36
7.5 Model coefficient estimates 38
8 References 40

2 Executive Summary

'Performance' in this report refers to economic performance, i.e. a farm business' ability to turn monetary inputs into monetary outputs. This analysis covers grazing livestock farms in England for the years 2010/11 – 2016/17, and examines two aspects of economic performance:

1) Farm business – which includes all the inputs and outputs for the farm business as a whole, including agricultural activities as well as diversified activities, and inputs and outputs associated with agri-environment schemes and direct payments.
2) Agriculture portion – which encompasses the inputs and outputs connected solely with agricultural activities.

There was a great deal of variation in performance for grazing livestock farms. Less than 1% of this variation was found to be related to large-scale geographic factors, such as regional differences in soil and climate. Around 25% was attributed to variation over time, such as adverse weather events. Over 70% was related to the characteristics of the farm business itself, such as differences in management ability and local geographic effects (e.g. small-scale variation in land quality).

Farm specific variables relating to performance were examined further, summarised in Table 1.

Table 1. Factors which were found to be related to performance, ↑ indicates a positive relationship with performance, ↓ indicates a negative relationship, and – indicates no relationship. The size of the arrow indicates the strength of the evidence, larger arrows indicating more confidence in the result and smaller arrows indicating less confidence.

Variable	Farm Business	Agriculture	Comments
Debt	↓	↓	More indebted farms tended to have reduced agricultural and farm business performance.
Diversification	–	↓	Farms which devoted more resources to diversified enterprises tended to perform less well in the agricultural portion of the business, but there was no relationship at the farm business level.
Specialisation	↑	↑	Lowland farms which were more specialised in their agricultural enterprises tended to also be better performers, whilst farms in less-favoured areas (LFA) had no relationship between specialisation and performance.
Agri-environment scheme payments	↑	↑	Membership of agri-environment schemes was associated with better agricultural and farm business performance.
Organic	↑	–	Organic farms tended to also have better performing farm businesses, but no relationship was found for the agricultural portion of the business.

Unpaid labour	↓	↑↓	When including an imputed cost for unpaid labour, farm businesses which utilised large proportions of unpaid labour tended to have poorer performing farm businesses. For the agricultural portion of the business the relationship was different between lowland and LFA farms; agricultural performance for LFA farms tended to reduce with increasing reliance on unpaid labour, whilst it increased for lowland farms.
Contracting	–	↑	Those farms which either used contractors to rear their livestock, or worked as contractors themselves tended to have better agricultural performance, while no relationship was found for farm business performance.
Farm assurance schemes	↑	↑	Membership of a farm assurance scheme was associated with increased farm business and agricultural performance.
Concentrated feed costs	–	↓	Farms which spent more on concentrate feed per head of livestock tended to have poorer agricultural performance, while no relationship was found for the farm business.

3 Introduction

There is a great deal of variation in the financial returns received by farmers in England. Farms with similar characteristics such as size, geography, enterprise type, might be expected to achieve similar incomes, but often do not. The 'performance' of farm businesses refers to the ability to convert monetary inputs into outputs (i.e. revenues), thus a higher performing farm would generate higher outputs from a given level of inputs in comparison to a less well performing farm business. For instance, in 2017/18 in England, the top 25% performing farms achieved on average £134 of outputs for every £100 of inputs (when including an imputed cost for unpaid labour), while the bottom 25% achieved just £73.

The variation in the performance of farms in England in 2017/18 can be seen in Figure 1, where performance was calculated as the ratio of outputs to inputs (including an imputed cost for unpaid labour). Perhaps surprisingly only 53% of farms broke even overall (those that achieved £100 or more of outputs, for every £100 of inputs, shaded in light green in Figure 1a). Even fewer farms (22%) broke even when considering only the agricultural portion of the business[1]; for every £100 of inputs the highest performing 25% achieved £112 of outputs on average, while the lowest performers received £47 (Figure 1b).

[1] The agricultural portion of the business excludes income from diversified enterprises, Agri-environment Schemes and Direct Payments.

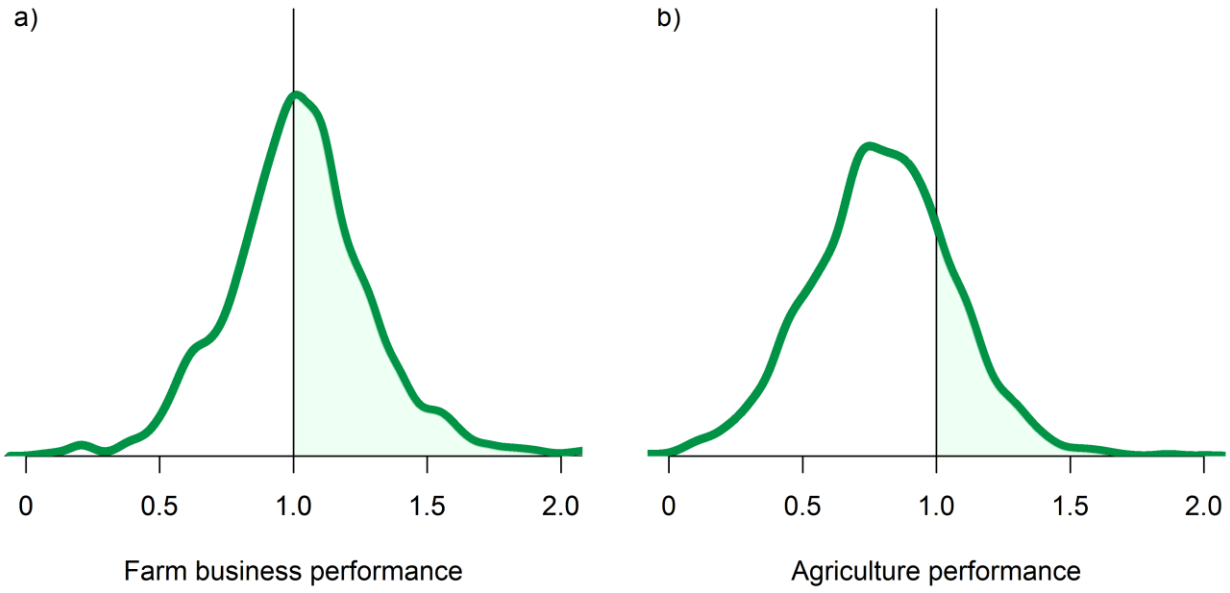

Figure 1. The distribution of farm performance scores for farms in England in 2017/18, calculated as the ratio of outputs to inputs (including an imputed costs for unpaid labour). (a) The farm business as a whole and (b) the agricultural portion of the business only. The proportion of farms who broke even (received £100 of outputs or more for every £100 of inputs) are shaded in light green, and equates to 53% of farms for the farm business, and 22% of farms for the agricultural portion of the business.

The average performance of English beef and sheep farms lags behind that of a number of other countries, and regions (Kimura & Le Thi, 2013). In this research, of the countries studied[2], Australian beef and sheep farms were found to be on average the most productive, achieving the largest output per $100 of inputs, whilst those in England were found to be the least productive, and even the top 25% performers of English farms were out performed by the average farm from Australia, Germany and the USA. However variation within countries was often greater than that between countries. A key finding which has been echoed from other studies is that there is no single factor that makes some farms better than others, rather high performing farms tend to be better at most processes throughout the farm (Kimura & Le Thi, 2013; Redman, 2015; Wilson, et al., 2012).

Across all countries and farm types, Kimura and Le Thi (2013) found that low performers relied much more on support as a source of farm income than the high performers, a pattern which is true of English farms too (Defra, 2018). For some, farming is not a business but rather a way of life, many (usually small) farmers fully realise that they could achieve higher incomes by selling or renting their assets to others and taking a salaried job (Wilson, et al., 2013). However, the lifestyle of a farmer offers more than just an income, often independence, status, work satisfaction and access to housing are cited as the dominant reasons for accepting lower financial incomes (Wilson, et al., 2013; Redman, et al., 2018). Added to this is the fact that many lower performing farms do not realise they are below average (Redman, et al., 2018), and so do not see the need for change. In summary, while there may be a great potential for improvement, not all of this potential will be realised as many will not have the capacity, or the appetite, to change. However

[2] Australia, Belgium (Flanders), Canada, Germany, Italy, Netherlands, England & the USA.

through identifying potential drivers of high performance there may be capacity for some to improve their performance through relatively small changes to their farm business.

3.1 Purpose

The purpose of this report is to provide an up to date assessment of the characteristics associated with economic performance for grazing livestock farms in England. This work was done in parallel with analysis looking at the characteristics associated with economic performance for dairy (Jones, 2020b) and cereal (Jones, 2020a) farms.

3.2 Definitions

In this report, by 'performance' we are referring to the economic performance of a farm. For many farmers this might describe only one aspect of what farming performance means to them, since other benefits and lifestyle choices might be just as, if not more, important than economic gain. However, for the purposes of this report we are concerned with the ability of farm businesses to turn monetary inputs into monetary outputs, which can be expressed as a ratio:

$$\frac{\text{Income generated by the farm}}{\text{Costs associated with it}}$$

Throughout the analysis presented here (unless explicitly stated), an imputed cost for unpaid labour using the market rate has been included as a cost, removing the inherent advantage of receiving labour for free. However, rent was not imputed for owner occupied farms because we were interested in assessing any relationship with tenancy explicitly, rather than representing the full economic cost of owner occupied/tenanted farms.

Within the Farm Business Survey of England[3], each farm business is broken down into four cost centres; agriculture, diversification, direct payments and agri-environment schemes. Costs and outputs are apportioned as appropriate between these cost centres. All the analysis in this report has been produced using both farm business costs and outputs (i.e. including all cost centres), and also for the agricultural portion of the business alone.

3.3 Data and Methods

Data was taken from the Farm Business Survey of England for 2010/11 – 2016/17. Farms were included in the analyses if they were classified as having a farm type[4] of lowland grazing livestock or LFA (Less Favoured Areas) grazing livestock in at least three of these years, 584 farms met this condition, with 299 of these surveyed in all seven years, and 434 providing data in at least five years. The majority (91%) of the farms were always classified as grazing livestock, with the remainder being classified as either mixed or dairy farms in a minority of years. Grazing livestock farms are predominantly involved in beef and/or sheep

[3] https://www.gov.uk/government/collections/farm-business-survey

[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/365564/fbs-uk-farmclassification-2014-21oct14.pdf

production. Dairy farms are not part of the grazing livestock type, although a few farms which are classified as grazing livestock due to their beef and sheep enterprises also have dairy cattle.

The analysis was completed in two phases; firstly the ratio of outputs to inputs was used to understand how much of the variation in economic performance can be attributed to the location of each farm (i.e. large scale geography), changes in time (e.g. price changes from year to year, or agricultural policy changes) and how much can be attributed to factors which are specific to each farm. Secondly, to expand on this analysis, and examine in more detail the farm characteristics which were associated with farming performance, performance was defined as the linear relationship between inputs, influencing variables and outputs. A detailed breakdown of data and methods used can be found in Appendix A.

All results presented in the second section are in the form of model predictions, which allow us to draw conclusions about the relationship between a farm/farmer characteristic and economic performance, once the impact of other variables have been accounted for. Predictions of outputs (the response variable used) were then divided by inputs to convert the model predictions into estimates of performance. In all instances, predicted values should be treated with caution since they are an estimation made based on a combination of average values of the other variables, which may not be representative of actual farms, and it would be uninformative to compare absolute predicted values across different pieces of analysis (i.e. those relating to other farm types), instead, consider the directional relationships between significant variables and economic performance as an indicator of the nature of the relationships.

The analysis presented here is principally directed towards identifying correlations and patterns in the data, and should not be used to infer causation. Just because two variables are highly related to one another, does not mean that one is the driving change in the other. For instance, one often cited example is that of the tight correlation between falling margarine consumption and falling divorce rate in the USA (Fletcher, 2014). Despite a very similar pattern in margarine use and divorce rate over time, it is accepted that neither is driving the change in the other. This example is often used to highlight the importance of thinking critically about possible causal mechanisms which may or may not lie behind correlations. While it is not possible to determine any causation with the analysis presented here, understanding the characteristics of high performers will allow informed decisions to be made around facilitating higher performance, both for the farmer and policy maker.

4 Results

Analysis was separated into two distinct sections; firstly attempting to understand how much of the variation in economic performance can be attributed to the location of each farm (i.e. large scale geography), changes in time (e.g. price changes from year to year, or agricultural policy changes) and how much can be attributed to factors which are specific to each farm. This final driver of performance – farm characteristics – is further explored in the second phase of analysis.

4.1 Breakdown of variation in performance

The aim for this section of the analysis was to understand how much of the variation in economic performance across farms in England could be attributed to changes in geography, how much to changes over time, and how much to characteristics specific to each farm.

To do this the output/input ratio[5] of each farm in each year was analysed. The National Character Area[6] (NCA) which each farm was predominantly located in was used to represent the geography of each farm. NCAs are a natural subdivision of England based on a combination of landscape characteristics, biodiversity, geology and economic activity. There are 159 National Character Areas and they follow natural, rather than administrative, boundaries.

Figure 2 shows the spatial distribution of farm performance based on agricultural inputs and outputs for grazing livestock farms for the years 2010/11 – 2016/17 (see Figure 20, Appendix B, for the farm business distribution). There is little sign of any wider regional effects, with most areas having a mix of high and low performers. This is reflected in Table 2, where NCA, accounts for 0.1% of the total variability in the output/input ratio for the farm business, and less than 0.01% of total variability in the output/input ratio for agriculture. These will likely be underestimates due to the limited geographic information available for FBS farms, but it is nevertheless much lower than year to year variation within farms, which accounted for 25% and 27% of variability in output/input ratios for the farm business and agriculture respectively. Year to year variation can be caused by factors such as poor weather at lambing time, disease outbreaks or price fluctuations. Gradual changes in efficiency over the seven years of data, such as the improvements that may happen when management passes from one generation to the next, will also contribute to the year to year variation.

The variability between farms, due to farm characteristics such as management practices or farm size, accounts for 75% of total variation in the farm business output/input ratio, and 73% of the total variation in agricultural output/input ratios. Variability between farms could be due to factors which a farmer might be able to influence, such as the skill or knowledge of the farmer and the livestock kept, as well as factors which are more difficult or

[5] The output/input ratio is the ratio of outputs (either farm business or agriculture outputs) to inputs (either farm business or agriculture inputs. Both inputs include an imputed cost for unpaid labour calculated at the market rate).

[6] National Character Areas, formerly known as Joint Character Areas (JCAs) are a subdivision of England into 159 areas based on landscape features. See https://www.gov.uk/government/publications/national-character-area-profiles-data-for-local-decision-making

impossible to change, such as local geographic factors, for instance, soil quality. This source of variation is explored further in the following stage of analysis.

Table 2. Sources of variation within the dataset

	Farm business		Agriculture	
Component	Variance	% of total	Variance	% of total
Geographical variation (NCA)	0.16	0.1	0.03	<0.01
Year to year variation within farms	68.48	24.8	49.11	27.0
Farm to farm variation	207.73	75.2	132.87	73.0

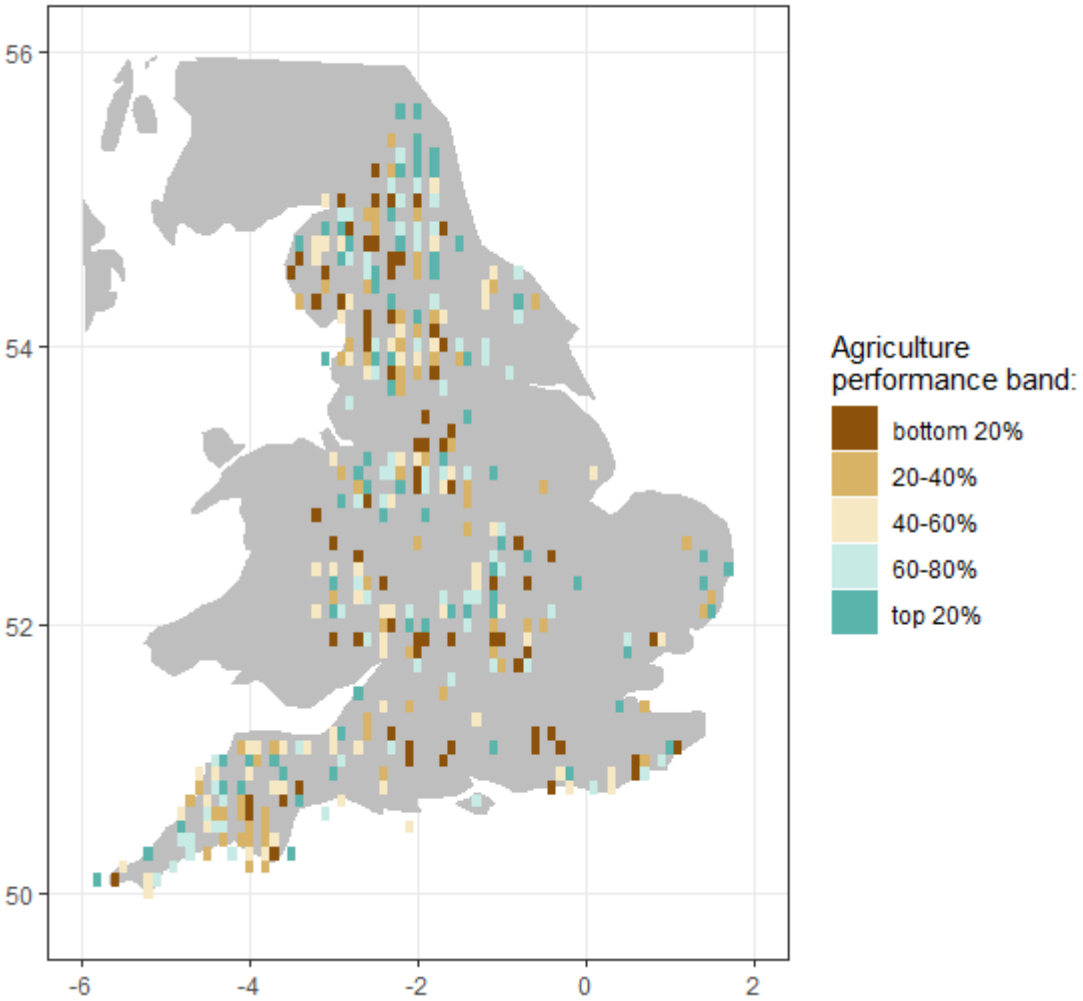

Figure 2. Spatial distribution of output/input ratios calculated from agricultural inputs and outputs only. Mean performance for farms falling within each 10km grid square are shown.

4.2 Farm characteristics related to farming performance

This section of the analysis considered variables which are particular to a farm. For the modelling in this section, the relationship between monetary inputs and monetary outputs was considered, alongside other variables which may influence that relationship. A variety of variables and their interactions were used in the modelling, chosen largely on the basis of theory, or for data quality issues. For instance, it was not possible to include some variables relating to business management practices (e.g. the use of financial plans) because this data was not collected for all farms, resulting in a very small sample size. For a full list with descriptions see Table 5 in Appendix A.

A summary of the variables found to be related to farm business or agricultural performance is in Table 3. Full model outputs (see Table 6,

Table 7), diagnostic plots (see Figure 23, Figure 24) and the results showing the general relationship for LFA/non-LFA farms (see Figure 21) and year (see Figure 22) can be found in Appendix B.

The results in this section have been grouped into 'farm characteristics' and 'business decisions', on the basis that, at least in principle, it may be easier for a farm business to make changes to its management decisions than to the characteristics of the farm.

Of those variables which were found to have a relationship with either farm business or agricultural outputs, each is discussed in turn in the following section. To visualise the results, predictions have been made using the fitted models, and those predictions of monetary outputs converted to output/input ratios, those farms with higher output/input ratios can be considered to be better performers. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

Table 3. Variables found to be related to either farm business or agricultural performance. See Table 5 in Appendix A for the full list of variables considered and their descriptions. P-values are in bold where variables were found to be related to either farm business or agricultural performance.

	Farm business performance		Agricultural performance	
	F-value	p-value	F-value	p-value
Costs (farm business or agriculture)	250	**<.0001**	267	**<.0001**
Farm type (LFA or non-LFA)	1.75	0.1859	9.61	**0.002**
Land area	74.1	**<.0001**	28.9	**<.0001**
Year	51.8	**<.0001**	39.6	**<.0001**
Debt	15.1	**0.0001**	2.85	0.0912
Farmer age	5.12	**0.0237**	3.76	0.0526
Farmer age^2 (quadratic term)	8.65	**0.0033**		
Diversified costs			22.1	**<.0001**
Agri-environment scheme membership	3.45	**0.0081**	4.03	**0.0029**
Income from agri-environment schemes	4.05	**0.0442**	263	**<.0001**
Farm assurance scheme membership	23.7	**<.0001**	17.6	**<.0001**
Agricultural specialisation	0.08	0.7719	0.24	0.6215
Organic	19.7	**<.0001**		
Unpaid labour	24.7	**<.0001**	3.24	0.0719
Bought feed costs			10.57	**0.0012**
Contract Rearing			5.7	**0.0171**
Costs and area interaction	24.9	**<.0001**	18.5	**<.0001**
Costs and debt interaction			6.22	**0.0127**
Farm type and specialisation interaction	5.96	**0.0147**	4.16	**0.0416**
Farm type and unpaid labour interaction			6.95	**0.0084**

4.2.1 Business Decisions

This section concentrates on variables which may affect economic performance, which are particular to each farm in each year. Here we concentrate on variables which might be

thought of as business decisions and which are amenable, at least in theory, to change. Further on we consider some variables which are largely beyond the scope of a farmer to change.

4.2.1.1 Debt

'Indebtedness', in this case, was measured as total interest payments as a proportion of total costs. Farms with greater levels of debt will pay higher interest charges, and larger farms tend to take on more debt (Defra, 2019). Making this measure proportional to total costs provides an indicator of debt which is independent of the economic size of the business. Debt was found to have a strong relationship with performance, farms with greater indebtedness tended to be poorer performers (see Figure 3). This pattern was found for both the farm business as a whole and the agricultural portion of the business.

This finding, that farms who are heavily indebted also tended to be poorer performers, seems to be a consistent trend and has been found previously for beef and sheep farms in New Zealand (Paul, et al., 2000), Spanish livestock producers (Iraizoz, et al., 2005), English farms across all farm types (Hadley, 2006) as well as English cereal (Langton, 2011) dairy (Langton, 2013) and grazing livestock farms (Langton, 2012). It is possible that the financial constraints faced by indebted farms restrict their ability to adjust to changing markets or make investments and thus reduces their performance. It is also possible that poorer performing farms are forced into greater levels of debt to their cover unexpected shortfalls in income. The degree of variability in the data is an important consideration here, many farms with moderate levels of debt performed well, while many farms with very little debt were amongst the poorest performers.

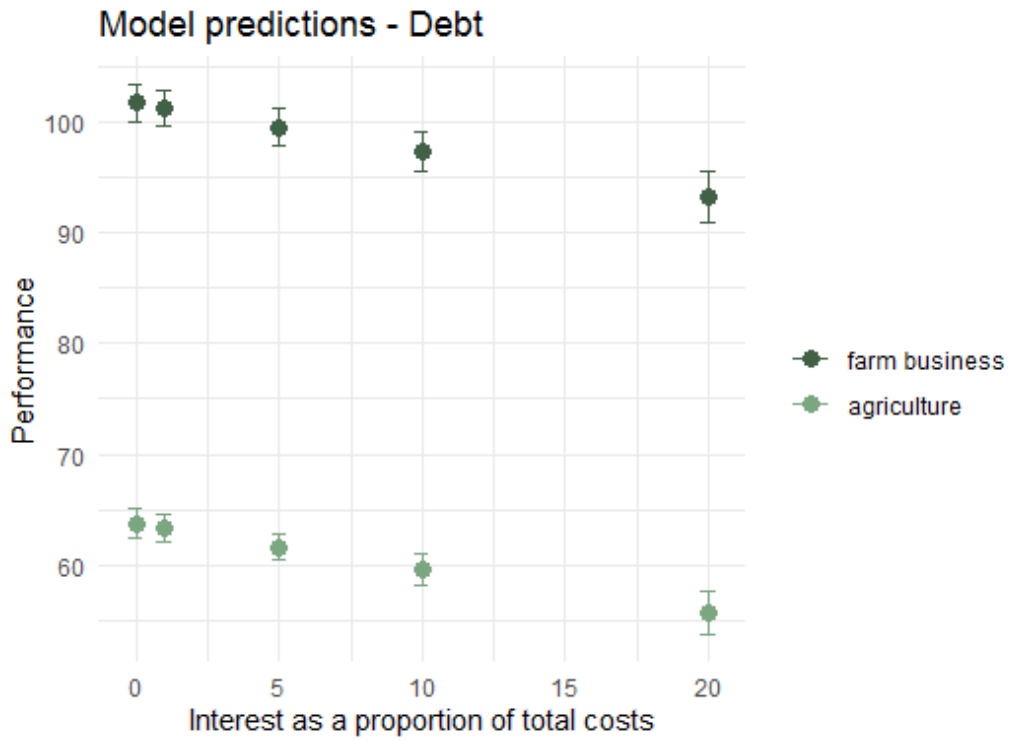

Figure 3. The relationship between debt and performance for both the farm business and agriculture models. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

4.2.1.2 Diversification

Diversification refers to enterprises that a farm business undertakes outside agriculture, such as tourism or renting out farm buildings, but which utilise the farm's resources. The extent of diversification was measured by looking at the proportion of business costs associated with diversified enterprises.

Diversification was associated with lower agricultural performance (see Figure 4). This might be expected as time and resources diverted away from agriculture might be expected to reduce the outputs from agriculture, i.e. farms may not hire more staff to set up/run diversified enterprises and therefore divert management capacity away from agriculture.

No relationship was found for the farm business, suggesting that increased investment in diversified activities doesn't have an impact on overall farm business performance. This suggests that although farms who invest more in diversified enterprises tend to have lower agriculture performance, this is then compensated for in other parts of the business resulting in a farm business performance which is unaffected by diversification.

Previous analysis on grazing livestock farms in England (Langton, 2012) found that increased diversification was associated with an increase in farm business performance, and there was a suggestion that it might be associated with reduced agriculture performance. The associated increase in farm business performance was however only slight, suggesting that there has been no material change in the relationship between this variable and performance since the previous analysis was done.

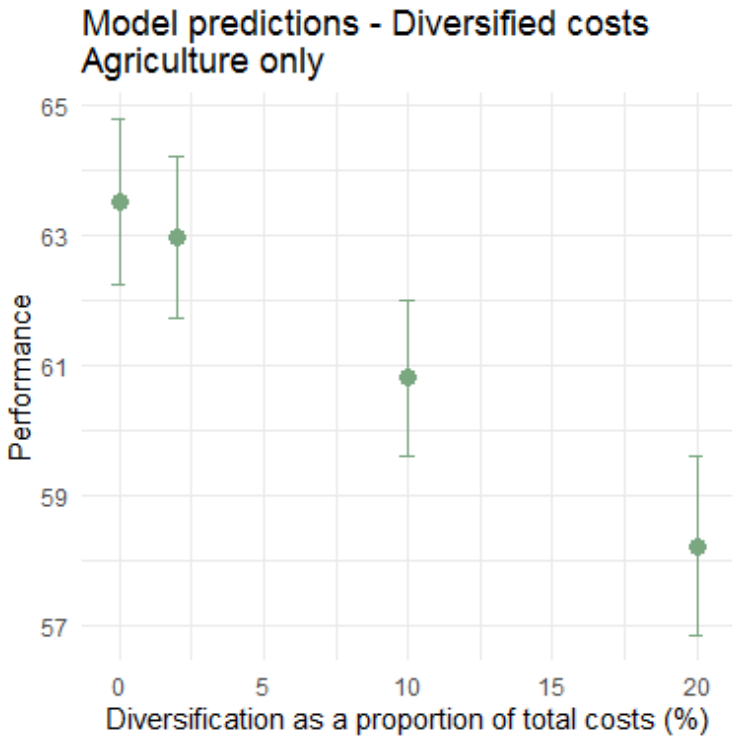

Figure 4. The relationship between costs associated with diversified enterprises and agricultural performance. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

4.2.1.3 Agricultural specialisation

The specialisation of each farm was assessed using a method based on the proportion of Standard Labour Requirement (SLR) from 34 different agricultural enterprises including a variety of crops and livestock. This is similar to the approach used in previous analysis (Clothier, et al., 2008; Langton, 2012). This measure is an index, where 100 represents a fully specialised farm which engages in only one agricultural enterprise (of the possible 34), and 0 represents a very un-specialised farm engaging equally in all 34 agricultural enterprises. For a full list of the 34 possible agricultural enterprises see Appendix A.

In general, increasing agricultural specialisation was associated with increased performance for both the farm business and in agriculture, and this general conclusion has been found elsewhere (Redman, et al., 2018). However this masks some complexities, the relationship between agricultural specialisation and performance differs between farms in Less Favoured Areas (LFA), which are more upland in character, and those in more lowland areas (see Figure 5). For those in lowland areas, increasing specialisation was associated with increased performance. However in the LFA, increasing specialisation is not related to increased performance. This pattern was consistent across both agricultural performance and farm business performance.

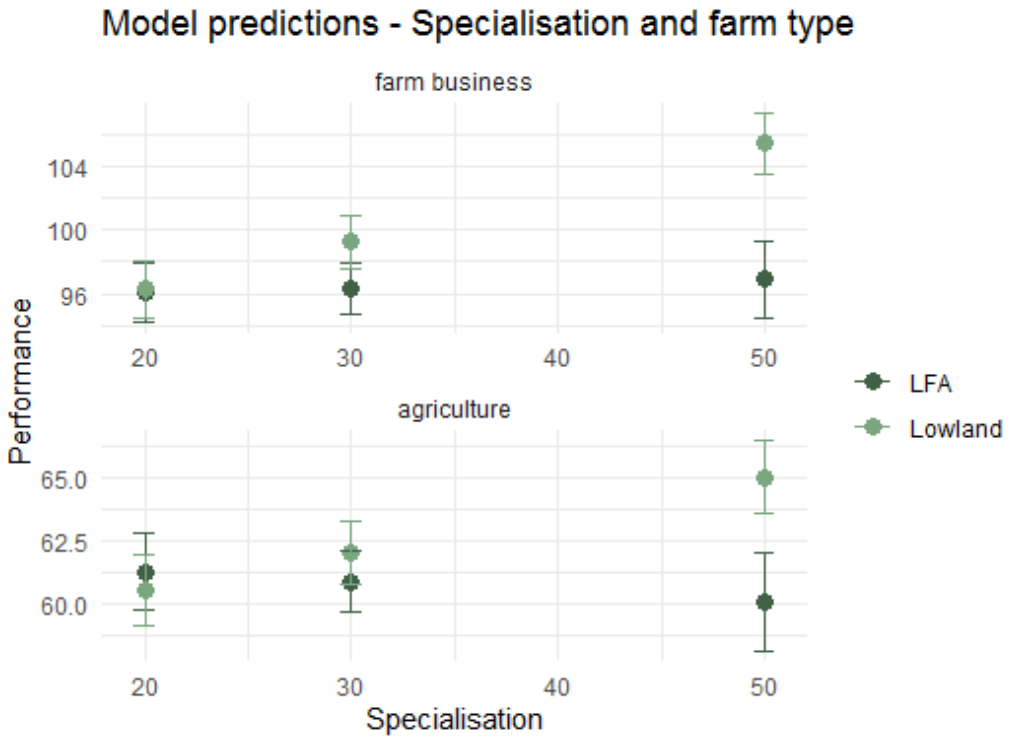

Figure 5. The relationship between agricultural specialisation, farm type and farm business and agriculture performance. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

It is possible that for farms in LFA, where farming conditions are more challenging, there is a greater risk of losses from specialisation, and so fewer farms pursue that route. For instance, challenging weather conditions might interfere with, and reduce outputs from lambing, if these farms also had other enterprises such as cattle their potential losses might be buffered. In the lowland, where farming conditions are less inclement,

specialisation might bring greater rewards to those who exploit their local conditions through specialisation. Figure 6 demonstrates that the majority of LFA farms tended to be relatively unspecialised, while lowland farms tended to be more specialised, with a small minority being highly specialised. It is noticeable that a significant minority of lowland farms in the sample kept only sheep or only beef, whereas the vast majority of farms in the LFA had a mixture of the two (46% and 19% of farms specialised in either beef or sheep in the lowlands and uplands respectively).

Langton (2012) also found that lowland grazing livestock farms which were more specialised tended to be better performers. A mixture of relationships have been reported in the literature, some work found a negative relationship across all farm types (Hadley, 2006) and other work found a positive relationship (Barnes, 2008) suggesting that the pattern is complex, and needs to be considered carefully when drawing conclusions.

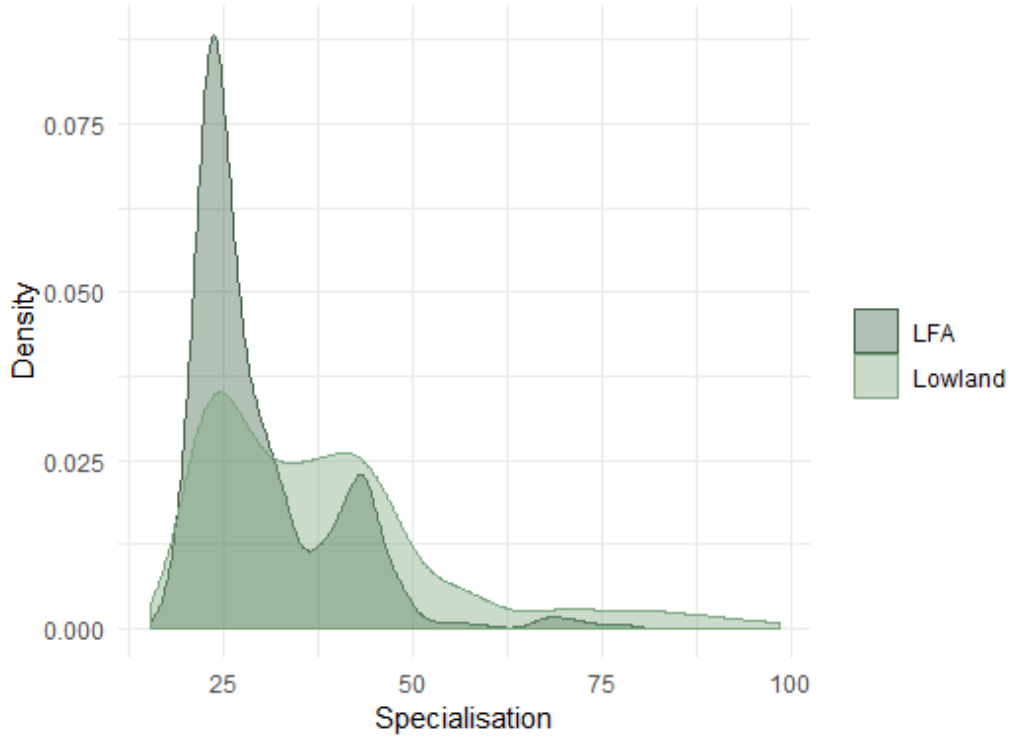

Figure 6. The distribution of specialisation scores for the farms used in the analysis.

4.2.1.4 Agri-environment schemes

Farms were categorised into agri-environment schemes based on the payments received by each farm in each year; where a farm received payments from more than one scheme in a year, the farm was assigned to the highest value scheme. Entry Level Stewardship (ELS) is considered a lower burden scheme with most of the scheme's options being relatively undemanding and many relating to boundary features, rather than the productive agricultural area. Farms often need to make few changes to existing practices in order to qualify. The previous Countryside Stewardship (CS), Environmentally Sensitive Area (ESA) and Higher Level Stewardship schemes were/are more onerous for farms, requiring more commitment and greater changes to agronomic practices. Schemes grouped into the 'other' category include organic aid, the Woodland Grant scheme, Farm Woodland Premium scheme and the post 2015/16 Countryside Stewardship scheme.

In general, membership of the more onerous agri-environment schemes (such as Higher Level Stewardship) was associated with higher performance for both the farm business and agriculture alone (see Figure 7a). Langton (2012) also found that grazing livestock farms which engaged more in agri-environmental practices tended to have better performing farm businesses.

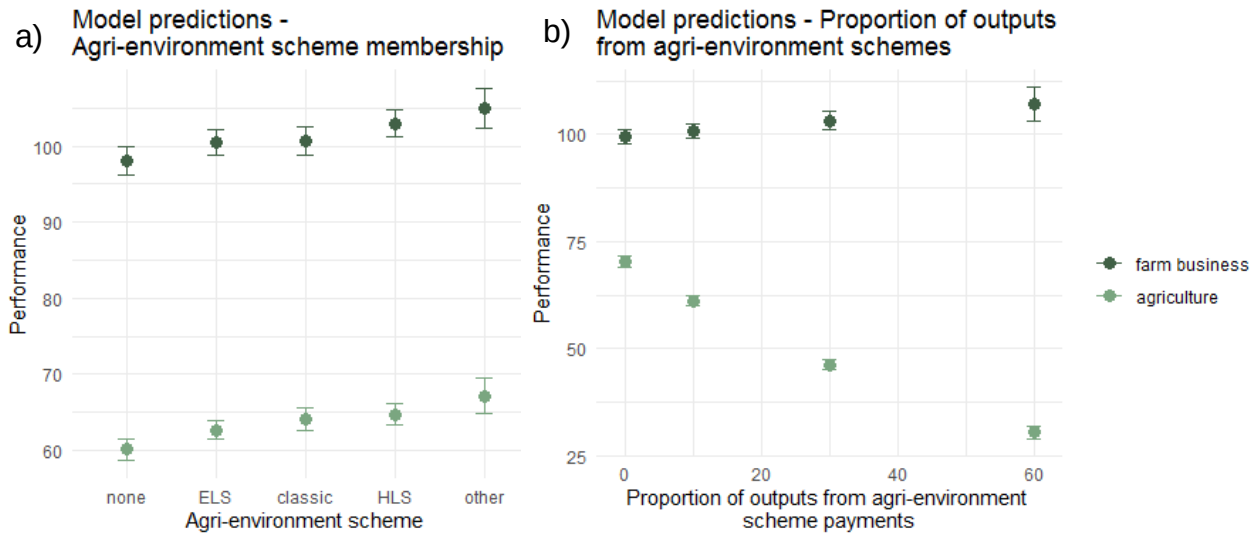

Figure 7. The relationship between agri-environment scheme membership (a), the proportion of total outputs from agri-environment scheme payments (b) and performance. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. ELS = Entry Level Stewardship; classic = Countryside Stewardship and Environmental Stewardship schemes; HLS = Higher Level Stewardship. Other = organic aid, the Woodland Grant scheme, Farm Woodland Premium scheme and the post 2015/16 Countryside Stewardship scheme. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

This pattern is echoed when considering the relationship between performance and the proportion of total outputs from agri-environment scheme payments. Increasing reliance on agri-environment scheme payments was associated with increased farm business performance, and reduced agriculture performance (see Figure 7b). This suggests that agri-environment scheme payments received offset loss in agricultural output, or that the business is able to access other forms of revenue.

There is some indication that there may be an interesting interaction between agri-environment scheme membership and reliance on agri-environment payments (see Figure 8). It appears that greater reliance on payments from agri-environment schemes, indicating a greater involvement and investment in environmental practices, was associated with reduced agricultural performance regardless of the scheme. This pattern of reduced performance with higher reliance on agri-environment payments is also true for the farm business for participants in ELS, but the opposite pattern was found for farm businesses which are in HLS or other schemes. This suggests that from the farmer's perspective, some schemes were more economically beneficial to join than others.

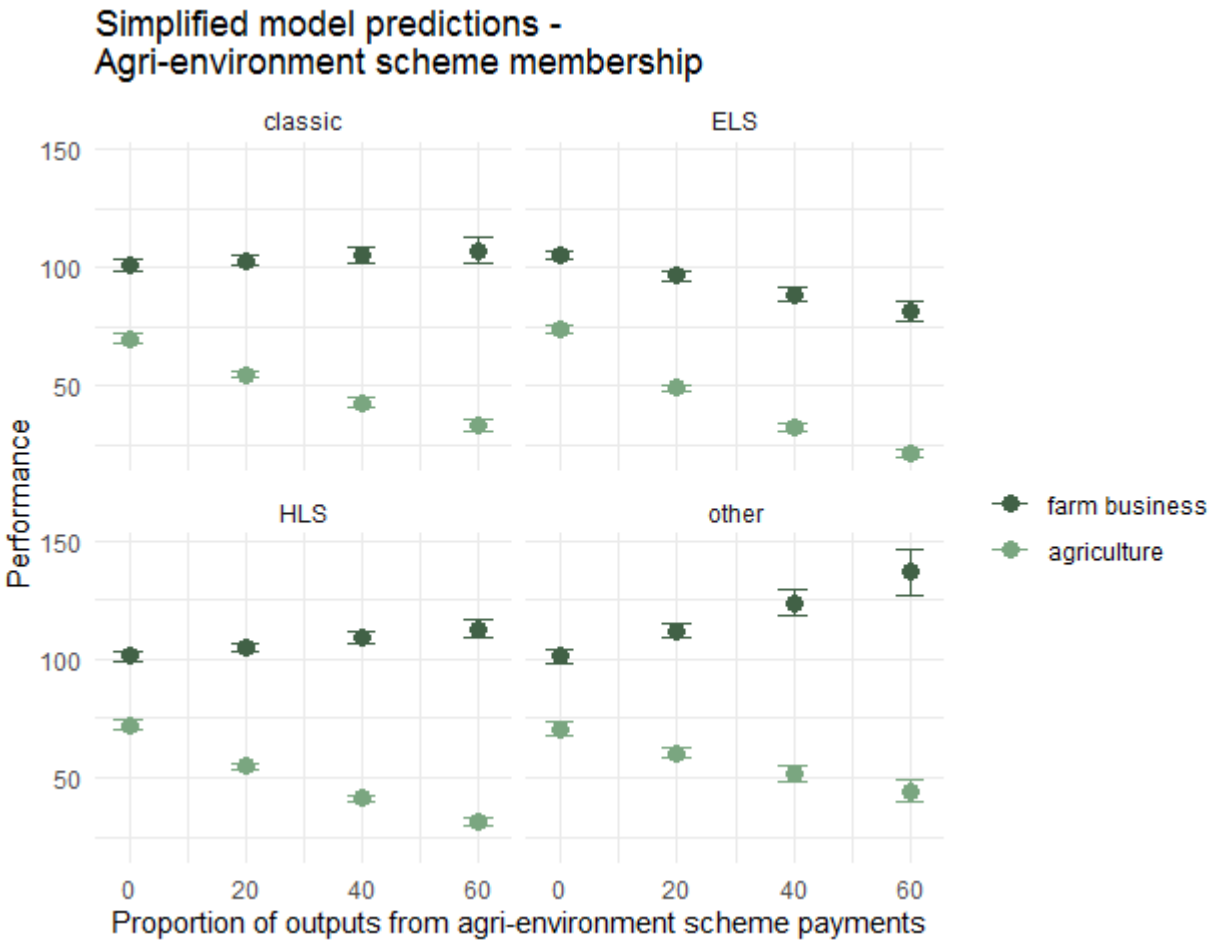

Figure 8. The relationship between agri-environment scheme membership, proportion of income from agri-environment scheme payments and performance. These predictions are not drawn from the main model, due to those farms that were a member of no schemes effectively having zero proportion of income from agri-environment scheme payments. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

4.2.1.5 Organic farming

Farms that have more land under organic certification (or in conversion) tended to be better performing farm businesses (see Figure 9). This improved performance at the business level might be due to grants (including those for in-conversion land) and agri-environment payments. Other added value activities, such as direct sales of organic meat, will also improve the financial position of some organic farms. A similar pattern was found for dairy farms (Jones, 2020b) and across all farm types for different countries (Kimura & Le Thi, 2013).

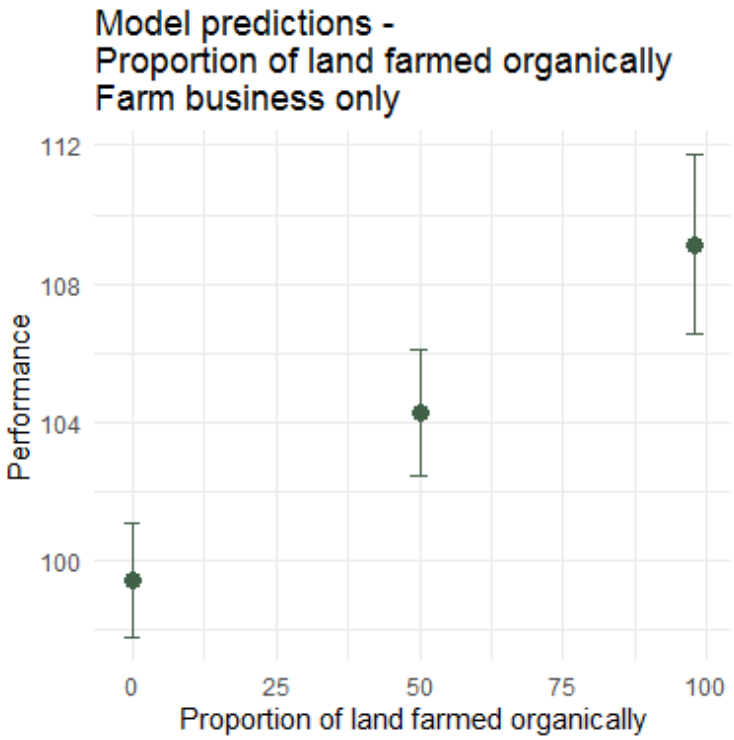

Figure 9. The relationship between organic farming and farm business performance. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

4.2.1.6 Unpaid labour

Unpaid labour (usually from the farmer and family members) has been costed using the market rate, and included as a cost in the modelling, this removes the inherent advantage of receiving labour at no cost.

Increasing unpaid labour was associated with reduced farm business performance (see Figure 10a). When imputed costs for unpaid labour are excluded from the modelling, the relationship with farm business performance is reversed, such that farms with greater reliance on unpaid labour tended to be better performers (see Figure 10b). This suggests that although there may be benefits to the business of using unpaid labour, there may also be disadvantages once the inherent monetary advantages have been removed from the calculations. This could be because unpaid labour isn't as efficient or effective as paid labour, or because those businesses which are most reliant, perhaps because they cannot afford to hire extra help, also tend to be poorer performers. Similar patters to this were found for dairy farm businesses (Jones, 2020b).

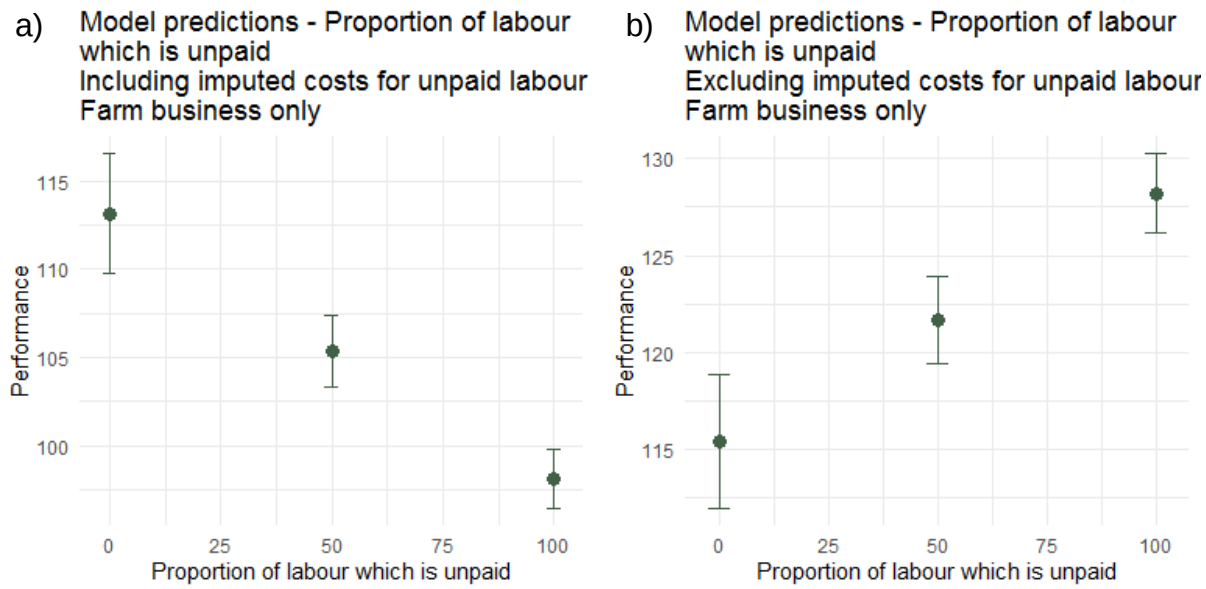

Figure 10. The relationship between unpaid labour and performance, including an imputed cost for unpaid labour using market rates (a) and excluding an imputed cost (b). Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

The relationship between unpaid labour and agricultural performance (including an imputed cost) differs between LFA and lowland farms; for lowland farms there is a positive relationship, whilst for those with land mostly in the LFA there is a negative relationship (see Figure 11a). When imputed costs were excluded, increasing reliance on unpaid labour was then associated with increased agricultural performance for both lowland and LFA farms (see Figure 11b), which is unsurprising given the inherent benefit of free unpaid labour. This suggests that there is some added value which unpaid labour contributes to the agricultural portion of lowland farm business, beyond that of the inherent value of free labour. In some circumstances unpaid labour may be more productive; it usually comes from the family, who are likely to be emotionally invested in the business and might be more dedicated than hired labour, perhaps this dedication is realised within the agricultural portion of the business for lowland farms, but not at the farm business level.

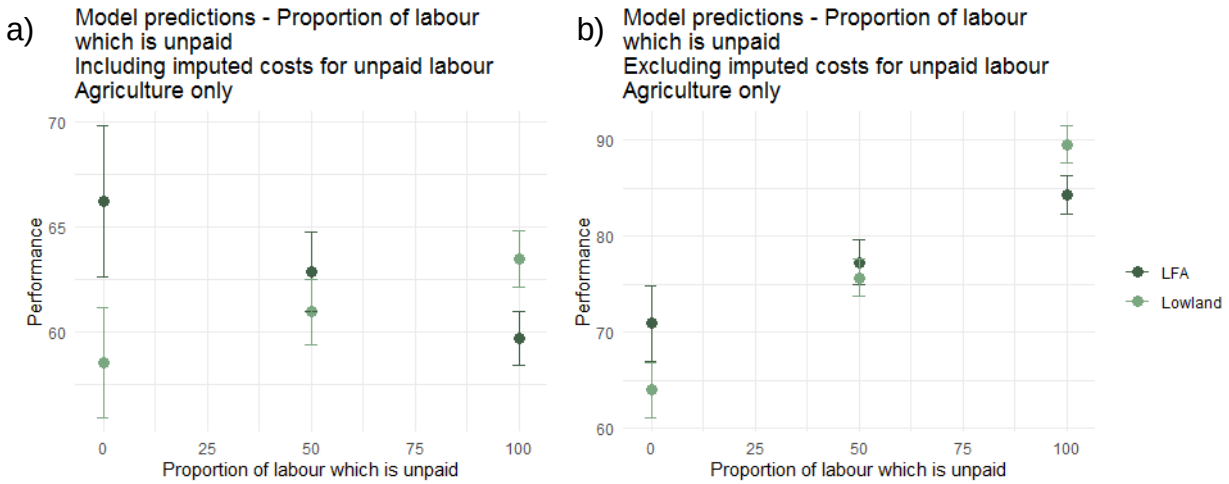

Figure 11. The relationship between unpaid labour, farm type and performance, including an imputed cost for unpaid labour using market rates (a) and excluding an imputed cost (b). Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

4.2.1.7 Contract work

Contract rearing of livestock, either rearing for other farm businesses or contracting others to do it for the farm business, was associated with increased agriculture performance (see Figure 12) but no relationship was found for the business as a whole. This suggests that contractors who specialise in rearing livestock are able to do so more efficiently, and may pass that benefit on to the agricultural portion of the farm business which has either utilised or provided that service.

Figure 12. The relationship between contract rearing (either using or providing contract rearing) and performance. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

4.2.1.8 Membership of farm assurance schemes

Farm assurance schemes (such as the Red Tractor Scheme) help to provide consumers and businesses with guarantees that food has been produced to particular standards. These schemes are mainly voluntary arrangements although many food businesses make certification in an assurance scheme a requirement for their suppliers. Membership of farm assurance schemes was associated with increased performance for both the farm business and agriculture (see Figure 13), this could be because practices associated with farm assurance schemes are themselves more economically efficient, or because farmers are given a higher price for their produce.

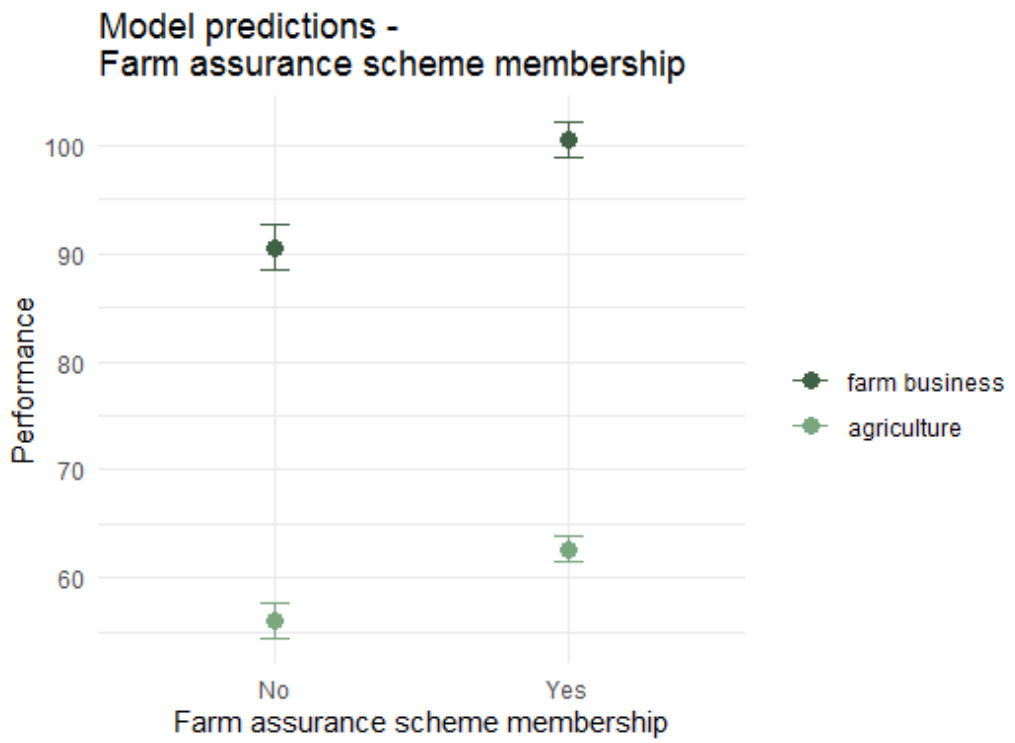

Figure 13. The relationship between farm assurance scheme membership and performance. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

4.2.1.9 Cost of bought feed

Farms with higher costs of bought feed concentrates per head of livestock tended to have poorer agricultural performance (see Figure 14). This suggests that it is better for a business to spend less on concentrated feed, perhaps augmenting this with feed grown on the farm such as hay or silage, or perhaps that the better performing farms were better able to access deals, or bulk buy when they purchase their concentrates. There was no relationship with the performance of the business as a whole.

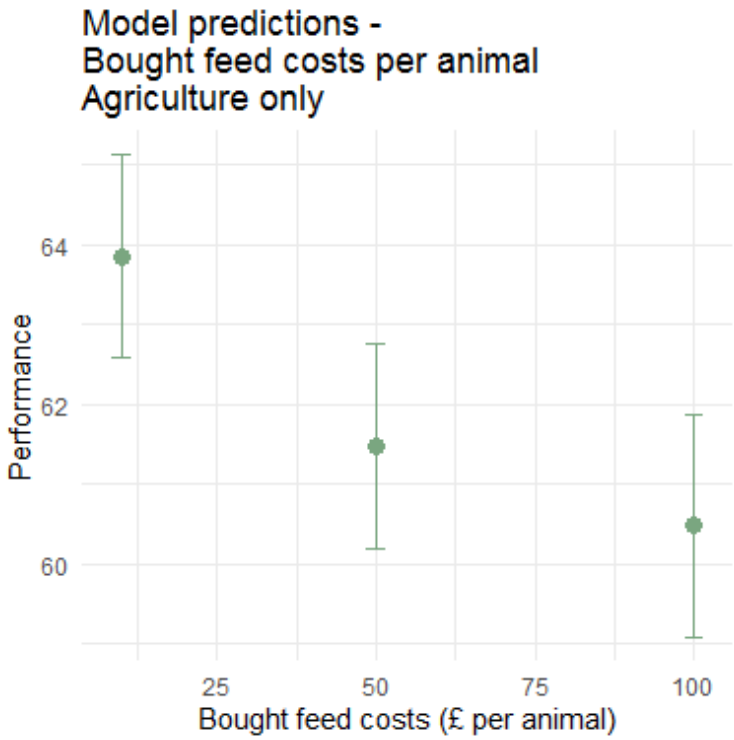

Figure 14. The relationship between bought feed costs and performance. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

4.2.2 Farm characteristics

This section concentrates on variables which may affect economic performance, which are particular to each farm in each year. Here we concentrate on variables which are largely beyond the scope of a farmer to change.

4.2.2.1 Land Area

There was a strong association between land area and performance, which is to be expected and should be interpreted with caution given the close relationship between costs and area. However, for the business as a whole, for a given level of inputs, larger farms tended to be better performers than smaller farms (see Figure 15), although this pattern was far less evident for the agricultural portion of the businesses. This conclusion has been found previously (Langton, 2012), as well as for other systems in England (Jones, 2020a; Jones, 2020b). This is likely because Direct Payments and agri-environment scheme payments, which are paid, at least in part, on a per area basis, were excluded from the agriculture model but included in the farm business model.

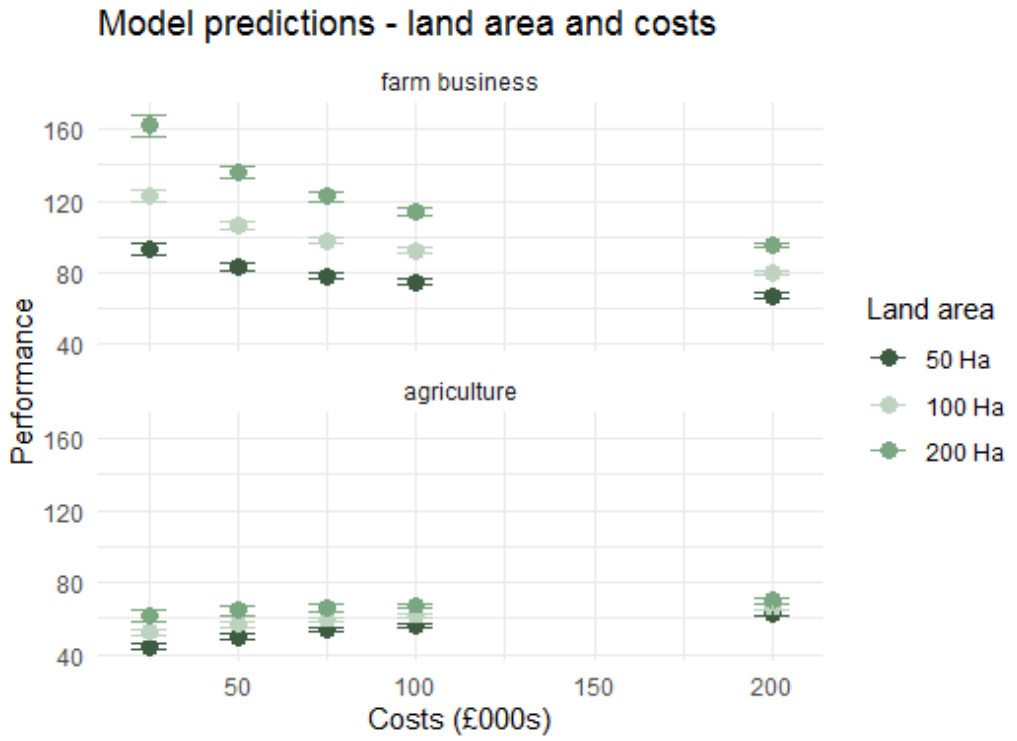

Figure 15. The relationship between costs and performance varies with farm size (in hectares), for both the farm business and agriculture models. Predictions were made for an average farm, variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

4.2.2.2 Farmer age

The age of the principal farmer was found to be related to performance for both the farm business and agriculture (see Figure 16); increasing farmer age was associated with reduced performance. This may indicate that older farmers have more scope to coast into semi-retirement, relying on their assets to survive as the business becomes less productive. It is known that a large proportion of farms with an older principle farmer do not have successional arrangements in place (Defra, 2018), it is possible that a farmer without successional arrangements in place and nearing retirement might be less motivated to take on new ventures or make new investments. Additionally, younger farmers, although they might be relatively inexperienced and more resource limited, may have more recently graduated from agricultural college, be up-to-date with cutting edge agricultural practices, be more open to technological innovation or be more driven to make the business succeed.

An important caveat to these findings is that only the age of the principal farmer is recorded in the Farm Business Survey. For instance, where more than one generation of a family works together to manage a farm, usually the details of the most senior family member will be recorded, while in reality the experience and knowledge of all the people involved in managing the business contributes to the overall performance, including non-family members such as workers, advisors or contractors.

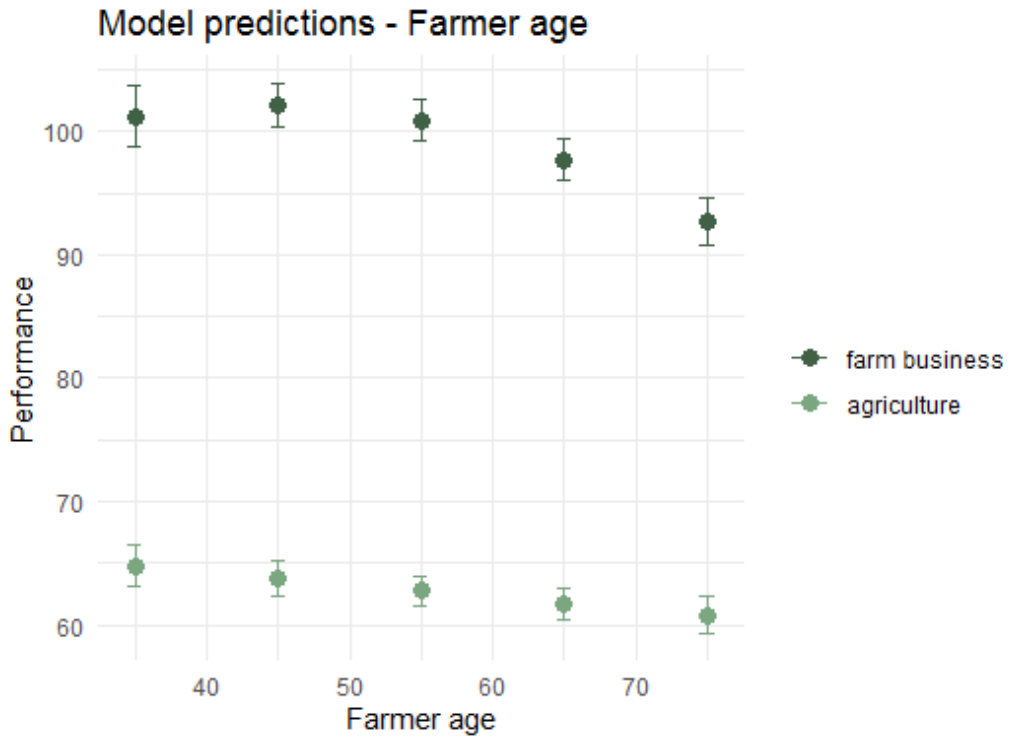

Figure 16. The relationship between farmer age and performance for both the farm business and agriculture models. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

5 Conclusions

The work here fits into an active area of research, and similar research questions have been asked of different farming systems within England, in particular the work of Jones (2020b) and Langton (2011; 2013; 2012), as well as farming systems across the rest of the world. A summary of the results found here are in Table 4.

Table 4. A summary of the results with comment on the strength of the evidence.

Variable	Evidence Strength	Comments
Debt	Strong – this pattern has been found across many systems and studies.	Increasing debt was related to decreasing performance
Diversification	Moderate – similar patterns have been found in other systems and previous studies.	Increased diversified activities were related to lower agricultural performance, but this was compensated for by the rest of the farm business such that overall performance was not impacted.
Agricultural specialisation	Moderate – similar and contrasting patterns have been reported elsewhere.	**Lowland farms**: increasing agricultural specialisation was associated with increased performance. **LFA farms**: performance was unrelated to agricultural specialisation.
Agri-environment scheme membership	Strong - this pattern has been reported elsewhere.	In general, membership of the more onerous schemes was associated with increased farm business performance. Increased reliance on payments from agri-environment schemes was associated with decreased agricultural performance. However this relationship varied with the particular scheme.
Organic practices	Strong - this pattern has been reported elsewhere.	Farms which had a larger proportion of land under organic certification tended to better performers.
Unpaid labour	Moderate – similar and contrasting patterns have been reported elsewhere.	Unpaid labour was advantageous for performance. However, once the inherent advantage of receiving labour for free was removed by including an imputed cost, more unpaid labour was associated with reduced farm business performance.
Contract work	Moderate – similar patterns has been reported elsewhere.	Contractors who specialise in rearing livestock are able to do so more efficiently, and were associated with increased agricultural performance.
Farm Assurance Schemes	Strong- this pattern has been reported elsewhere.	Membership of farm assurance schemes such as the Red Tractor Scheme was associated with increased performance.

Cost of bought feed	Moderate– similar patterns has been reported elsewhere.	Increased costs of bought feed per animal was associated with decreased performance.
Land area & costs	Strong – a well-established pattern due to the impact of area-based payments.	Larger than average farms with lower than average costs tended to have better farm business performance.
Farmer age	Weak – the quality of the underlying data is poor.	Farms with older principal farmers tended to have slightly reduced performance.

Just because a variable considered here doesn't appear to have a relationship with performance, does not necessarily mean that it is unrelated. All statistical analysis is limited by the sample size of the data considered, with more data comes more power to detect relationships. Subtler, or nuanced, relationships may not be picked up by the models.

One key conclusion from this work is the considerable variation in the performance of farms across England (Figure 1), and this has also been demonstrated elsewhere (Kimura & Le Thi, 2013). It may be short-sighted to assume that all poor performing farms can or should be brought up to the level of the best. A large unknown is how much of the variation in performance is due to factors such as business management decisions and husbandry practice which are, at least in theory, amenable to change, and how much is due to those factors that are essentially fixed, such as land quality and topography. Very little (<1%) of the variation in farm business performance in England was explained by geography (Figure 2 and Table 2). This may be for a number of reasons. For instance, the geographic factors influencing grazing livestock farms could operate at a smaller scale than the National Character Area level information used to differentiate FBS farms in this analysis; this seems likely since grazing quality can change considerably within a short distance, particularly when moving up a hillside. At present it is not possible to examine fine scale environmental differences in land quality for FBS farms, because the precise location of farms, and for that matter the location of each field, is not available for analysis. It is also unknown where on a farm livestock are grazed; many farms will contain a mixture of lowland and LFA land, and will likely make business decisions to maximise the output from that land, such as grazing livestock in the LFA and growing some crops in more lowland areas.

There is a complex relationship between efficiency or productivity gains and other policy aims, such as improving environmental outcomes. Much historic productivity growth in agriculture can be attributed to the substitution of labour for energy intensive machinery, as well as growth in the use of fertilisers and pesticides. These inputs tend to have a number of negative environmental consequences associated with them. Depending on the nature of gains, the move towards greater efficiency on farms has the potential to either exacerbate or mitigate environmental degradation. Foster et al. (2007) show that there are often trade-offs between reducing one negative input and another. For example using less fertiliser will have positive environmental impacts but will require the use of more land to produce the same amount of output, thus negatively impacting on biodiversity and carbon

sequestration. There are indications however that increased efficiency may also lead to environmental benefits, Shortall and Barnes (2013) found that more efficient Scottish dairy farms also produced less greenhouse gasses per litre of milk produced, although they acknowledge that how efficiency gains are achieved is hugely important.

Although it is largely unknown how much improvement is possible at the scale of individual farms, results presented here demonstrate that there is the potential for an improvement in performance through business decisions.

6 Appendix A

Data was taken from the Farm Business Survey of England for 2010/11 – 2016/17. Farms were included in the analyses if they were classified to 'robust' type[7] lowland grazing livestock or LFA (Less Favoured Areas) grazing livestock in at least three of these years, 584 farms met this condition, with 299 of these surveyed in all seven years, and 434 providing data in at least five years. The majority (91%) of the farms were always classified as grazing livestock, with the remainder being classified as either mixed or dairy farms in a minority of years. Grazing livestock farms are predominantly involved in beef and/or sheep production. Dairy farms are not part of the grazing livestock type, although a few farms which are classified as grazing livestock due to their beef and sheep enterprises also have dairy cattle.

Unpaid labour was given an imputed cost equivalent to the amount that the unpaid staff could earn in similar work elsewhere. Rent was not imputed for owner occupied farms.

Anomalous data were excluded from the analysis, this included one farm in one year with a very large negative farm business output (where normally output, being money into the business, is expected to be positive), 5 instances where farms had no agricultural output, and 30 instances where farms had no agricultural costs.

Statistical analysis was broken up into two sections; the first using two models to assess the spatial and temporal variation in farm output/input ratios, the second assessing variables which might be associated with the economic performance at the farm business level, and agricultural portion of the business only. The farm business accounts includes costs and outputs from traditional farming sources, as well as diversified activities (such as tourism or renting out buildings), direct payments from government and payments from agri-environment schemes.

All statistical analyses were done in R (R Core Team, 2018), using the lme function in the nlme (Pinheiro, et al., 2018) package to fit mixed effects models. For both the farm business and agriculture models, farm ID was fitted to have a random effect on the intercept. Models were fitted using Maximum Likelihood during model simplification, and Restricted Maximum Likelihood to obtain final coefficient estimates.

Response variables were either log transformed farm business outputs, or log transformed agricultural outputs (both in whole £000s).

6.1 Breakdown of variation in performance

To partition the variation in performance between geographical (using National Character Areas), temporal (year) and idiosyncratic (farm ID) sources, a simple ANOVA was used taking the form:

$$performance\ ratio \sim \mathrm{Farm/Year} + \mathrm{NCA}$$

7 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/365564/fbs-uk-farmclassification-2014-21oct14.pdf

Where performance ratio refers to the output/input ratio for the farm business and agriculture respectively, and NCA refers to the National Character Area. Each dependant variable was fitted as a factor.

To visualise the spatial distribution of performance, for each 10km grid square across England, an average performance score was calculated, where data existed. These scores were then categorised into bands (bottom 20%, 21-40%, 41-60%, 61-80% and top 20%) and plotted.

6.2 Farm characteristics related to farming performance

6.2.1 Fixed effects structure

Generalised linear mixed models were used to assess other putative explanatory variables associated with farm business and agricultural performance, taking the general form:

$$\log(outputs) \sim \beta_0 + \log(costs) + \text{year} + \text{type} + \log(area) + variable_1 + \cdots + variable_n + \text{farm} + \varepsilon$$

Where;

- log(outputs) and log(costs) are log transformed outputs and costs in whole thousands of pounds.
- β_0 is a global intercept
- year is a categorical variable denoting each year
- type is a categorical variable denoting the farm type (lowland or LFA)
- log(area) is log transformed total area, including woodland, buildings etc.
- $variable_1$ … $variable_n$ are additional variables
- farm is fitted to have a random effect on the intercept
- ε is residual error

The full list of variables used in the modelling is shown in Table 5:

Table 5. The full list of variables and their interactions specified in the maximal model.

Main effects:				
Variable	Description	Min	Max	Mean/mode
Log(costs)	Log_{10} transformed farm business costs	1.328	2.980	2.112
Type	lowland or LFA	2 factor levels		Lowland
Log(area)	Log_{10} transformed land area	1.189	3.193	2.078
interest	Interest payments as a proportion of costs – a measure of debt	0	40.486	2.649
Farmerage	farmer age	supressed		56.17
Farmerage2	quadratic term	supressed		3268

Divcostsall	percentage of total costs from diversified income	0	78.869	3.169
Scheme2	agri-environment scheme membership	5 factor levels		ELS
PropIncomeAgri	proportion of output from payments	0	68.7	8.331
tenancy	Mainly FAT tenancy, mainly FBT tenancy or owner occupied	3 factor levels		Owner occupied
FARMASS	membership of farm assurance scheme	2 factor levels		TRUE
Special	enterprise specialism	15.26	98.38	34.23
Porganic	proportion of land which is organic	0	99.93	11.2
Unpaid labour	Proportion of labour which is unpaid	1.1	100	83.04
Contract work	Proportion of costs associated with contract work	0	93.3	20.23
RuralityScoreFull	Rurality category	8 factor levels		Hamlet & isolated dwellings – less sparse
FarmerEducation	Farmer education category	8 factor levels		College/National Diploma/certificate
NVZindicator	Most of farm in or out of a NVZ	2 factor levels		FALSE
Log(bought feed costs)	Log_{10} transformed costs of bought feed concentrates per head of livestock	0	3.634	1.356
Veterinary costs	Log_{10} transformed veterinary costs per animal	0	2.83	0.896
Contract Rearing Indicator	Any contract rearing	2 factor levels		FALSE

Interactions:

Interaction	Description
log(costs) * log(area)	costs and area interaction
log(costs) * interest	Costs and debt interaction
Farmerage * tenancy	age and tenancy interaction
Type * Special	farm type and specialism interaction
Type * log(area)	Farm type and land area interaction
Type * interest	Farm type and debt interaction

Type * Farmerage	Farm type and farmer age interaction
Type * Divcostsall	Farm type and diversification interaction
Type * tenancy	Farm type and tenancy interaction
Type * Unpaid labour	Farm type and unpaid labour interaction
Type * Contract work	Farm type and contract work interaction
Type * Scheme	Farm type and agri-environment scheme interaction
Type * PropIncomeAgri	Farm type and proportion of output from payments interaction
log(area) * Special	Area and specialism interaction
log(costs) * tenancy	Costs and tenancy interaction

The full list of agricultural enterprises which feed into the specialisation index calculation are:

- Cereals
- Oilseeds
- Hops
- Sugar Beet
- Field peas & beans
- Main crop Potatoes
- Early Potatoes
- Outdoor Vegetables
- Other peas & beans
- Vining Peas
- Top soft fruit
- HNS
- Vegetables under glass
- Flowers under glass
- Mushrooms
- Set aside
- Dairy cows
- Beef cows
- Other cattle
- Ewes and rams
- Other sheep
- Sows
- Finishing rearing pigs
- Piglets
- Table fowl
- Laying hens
- Growing pullets
- Other poultry
- Fodder crops
- Horses

- Goats
- Deer
- Grassland
- Rough grazing

The same maximal model was fitted to both the farm business data and the agricultural data, and potential fixed effects were assessed on the basis of stepwise model simplification (Crawley, 2013), model AIC and model performance. No automated model simplification or variable selection procedures were used.

Model performance was assessed by fitting the model to a subset of 65% of the original data frame selected at random (the training data), and then used to make predictions for the remaining test set of data. The predictions were then regressed against the known data and the R^2 extracted as a measure of performance.

6.2.2 Random effects structure

A variety of random effects structures were considered, including NCA, farm ID and year. A summary of the models considered is as follows:

Random effect structure	d.f.	AIC	BIC	Log-likelihood	Adjusted R-squared	
No random effects	26	-5957	-5798	3005	0.901	
Random effect structure	d.f.	AIC	BIC	Log-likelihood	Marginal R-squared	Conditional R-squared
Random effect of farm ID on the intercept	27	-7634	-7468	3844	0.886	0.962
Random effect of year on the intercept	27	-5672	-5507	2863	0.900	0.902
Random effect of year, nested within farm ID on the intercept	28	-7632	-7461	3844	0.886	0.993
Random effect of National Character Area on the intercept	27	-5890	-5725	2972	0.891	0.913

Final model checking was done by examining the distribution of residuals using q-q plots, standardised residuals vs fitted values for approximate normality and constant variance. The Random effects structure used in the models was a random effect of farm ID on the intercept.

7 Appendix B

The economic landscape of farming in England changes considerably over time, average costs and outputs have both steadily increased since 2003 (see Figure 17, Figure 18). However economic performance does not appear to have changed systematically for grazing livestock farms (see Figure 19).

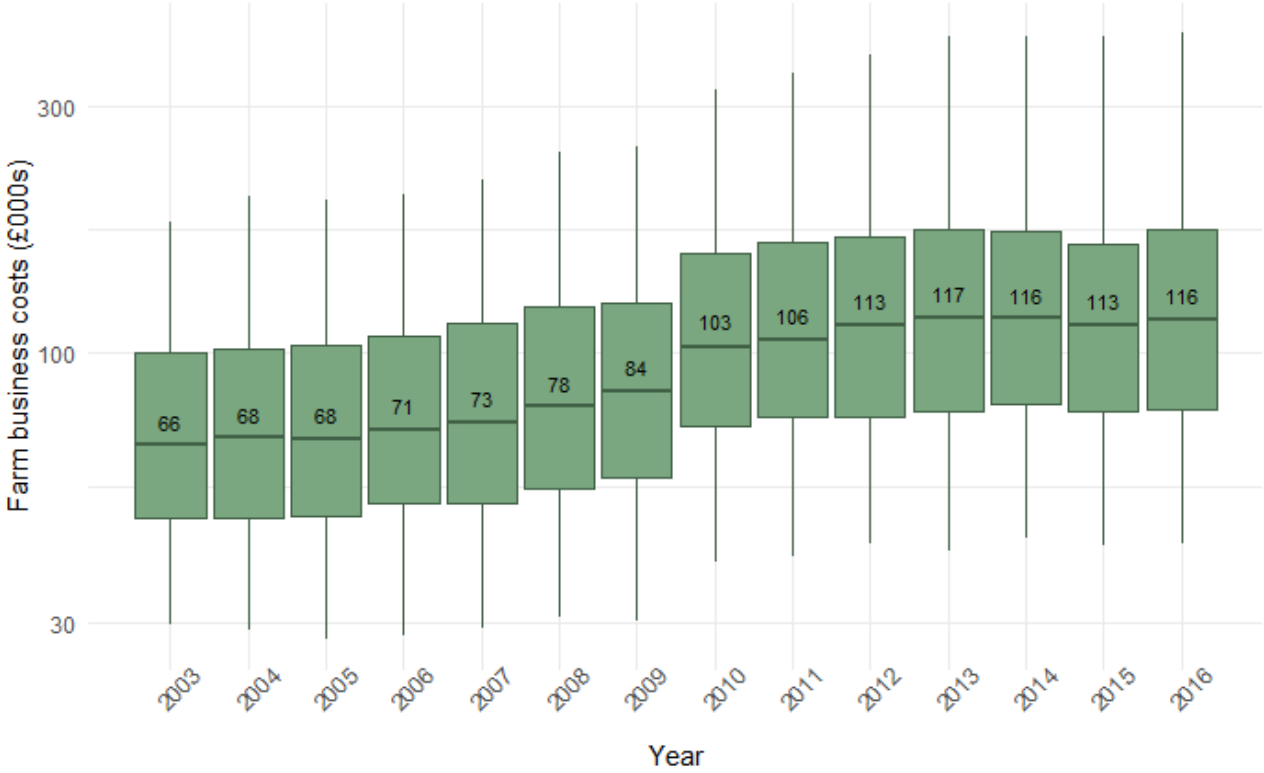

Figure 17. Farm business costs have steadily increased over time. Previous work (Langton, 2012) covers the years 2003/04 – 2009/10, current analysis covers the years 2010/11 – 2016/17. Values shown are the median ratio for grazing livestock farms in each year.

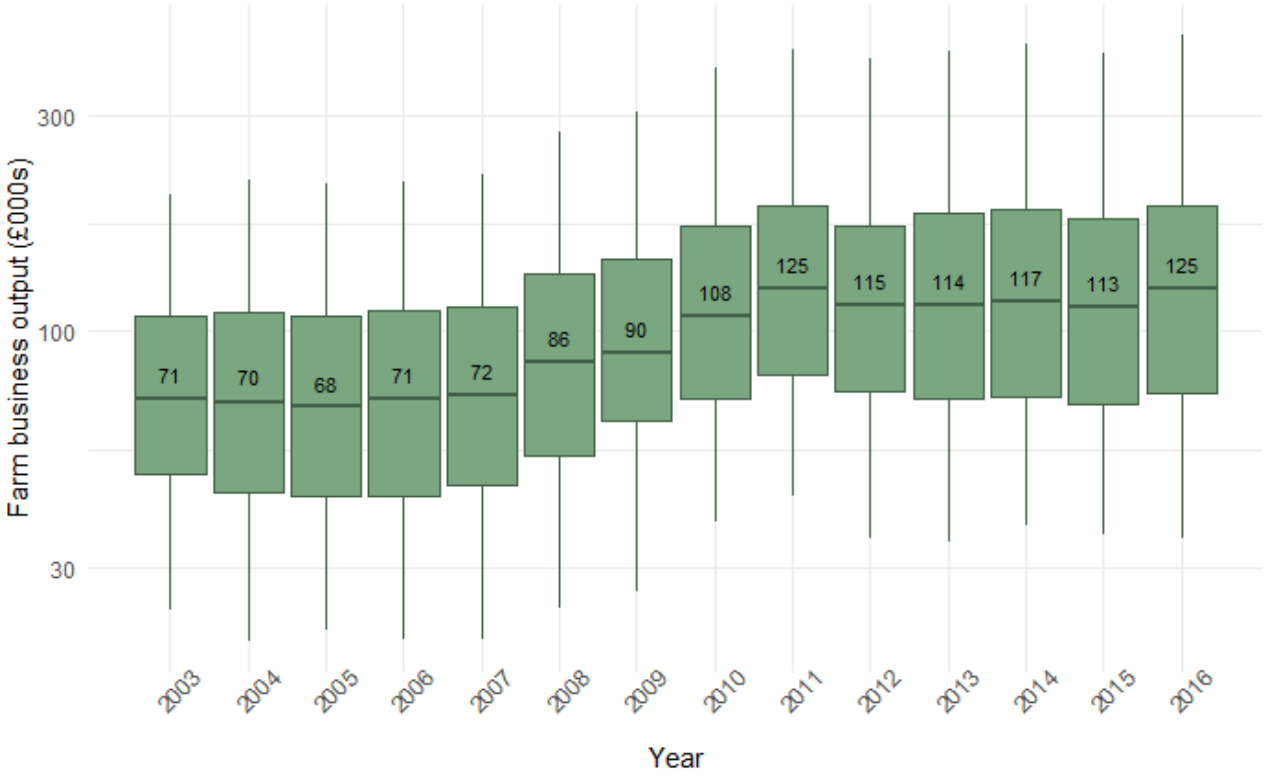

Figure 18. Farm business outputs have steadily increased over time. Previous work (Langton, 2012) covers the years 2003/04 – 2009/10, current analysis covers the years 2010/11 – 2016/17. Values shown are the median ratio for grazing livestock farms in each year.

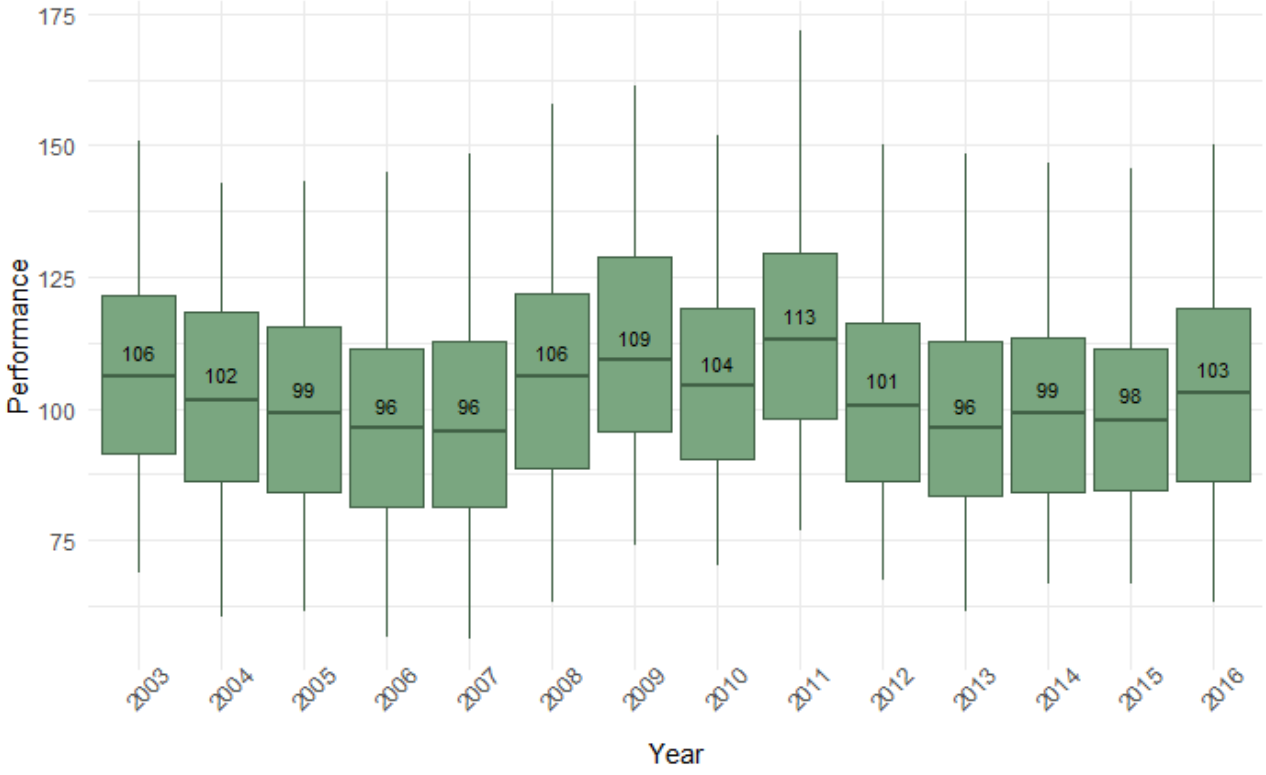

Figure 19. Farm business performance of grazing livestock farms (calculated as the ratio of outputs to inputs (including an imputed costs for unpaid labour)) has not changed systematically over time. Previous work (Langton, 2012) covers the years 2003/04 – 2009/10, current analysis covers the years 2010/11 – 2016/17. Values shown are the median ratio for grazing livestock farms in each year.

7.1 Spatial distribution of farm business output/input ratio

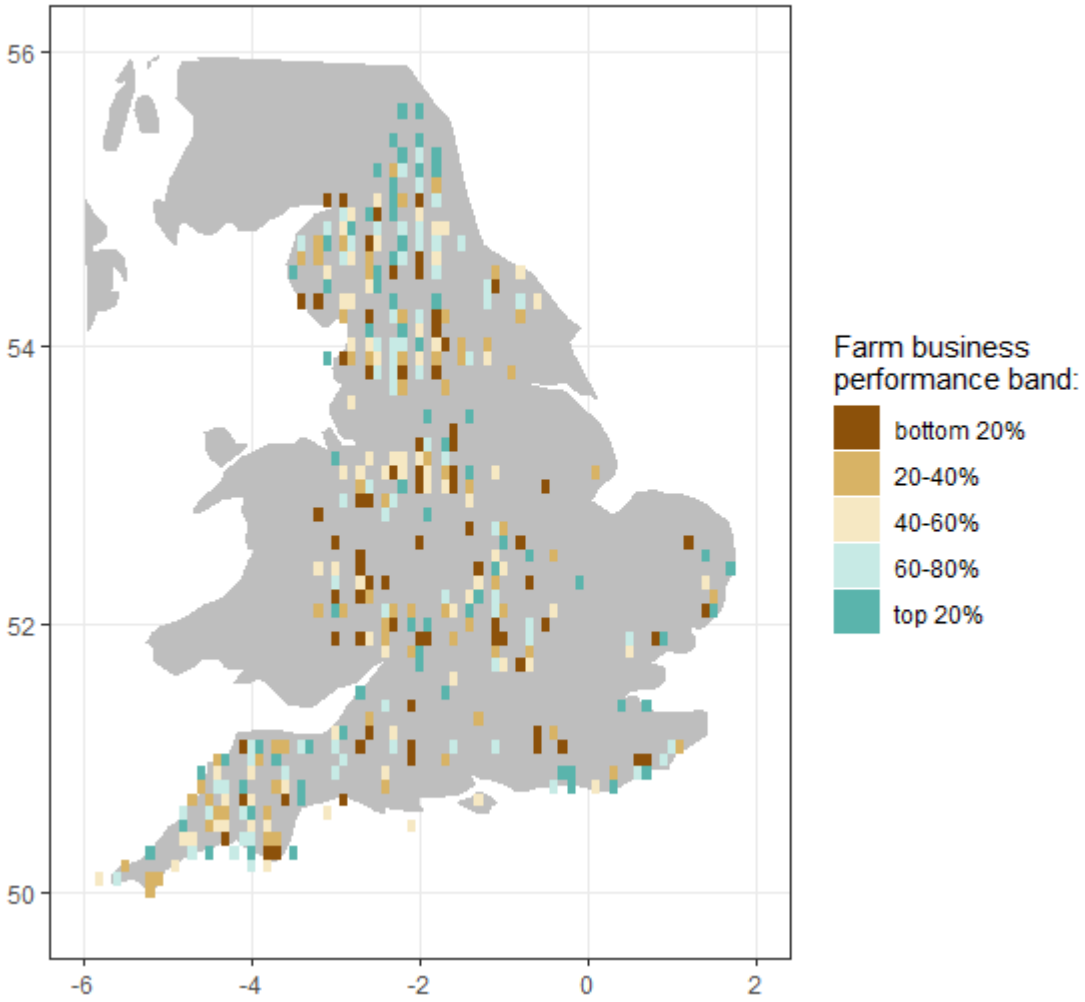

Figure 20. Spatial distribution of output/input ratios calculated from farm business inputs and outputs. Mean performance for farms falling within each 10km grid square are shown.

7.2 Relationship between farm type and performance

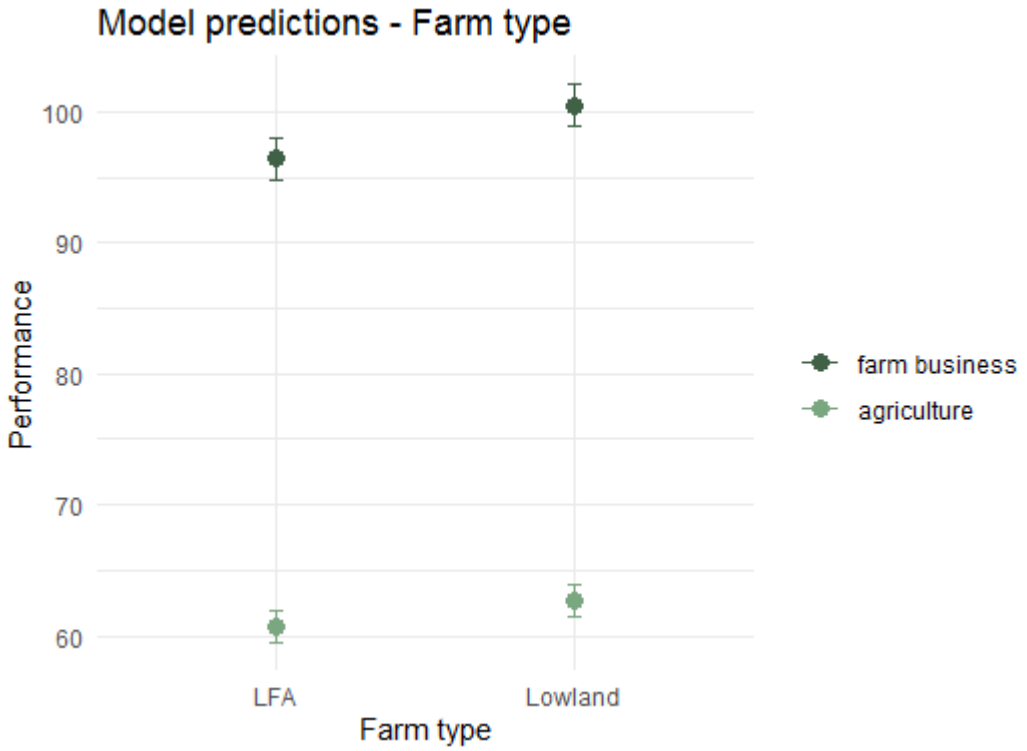

Figure 21. The relationship between farm type (lowland or upland) and performance for both the farm business and agriculture models. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

7.3 Relationship between year and performance

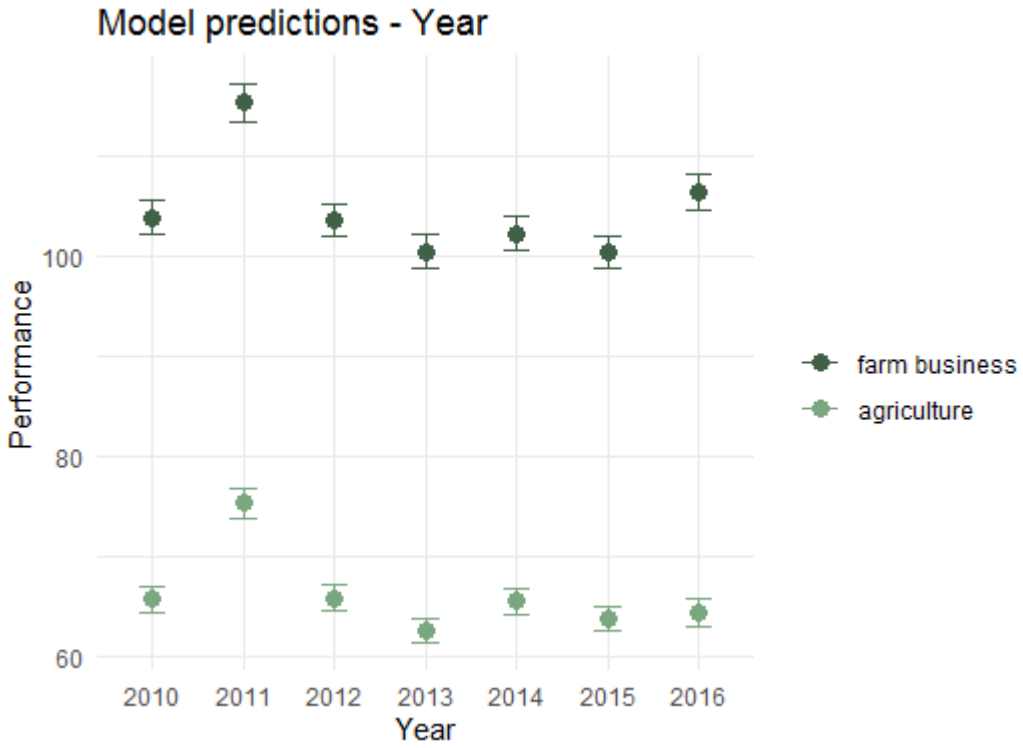

Figure 22. The relationship between year and performance for both the farm business and agriculture models. Predictions were made for an average farm with £90,000 inputs per annum and 120ha of land, remaining variables were averaged or the most common factor level used. Error bars represent standard error. Absolute predicted values should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice.

7.4 Model diagnostic plots

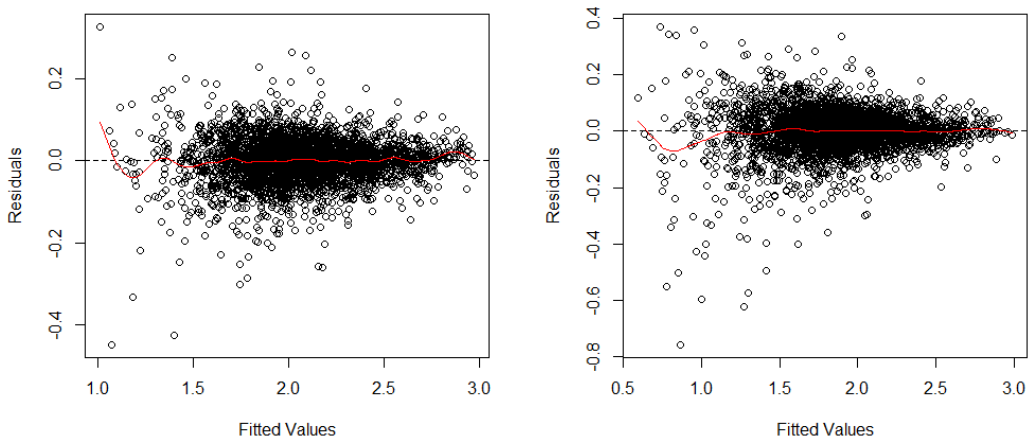

Figure 23. Model residuals plotted by their fitted values for the minimum adequate farm business performance model (left) and minimum adequate agriculture performance model (right).

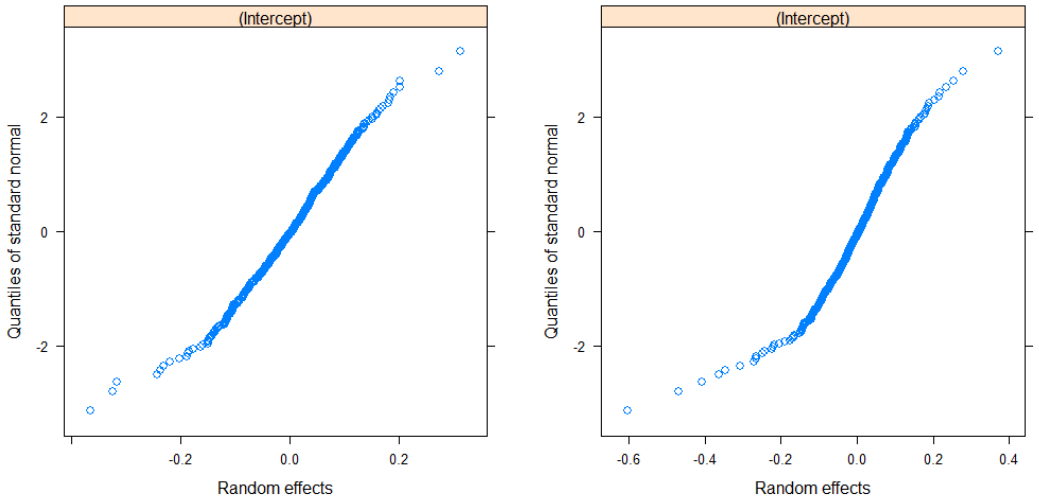

Figure 24. Quantile–quantile plot for the minimum adequate farm business performance model (left) and minimum adequate agriculture performance model (right).

7.5 Model coefficient estimates

Table 6. Coefficient estimates for terms in the farm business performance model.

Predictors	Estimates	CI
Costs		
log FBC full	1.127 *	0.987 - 1.266
Farm Type		
Reference group: LFA		
Lowland	-0.023	-0.056 - 0.011
Land Area		
LADJAREA	0.635 *	0.491 - 0.779
Year		
Reference group: 2010		
Year 2011	0.045 *	0.037 - 0.053
Year 2012	-0.001	-0.009 - 0.007
Year 2013	-0.014 *	-0.023 - -0.006
Year 2014	-0.007	-0.015 - 0.001
Year 2015	-0.015 *	-0.024 - -0.006
Year 2016	0.011 *	0.002 - 0.02
Debt		
interest	-0.002 *	-0.003 - -0.001
Age		
Farmer age	0.0039 *	0.0005 - 0.0073
Farmer age squared	-0.00004 *	-0.00007 - -0.00001
Agri-environment schemes		
Reference group: none		
ELS	0.011 *	0.001 - 0.021
classic	0.012	-0.002 - 0.025
HLS	0.021 *	0.008 - 0.035
other	0.029 *	0.01 - 0.049
Proportion of outputs from Agri-environment schemes		
Prop Agri	0.0005 *	0 - 0.001
Farm Assurance scheme membership		
Reference group: No		
FARMASS	0.045 *	0.027 - 0.063
Agricultural specialisation		
Special	0.0001	-0.0007 - 0.001
Organic		
Porganic	0.0004 *	0.0002 - 0.0006
Unpaid labour		
UNPAID	-0.0006 *	-0.0009 - -0.0004
Costs and area interaction		
logFBC.full:LADJAREA	-0.1659 *	-0.2309 - -0.1009
Farm type and specialisation		
TypeLowland:Special	0.001 *	0 - 0.002

Table 7. Coefficient estimates for terms in the agriculture performance model.

Predictors	Estimates	CI
Costs		
log AGC full	1.494 *	1.316 - 1.673
Farm Type		
Reference group: LFA		
Lowland	-0.098 *	-0.16 - -0.036
Land Area		
LADJAREA	0.493 *	0.314 - 0.672
Year		
Reference group: 2010		
Year 2011	0.059 *	0.048 - 0.07
Year 2012	0.001	-0.011 - 0.012
Year 2013	-0.021 *	-0.033 - -0.01
Year 2014	-0.0013	-0.0133 - 0.0107
Year 2015	-0.0133 *	-0.0258 - -0.0009
Year 2016	-0.009	-0.022 - 0.004
Debt		
interest	0.008	-0.001 - 0.017
Age		
Farmerage	-0.00069 *	-0.0013 - 0.00001
Diversified enterprises		
Divcostsall	-0.002 *	-0.003 - -0.001
Agri-environment schemes		
Reference group: none		
ELS	0.018 *	0.004 - 0.032
classic	0.028 *	0.009 - 0.047
HLS	0.032 *	0.013 - 0.051
other	0.048 *	0.02 - 0.076
Proportion of outputs from Agri-environment schemes		
Prop Income Agri	-0.006 *	-0.007 - -0.005
Farm Assurance scheme membership		
Reference group: No		
FARMASS	0.048 *	0.026 - 0.071
Agricultural specialisation		
Special	-0.0003	-0.0013 - 0.0008
Unpaid labour		
UNPAID	-0.0005	-0.0009 - 0
Bought feed		
log(bought feed costs)	-0.0236 *	-0.0378 - -0.0094
Contract rearing		
Reference group: None		
Contract rearing	0.01783 *	0.00324 - 0.03242
Costs and area interaction		
logAGC.full:LADJAREA	-0.1825 *	-0.2654 - -0.0997
Costs and debt interaction		
logAGC.full:interest	-0.006 *	-0.01 - -0.001
Type and specialisation interaction		
TypeLowland:Special	0.001 *	0 - 0.003
Type and unpaid labour interaction		
TypeLowland:UNPAID	0.001 *	0 - 0.001

8 References

Barnes, A., 2008. Technical Efficiency Estimates of Scottish Agriculture: A Note. *Journal of Agricultural Economics,* Volume 59, p. 370–376.

Clothier, L., Langton, S., Boatman, N. & Woodend, A., 2008. *Agricultural Specialisation, Defra Agricultural Change and Environment Observatory Research Report No. 11,* London: Defra.

Crawley, M. J., 2013. *The R Book.* 2nd ed. Chichester: John Wiley & Sons Ltd..

Defra, 2018. *Farm accounts in England - Results from the Farm Business Survey of England 2017/18,* London, https://www.gov.uk/government/statistics/farm-accounts-in-england: s.n.

Defra, 2019. *Balance sheet analysis and farming performance, England 2017/2018,* London, https://www.gov.uk/government/statistics/balance-sheet-analysis-and-farming-performance-england: s.n.

Fletcher, J., 2014. *Spurious correlations: Margarine linked to divorce?.* [Online] Available at: https://www.bbc.co.uk/news/magazine-27537142 [Accessed 21 March 2019].

Foster, C. et al., 2007. *The Environmental, Social and Economic Impacts Associated with Liquid Milk Consumption in the UK and its Production, A Review of Literature and Evidence,* London: Defra.

Hadley, D., 2006. Patterns in Technical Efficiency and Technical Change at the Farm-level in England and Wales, 1982–2002. *Journal of Agricultural Economics,* Volume 57, pp. 81-100.

Iraizoz, B., Bardaji, I. & Rapun, M., 2005. 'The Spanish beef sector in the 1990s: Impact of the BSE crisis on efficiency and profitability. *Applied Economics,* Volume 37, pp. 473-484.

Jones, C., 2020a. *Characteristics of high performing cereal farms in England,* London: Defra.

Jones, N., 2020b. *Characteristics of high performing dairy farms in England,* London: Defra.

Kimura, S. & Le Thi, C., 2013. *"Cross Country Analysis of Farm Economic Performance", OECD Food, Agriculture and Fisheries Papers, No. 60,* Paris: OECD Publishing.

Langton, S., 2011. *Cereals Farms: Economic Performance And Links With Environmental Performance,* s.l.: Defra Agricultural Change and Environment Observatory Research Report No. 25.

Langton, S., 2012. *Grazing Livestock Farms: Economic Performance and Links With Environmental Performance,* s.l.: Defra Agricultural Change and Environment Observatory Research Report No. 30.

Langton, S., 2013. *Dairy Farms: Economic Performance And Links With Environmental Performance,* s.l.: Defra Agricultural Change and Environment Observatory Research Report No. 31.

Paul, C. J. M., Johnston, W. E. & Frengley, G. A. G., 2000. Efficiency in New Zealand sheep and beef farming: The impacts of regulatory reform. *Review of Economics and Statistics,* Volume 82, p. 325–337.

Pike, T., 2008. *Understanding Behaviours in a Farming Context: Bringing Theoretical And Applied Evidence Together From Across Defra And Highlighting Policy Relevance And Implications For Future Research,* London: Defra.

Pinheiro, J. et al., 2018. *nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-137, https://CRAN.R-project.org/package=nlme,* s.l.: s.n.

R Core Team, 2018. *R: A language and environment for statistical computing ,* Vienna, Austria. URL https://www.R-project.org/: R Foundation for Statistical Computing.

Redman, G., 2015. *The Best of British Farmers; What gives them the edge?,* s.l.: The Andersons Centre for The Oxford Farming Conference.

Redman, G. et al., 2018. *The characteristics of high performing farms in the UK,* s.l.: AHDB.

Shortall, O. & Barnes, A., 2013. Greenhouse gas emissions and the technical efficiency of dairy farmers. *Ecological Indicators,* pp. 478-488.

Wilson, P., Harper, N. & Darling, R., 2013. Explaining variation in farm and farm business performance in respect to farmer behavioural segmentation analysis: Implications for land use policies. *Land Use Policy,* 30(1).

Wilson, P., Harpur, N. & Darling, R., 2011. *Analysis of Farmer Segmentation across farms contributing to the Farm Business Survey: A Pilot Study,* s.l.: Rural Business Research.

Wilson, P. et al., 2012. *Farm Level Performance: Identifying Common Factors Determining Levels of Performance,* s.l.: Rural Business Research.

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