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Drivers of production performance and profitability of the livestock sector in the less favoured areas of England: the impact of distance, financial dependency and machinery

By G VITTIS, Y GADANAKIS and S MORTIMER

School of Agriculture, Policy and Development, University of Reading, Whiteknights, PO Box 237, Reading, Berkshire RG6 6AH, UK
Corresponding Author Email: G.Vittis@pgr.reading.ac.uk

Abstract

Agricultural production in Less Favoured Areas (LFAs) is more difficult since farming faces certain natural challenges. Such barriers may lead to a reduction or suspension of agricultural activities resulting in a series of environmental pressures such as loss of biodiversity and land abandonment. Thus, maintenance and sustainable development of the agricultural systems within the LFAs emerges as a prerequisite for preserving the environment of the English uplands. Towards this direction, the identification of factors that enhance or hinder agricultural performance in the LFAs is required to enable the design of future development strategies and policy interventions. Principal Component Analysis (PCA) is employed here to group into core underlying factors variables related to climate and landscape characteristics as well as management choices. Multiple Linear Regression (MLR) was then used to test the explanatory power of the independent variables in explaining variations in business performance. Financial and physical data used in the study were derived from the Farm Business Survey dataset whereas climate variables were obtained from the Met Office climate monitoring. The results provide evidence to support that remoteness, climate, financial aid and technological level are drivers of good performance of the grazing livestock systems. Hence, the results suggest areas of policy-making interventions in the livestock sector of the LFAs that aim towards sustainable intensification of production.

Key words: Grazing livestock farming, less favoured areas, production performance drivers, multiple linear regression

Introduction

In England, a total of 2.2 million hectares or 17% of the total farmed area is classified as Less Favoured Area (LFA) (DEFRA, 2010). Grazing livestock farming is the main agricultural activity in the LFAs of England (Harvey & Scott, 2015). However, farming systems in the LFAs face significant challenges in performance due to the presence of environmental constrains (Battaglini *et al*., 2014). They are quite heterogeneous in terms of landscape characteristics, availability of natural resources and historically established agricultural practices (Micha *et al*., 2015). As a result, hill farm businesses underperform financially (Acs *et al*., 2010) depending largely on the provision of aid (Morgan-Davies *et al*., 2014). The EU has provided financial aid in order to support hill farming and secure its continuity in an attempt to avoid a reduction in agricultural activity which may otherwise lead to increased land abandonment and a series of environmental risks (European Commission, 2010, 2005).

Hill farming plays a critical role in maintaining the cultural identity of the English uplands (DEFRA, 2004), managing essential wildlife habitats and biodiversity (English Nature, 2005) as well as vitalising the local economy (Harvey & Scott, 2015). On the other hand, technological and political restructurings have generated pressures triggered by increased numbers of livestock that over-graze pasture areas and in turn lead to stresses in biodiversity (English Nature, 2005). Therefore, continuity of grazing livestock production in the LFAs emerges as essential but it calls for a sustainable approach that will be beneficial for the natural resources as well as the rural communities underpinning the farming systems of the uplands.

Towards this direction, previous studies aimed to highlight the factors with an impact on production performance for enabling the discussion of a sustainably productive system (Flaten, 2017; Morris *et al*., 2017; Rojas-Downing *et al*., 2017; Sturaro *et al*., 2013). Goswami *et al*. (2014) considered a large set of social, managerial and physical parameters as triggers of differentiation in agricultural performance. Their approach used Principal Component Analysis (PCA) and Cluster Analysis which generated farm typologies according to the significance of these parameters. Battaglini *et al*. (2014) investigated the development of livestock systems in alpine LFAs, considering economic and technical parameters (management practices, level of intensification, self-sufficiency of feeding stuffs), social characteristics of the farmer and environmental backgrounds (landscape, terrain, biodiversity, etc.). Furthermore, Micha *et al*. (2015) examined the vine-growing systems in Greek LFAs using a non-linear PCA followed by a regression analysis identifying the factors affecting farmers' decision to take part in rural development schemes.

The present study incorporates parameters regarding landscape characteristics, climate and management decisions to investigate the factors that trigger leading or lagging performances in the agricultural systems of LFAs. Farming systems within the LFAs are fairly diversified, mainly affected by landscape characteristics, historically established practices and availability of natural resources (Micha *et al*., 2015). Thus, the analysis of variations in performance corresponds to the examination of farm attributes as potential drivers.

Aims and objectives

The objective of this study is to explore disparities in performances of beef and sheep farming in the LFAs of England towards two main dimensions. The first corresponds to wide spatial patterns in which livestock farming is less or more suitable due to inherent environmental constraints. The second corresponds to farm-level management choices that either improve or burden performance. Both elements provided knowledge regarding improving beef and sheep farming in LFAs. Additionally, the first dimension will enable discussion for policy making interventions that focussed on the mitigation of environmental barriers for agricultural production in environmentally challenging areas. The second will provide knowledge regarding farm-level management decisions leading to higher productivity and profitability that may be replicated and adopted by livestock farm businesses.

Methodology

Initially, a Principal Component Analysis (PCA) (using Oblimin rotated factor loadings) was used to reduce the dimensionality of the data by transforming the original data sample into a new set of linearly non-correlated variables (Abdul-Wahab *et al*., 2005; Jolliffe, 2002). The outputs derived from the PCA were then used as independent variables in a Multiple Linear Regression (MLR) analysis to identify the direction and magnitude of variations in agricultural performance (Areal *et al*., 2012; Tian *et al*., 2016). More specifically, the dependent variables of the regression analysis reflect profitability (Agricultural Gross Margin, AGM) and productivity (Enterprise Output, EO). In addition, the three geographical blocks of North, South and Welsh Borders-Peak District are incorporated in the modelling to investigate for regional differentiation of performance.

Dataset and variables

Data concerning farm business performances and management decisions were derived from the Farm Business Survey (FBS) which is a comprehensive dataset that provides information regarding physical and financial performance of farm businesses across England and Wales. This dataset included the accounting year 2013–2014; included 219 records for beef cattle enterprises and 207 for sheep enterprises. Climate data was obtained from Met Office climate monitoring datasets that provided averaged gridded annual data. Finally, data was also obtained from the Food Standards Agency (FSA) that provided a list with the approved abattoirs. The latter allowed the calculation of the shortest distance between farm businesses and abattoirs which was used as an indicator of remoteness.

Study area

The study area consists of all the LFAs of England covering 2.2 million hectares (DEFRA, 2005) of which 1.8 million hectares are farmed area (17% of the total farmed area) (Harvey & Scott, 2015). The LFAs correspond to two categories a) Severely Disadvantaged Areas (SDAs) and b) Disadvantaged Areas (DA) (DEFRA, 2005). LFA altitudes range from 50 m to 950 m ($\mu = 313$ m and SD = 160 m). The dominant farming activity of the study area was grazing livestock production (DEFRA, 2010).

Results

PCA

For the identification of factors that affect the performance of beef cattle and sheep enterprises, a PCA followed by an MLR were conducted, separately for each enterprise. In particular, eight principal components were indicated that cumulatively explained 66% and 69% of the variance in the dataset for the beef cattle and sheep enterprises respectively. Table 1 and Table 2 present the PCA outputs for the beef cattle and sheep enterprises respectively, values above 0.3 are presented in bold signifying the loadings that were considered for the interpretation of the underlying factors within principal components.

According to Table 1, aggregations of higher loadings indicate that component 1 relates to fair climate, component 2 corresponds to the level of physical disadvantage, the third component corresponds to financial dependency, the fourth component regards lower machinery and equipment evaluation, component 5 relates to the social characteristics of the farmer (corresponding to younger and more educated farmers), component 6 captures remoteness, component 7 size of farm (LU) and paid labour and finally, component 8 regards rurality class.

According to Table 2, factor loadings indicate that the first component corresponds to fair climate, the second component regards level of physical disadvantage, component 3 relates to feeding stuffs, component 4 captures size of farm enterprise (LU), component 5 reflects the social characteristics of the farmer and particularly describing the older and less educated farmers, component 6 regards remoteness, component 7 corresponds to financial liabilities and component 8 relates to family labour.

Table 1. *Variable loadings on principal components for beef enterprises in LFA farms (N = 219)*

Variable	Oblimin rotated factor loadings							
	Fair Climate	Physical Disadvantage	Financial dependency	Low machinery evaluation	Social characteristics of farmer (younger and more educated)	Remoteness	Size of farm and paid labour	Rurality class
Mean min temperature	**0.86**	-0.07	0.02	0.17	0.02	0.01	0.01	-0.03
Mean max temperature	**0.79**	0.06	-0.21	-0.17	0.12	0.02	0.06	-0.06
Sunshine	**0.63**	-0.07	0.09	-0.21	-0.13	0.03	0.08	**0.39**
SDA class*	-0.13	**0.75**	-0.03	-0.03	-0.08	-0.13	0.04	0.03
Beef only	-0.04	**-0.74**	0.03	0.02	-0.18	0.02	0.03	0.15
Altitude	0.01	**0.45**	-0.04	**0.34**	-0.03	**0.36**	0.32	0.28
LU*	-0.1	**-0.42**	**-0.42**	0.03	0.12	-0.14	**0.4**	-0.12
Forage area common land incl per LU	-0.22	**0.39**	0.25	0.23	-0.01	-0.31	-0.01	0.02
Liabilities per LU	-0.05	-0.24	**0.76**	-0.03	0.14	-0.03	0.1	0.08
SFP per LU*	-0.11	0.19	**0.74**	-0.06	0.04	-0.02	0.05	-0.09
Coarse fodder per LU	-0.09	0.02	0	**0.68**	0.01	0.13	-0.07	-0.08
Machinery equipment evaluation per LU	-0.17	0.18	0.3	**-0.6**	0	0.28	-0.01	-0.02
Rainfall	-0.22	0.23	0.14	**0.5**	0.05	0.03	-0.22	0
Age of farmer	-0.13	-0.12	0.02	0.09	**-0.81**	0.04	0.17	-0.08
Education of farmer	-0.06	-0.1	0.16	0.14	**0.76**	0.05	0.16	-0.02
Distance to closest abattoir	-0.27	0.13	-0.16	-0.11	0.1	**-0.7**	0.19	0.18
Concentrates per LU	**-0.32**	-0.03	**-0.34**	-0.18	0.1	**0.62**	0.06	0.07
Paid labour per LU	0.08	0.03	0.1	-0.06	-0.04	-0.04	**0.89**	-0.06
Rurality class	-0.01	-0.04	0	0	0.05	-0.05	-0.07	**0.92**

*SDA: Severely Disadvantaged Areas, LU: Livestock Unit, SFP: Single Farm Payment

Table 2. *Variable loadings on principal components for sheep enterprises in LFA farms (N = 207)*

Variables	Oblimin rotated factor loadings							
	Fair climate	Physical disadvantage	Feeding stuffs per LU	Size of farm (LU)	Social characteristics of farmer (Older and less educated)	Remoteness	Liabilities	Family labour
Mean max temperature	**0.79**	-0.04	0.03	0.07	-0.01	-0.16	0.14	0.01
Mean min temperature	**0.76**	0.09	-0.05	0	0.11	0.08	0.18	-0.13
Sunshine	**0.69**	0.04	-0.05	0.12	0.05	-0.12	-0.3	0.06
Rurality class	**0.67**	0.01	-0.03	-0.16	-0.06	**0.35**	-0.11	0.1
Rainfall	**-0.54**	0.21	0.02	-0.19	0.12	0.4	0.15	-0.06
SFP per LU*	0.13	**0.83**	0.13	-0.16	0.03	-0.09	0.17	0
Forage area common land included per LU	-0.13	**0.83**	-0.07	0.15	-0.05	0.1	-0.09	0.05
Machinery per LU	0.05	**0.48**	-0.18	**-0.31**	-0.27	-0.1	**-0.36**	0.11
Concentrates per LU	-0.08	-0.1	**0.87**	0.16	-0.06	-0.02	-0.16	0.02
Coarse fodder per LU	0.07	0.12	**0.86**	-0.22	-0.01	-0.04	0.1	0.01
LU*	0.09	-0.14	-0.13	**0.81**	-0.03	0.02	-0.08	0.09
Paid labour per LU	0.2	0.22	0	**0.43**	**0.41**	0.09	0.02	**-0.41**
Age of farmer	0	-0.04	-0.05	0.04	**0.82**	0.01	0.04	0.14
Education of farmer	0.01	0.06	0.13	**0.45**	**-0.6**	0.13	0.25	-0.08
Altitude	-0.1	0.01	-0.11	0.15	-0.04	**0.77**	-0.04	-0.03
Distance to closest abattoir	**-0.33**	0.25	-0.07	**0.45**	-0.02	**-0.49**	-0.01	-0.11
Liabilities per LU	-0.01	0.07	-0.05	-0.03	-0.03	-0.03	**0.78**	0.17
SDA class*	**-0.35**	0.1	0.23	0.15	0.11	0.22	**-0.4**	0.13
Unpaid labour per LU	0.02	0.07	0.03	0.1	0.12	0.01	0.09	**0.92**

* SFP: Single Farm Payment, LU: Livestock Unit, SDA: Severely Disadvantaged Areas.

Table 3. *Aggregated results for the beef cattle and sheep enterprises MLR*

Enterprise	Geographic Block	Dependent variables	Independent variables								
			Fair climate	Physical disadvantage (+)	Financial dependency	Younger and more educated farmer	Size of enterprise (LU) and hired labour	Low machinery evaluation per LU	Remoteness /Proximity to abattoir		
Beef cattle	North										
		AGM per LU			63.93[c]			−125.49[a]	−78.2[b]		
		EO per LU	−76.83[c]			78.43[b]		−193.68[a]	143.95[a]		
	South										
		AGM per LU							176.65[a]		
		EO per LU			−156.48[b]			−141.06[b]	310.58[a]		
	Peaks and Welsh borders										
		AGM per LU					93.24[c]	−206.3[a]			
		EO per LU			−178.26[a]		141.46[a]	−187.2[a]	139.48[c]		
	All blocks									Peaks and Welsh borders block	South block
		AGM per LU						−128.18[a]	−54.11[c]		
		EO per LU	−76.98[b]		−46.09[c]	69.25[b]		−180.93[a]	161.4[a]		

Table 3. (con'd)

Enterprise	Geographic Block	Dependent variables	Independent variables									
			Fair climate	Physical disadvantage (+)	Feeding stuffs per LU	Financial dependency	Aged and less educated farmer	Size of enterprise (LU) and hired labour	Family labour	Remoteness / Proximity to abattoir		
Sheep	North											
		AGM per LU	58.91[b]									
		EO per LU		−33.63[c]								
	South											
		AGM per LU			64.68[c]	−130.6[c]						
		EO per LU			104.16[b]	−165.9[b]				88.94[b]		
	Peaks and Welsh borders											
		AGM per LU			−127.55[b]				79.52[b]			
		EO per LU							102.29[a]			
	All blocks										Peaks and Welsh borders block	South block
		AGM per LU	37.45[c]	−36.95[c]							90.59[c]	
		EO per LU		−36.42[b]								

[a]Statistically significant coefficient at the 1% level or less.
[b]Statistically significant coefficient at the 5% level or less.
[c]Statistically significant coefficient at the 10% level or less.

MLR

16 MLR models, examining profitability and productivity for the whole study area and each geographic region for both beef cattle and sheep enterprises were performed. The statistically significant (a = 0.1) estimated coefficients are presented aggregated in Table 3. The factors of financial dependency, low machinery and equipment evaluation and remoteness emerge as the most essential determinants of performance for the beef cattle production systems across the whole study area. Specifically, the first two were found to be negative drivers of performance whereas remoteness was found to have positive effects both in profitability as well as productivity for all geographic blocks.

Sheep enterprises in the geographic block of Welsh border-Peak district are estimated to be more profitable than their counterparts in the North block. The factors of physical disadvantage and financial dependency are negative drivers of performance. Furthermore, fair climate, feeding stuffs per LU, family labour and remoteness emerge as positive determinants of performance of sheep enterprises.

Discussion

According to the results, fair climate appears to be a positive determinant for sheep enterprises. Previous studies have suggested the vital role that climate plays for performance as it affects animal mortality and morbidity (Gaughan, 2012; McCann *et al*., 2010; Rojas-Downing *et al*., 2017). Physical disadvantages, such as steep slopes or challenging climate, are a negative determinant for sheep enterprises. This result is in line with Kowalczyk *et al*. (2014) and Mena *et al*. (2017) who suggest that altitude is an essential parameter for agricultural performance and vegetation growth.

Financial dependency is identified as a negative driver. In previous studies, receipt of SFP has found to be an important factor in livestock production systems, as it leads to decreasing numbers of sheep and beef cattle (Acs *et al*., 2010; Morgan-Davies *et al*., 2014). The social characteristics of the farmer and specifically lower age and higher level of education are found to be positive drivers for the beef cattle enterprises. Studies have examined the effects of age and education in the performance of agricultural systems, suggesting ambiguous results highlighting both their importance (Giannakis & Bruggeman, 2015; Goswami *et al*., 2014; Hansson, 2008) as well as their insignificance (Finneran, 2013).

The results on the size of the enterprise and hired labour are in concordance with Morgan-Davies *et al*. (2012), who point out that the size of production is affected essentially by availability of external labour which shapes management decisions on the farm. Remoteness drastically affects beef cattle enterprises as well as sheep but to a lesser degree. Studies have analysed this parameter pointing out that differentiation of performance of farm businesses may be influenced by remoteness (Darnhofer *et al*., 2010; Krishna & Veettil, 2014).

Low machinery and equipment evaluation negatively affects performance of beef cattle production systems in all geographic blocks. Hansson (2007) reported the significance of the adoption of new technologies for the profitability of farm businesses.

Finally, feeding stuffs is identified as a positive determinant for sheep enterprise performance. This finding is in contrast with relevant studies that have highlighted that although this factor is a vital parameter for farm profitability, it may also lead in higher levels of purchased feeds and increase variable costs (Finneran, 2013; Ripoll-Bosch *et al*., 2012).

In addition, of particular importance is the finding that the Welsh Borders-Peak District geographic block emerges as more profitable than the North block for sheep enterprises. Previous research on the regional variability of financial performance and productivity of agricultural systems has examined parameters such as farmer training, age and education as well as investments in agriculture as determinants of the differentiation (Giannakis & Bruggeman, 2015). Moreover, the development of regional heterogeneity depends on environmental and economic aspects that in turn impact on management practices as well as prices (Hanley *et al*., 2007; Karlsson & Nilsson, 2014).

Conclusions, Limitations and Future Steps

A demonstration of an approach for exploring and identifying factors that trigger disparities in the performance of LFA livestock farms is presented. Ultimately, this research collapses the variations of performance into two core dimensions. The first regards the identification of broad spatial patterns in which livestock production systems are less or more feasible because of the presence of natural constraints. The second addresses farm-level management decisions that either enhance or hinder agricultural performance.

This study follows a methodology that integrates several farm attributes as potential drivers of agricultural performance generating a smaller set of principal components through PCA and investigates the explanatory power of this set for variations in agricultural performance through MLR. These farm attributes included variables relative to climate, landscape characteristics and management decisions of the farmer.

Results indicated that within a broad geographical classification, sheep enterprises in the Welsh borders-Peak district block perform better than their counterparts in the North. Farming systems in the former block either benefit from more favourable environmental conditions or have adopted management decisions enhancing farm businesses performance. Regarding the latter, the present analysis found that that financial dependency and low machinery and equipment evaluation affect negatively performance whereas remoteness are highlighted as positive driver of performance.

A limitation emerges through this analysis due to lack of precise geographical information of the farms. Specifically, the FBS provides the geographical reference of the farms on the 10 km × 10 km grid square rather than their actual location. Moreover, the three datasets of this analysis (derived from the FBS, Met Office and the FSA) are linked geographically. Thus, the linked data regarding climate and remoteness are approximate and not precise. Consequently, the results lose some accuracy which could be increased were the actual location of the farms used.

These findings allow the discussion of policy interventions that will accommodate the natural environmental challenges of LFAs as well as inform farmers about successful practices that enhance farm performance. The focus of these interventions could be on identifying particular natural obstacles of the more challenging areas and provide financial aid to those that are not able to overcome obstacles emerging from the environment, allowing the continuity of hill farming systems. Furthermore, it would be important to provide farmers with knowledge relating to particular practices which may benefit their businesses, thus providing them with valuable information regarding future-proofing agricultural production in the uplands.

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