An exploration of the labour and environmental efficiency of Scottish cattle and sheep farms

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Abstract

The analysis on labour conditions in the Scottish case study focuses on how efficient these farms are in their use of (paid and unpaid) labour to deliver environmental (renewable energy and woodland) and diversification (tourism) outputs. We use FADN data and data envelopment analysis (DEA) i.e., Russell non-radial (NR) efficiency measure in an adjusted CCR model. Results show a strong difference between how efficiently paid and unpaid labour are used for creation of both environmental/ diversification and livestock outputs, with unpaid labour scores consistently higher than paid labour scores. The efficiency of unpaid labour in creation of traditional livestock products as compared to environmental/diversification is, as expected, lower. Both paid and unpaid labour are more efficiently used on sheep farms than cattle farms to produce livestock outputs. It is less surprising that, compared to all other inputs, the use of unpaid labour is the most efficient for

creation of environmental outputs, than it is the fact that unpaid labour is still highly efficient for creation of traditional livestock products, e.g., higher than land area and paid labour. This is consistent with the current discussion on distribution of paid and unpaid labour across these types of farms.

Keywords: Labour, efficiency analysis, diversification, livestock farming, Scotland

JEL Codes: Labor and Demographic Economics J0; Q120 Micro Analysis of Farm Firms, Farm Households, and Farm Input Markets; C6 Mathematical Methods; Programming Models; Mathematical and Simulation Modeling

Introduction

The majority of the Scottish cattle and sheep farms (corresponding to 72 per cent of cattle and 89 per cent of sheep numbers) are operating in Less Favoured Areas (LFA) reflecting the distribution of grassland and rough grazing (Scottish Government, 2016). Cattle and sheep (LFA) farms vary from large and extensive holdings in the south-west to small holdings and crofts in the north-west of Scotland. Cattle and sheep farms contribute about a third of the total Scottish agricultural output (Vosough-Ahmadi et al., 2015).

Cattle and sheep farms have a key contribution to greenhouse gas (GHG) emissions in Scotland while overall following the slowly decreasing trend at agricultural sector level, which shows a 16 per cent reduction in GHG emissions during the past three decades (Quality Meat Scotland 2020). GHG emissions from cattle and sheep farms account for methane, nitrous oxide and carbon dioxide emissions sourced from livestock and crop related activities e.g., through (over)grazing, agricultural waste and chemical inputs, some of which are also monitored for regulatory purposes

(Scottish Environment Protection Agency 2020). Overall, cattle and sheep farms show a high negative correlation between financial returns and technical efficiency, and their GHG emissions per unit of output; this indicates that the more efficient farms are also the more environmentally sustainable (Quality Meat Scotland 2020).

Cattle & sheep (LFA) farms represent 42 per cent of total Standard Labour Requirements (SLR) compared to their 27 per cent share of standard output (SO) in the Scottish agriculture i.e., this farm type has a much higher labour requirement in proportion to its total SO. The average income of commercial farms in Scotland is estimated to have halved over the period covered in this study (2011-2015), where the largest decline was seen in sheep farms in LFA (Scottish Government, 2016). This has been reflected in a return to unpaid labour on commercial farms. In absence of direct payments post-Brexit, the potential decline *ceteris paribus* in the profitability of many cattle and sheep farms will reflect in a further decline in paid labour.

Reliance on non-agricultural sources of income e.g., tourism, renewables and woodland, and financial support from grants and subsidies is apparent for many farms in the cattle and sheep industry (Scottish Government, 2016). This is even more relevant post-Brexit, with the economic viability of cattle and sheep farms at risk according to many studies analysing the impacts of Brexit on the UK agriculture. While there are mixed findings based on modelling assumptions, overall, this farm type is under threat in most scenarios forecasting the separate or combined effects of changes in prices, trade, and farm payments. Ojo et al. (2020) found that close to 60 per cent of beef and sheep farms are sustainable due to access to non-farm income, and their sustainability may be dependent on e.g., on-farm diversification or increased labour efficiency contingent to changes in farm payments and international trade.

It is unclear to what extent the inevitable economic adjustments on cattle and sheep farms post-Brexit may translate into further negative effects on the environment (e.g., climate and biodiversity) as there is a confirmed context of strengthening the post Brexit policy support for further greening of agriculture and food production through e.g., environmentally related subsidies. In a pre-Brexit assessment of the impact of greening measures on the Scottish cattle and sheep farms, Vosough Ahmadi et al. (2015) found that all farm types benefitted from adopting the greening measures as opposed to non-compliance and subsequent ineligibility for the greening payments.

Method and Data

As indicated in the context description of the Scottish cattle and sheep farms, the elements shaping the research question focus on how efficient these farms are in their use of (paid and unpaid) labour to deliver environmental (renewable energy and woodland) and diversification (tourism) outputs. This is compared with the efficiency of the labour input used to produce ‘traditional’ livestock products output.

Data envelopment analysis (DEA) is a frequently used method to estimate the efficiency of production systems (Färe and Knox Lovell, 1978). The main advantage of DEA is that it does not require a priori assumptions on the underlying functional relationships between inputs and outputs (Seiford and Thrall, 1990). According to traditional microeconomic theory based on the assumption of optimising behaviour, producers optimise from a technical perspective by not wasting resources i.e., they operate on the boundary, rather than on the interior, of their production possibility sets. DEA offers a method to analyse the degree to which producers fail to optimise and the extent of the deviations from technical and economic efficiency (Färe and Knox Lovell, 1978).

We use a non-radial (NR) version of the CCR model developed by Färe and Knox Lovell (1978). We use Russell non-radial efficiency measure, which allows for the nonproportional adjustment of different inputs/outputs and has a higher discriminating power than the radial efficiency measure in comparing decision making units (farms). The NR CCR model provides information on the efficiency of specific inputs or outputs.

We run input-oriented DEA for both constant returns to scale (CRS) and variable returns to scale (VRS). While the reference technology for the CCR model presents constant returns to scale (CRS), the addition of a separate constraint to the reference technology allows for a VRS setting (adjusting the CCR into the BCC model (Färe et al. 1983). As we are not including undesirable outputs, integrating efficiency measures with the CRS and VRS reference technologies is fitting since this provides information on both the technical and scale efficiency.

We estimated the models on the cattle and/or sheep samples and tested for difference by mean scores across the ecological types developed in the LIFT FADN protocol (low input score and integration score). The models were developed in Excel Visual Basic for Applications (VBA) (self-coded programs).

Next, we run OLS regressions with Huber-White robust standard errors to estimate the effect of secondary variables on efficiency scores within and across farm type (cattle and sheep samples) using SHAZAM v11.1 software package.

We used EUROSTAT Farm Accountancy Data Network (FADN) for Scotland for 165 cattle and 104 sheep farms (defined by FADN as farms where at least 66% of their gross margin comes from cattle and sheep products respectively). Observations for each farm for years 2011 to 2015 led to a total sample of 1006 farms (630 cattle and 376 sheep farm observations).

As with the FADN WP1 typology, the data was pooled in order to generate a usable sample size for the case study, and monetary values are deflated with the appropriate indices using 2010 as the base year.

We estimated two models, the 'environmental labour' model estimating the efficiency of labour used to create the environmental (renewable energy and woodland)/ diversification (tourism) output; and the 'traditional labour' model estimating the efficiency of labour used to create livestock/ livestock products output.

The reason for estimating the two models separately is linked to the empirical focus of the exercise i.e., a ranking of farms with a specific environmental/ diversification profile. This has the added benefit of simplification of the models i.e., a lower number of variables which is particularly welcome for the 'environmental labour' model run on a smaller sample. Additionally, not including both the traditional and environmental outputs in the same model prevents the exclusion of a large number of farms that produce only the traditional output (i.e., not the environmental/ diversification one) from a model that would focus on both types of outputs. Moreover, we assumed there will be fewer differences by LIFT typology variables – 'high input vs low input' and 'high integration vs low integration' - between efficiency scores for the 'environmental labour' models than for the 'traditional labour' ones due to the environmental/diversification profile of the farms overlapping with the nature of the typology variables.

The 'environmental labour' model estimates the efficiency of labour used to create the environmental (renewable energy and woodland)/ diversification (tourism) output. This was run for the farms with an environmental/ diversification output, which constitute a small sample (89 observations pooled for years 2014 and 2015 - cattle and sheep farms together). The number of observations is acceptable according to both widely adopted rules of thumb i.e., the number of DMUs should be larger than the product and be at least two times larger than the sum of the number of inputs and outputs (Dyson et al., 2001; Ramanathan, 2003 as cited in Zhou et al., 2008).

The ‘environmental labour’ model has four input variables - total assets (minus land value), total intermediate consumption, paid labour (hours), unpaid labour (hours) – and one output variable - environmental/ diversification output.

The ‘traditional labour’ model estimates the efficiency of labour used to create livestock/ livestock products output. This was run for the farms with livestock/ livestock products output (run separately for 630 cattle and respectively 376 sheep farm observations).

The ‘traditional labour’ model has five input variables - total assets (minus land value), total intermediate consumption, paid labour (hours), unpaid labour (hours), land area owned or rented (ha) – and one output variable - livestock/ livestock products output.

Table 4 and Tables 5 and 6 in Appendix present the variables included in the analysis.

Results and discussion

Figures 1-6 present the histograms for all NR CCR input-orientated models run for all inputs, and separately for each input. Re the latter, it is important to recall that NR CCR model assumes that all the other inputs are held constant.

Figures 1 and 2 for the VRS and CRS ‘environmental labour’ models run for the cattle and sheep farms together show a dispersed distribution of the input scores, indicating significant potential for efficiency improvements. Scores for all inputs, and assets and intermediate consumption run separately show similar trends and values (with twice as high averages for the VRS case).

There is a strong difference between how efficiently paid and unpaid labour are used for creation of environmental/ diversification outputs in both CRS and VRS models, with unpaid labour scores three (CRS) to four times (VRS) higher than paid labour scores.

Moreover, efficiency scores for unpaid labour are the highest across all inputs. This is consistent with the current discussion on distribution of paid and unpaid labour across these types of farms – even more evident following the period of analysis due to recent developments e.g., Brexit -, and certainly not surprising for the case of environmental/ diversification activities.

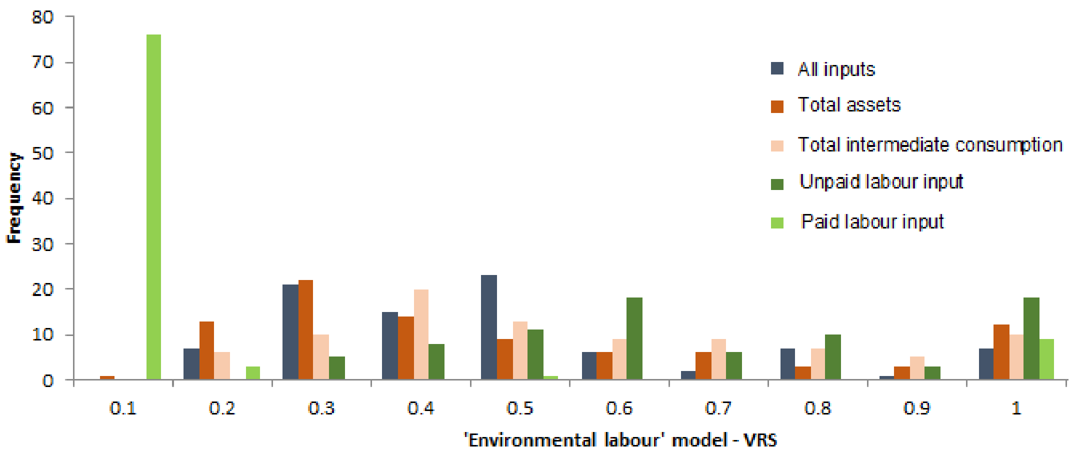

Figure 1. ‘Environmental labour’ model_VRS_efficiency scores_cattle and sheep farms sample (superimposed histograms)

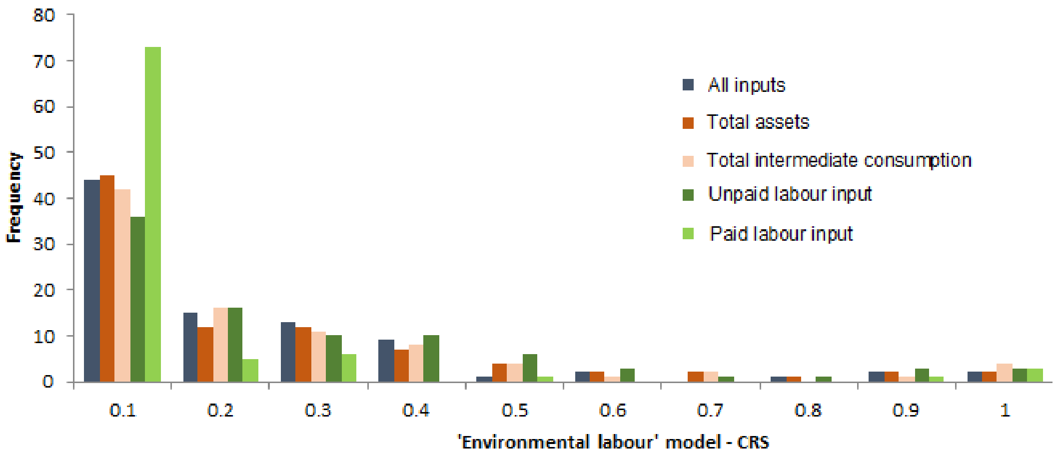

Figure 2. ‘Environmental labour’ model_CRS_efficiency scores_cattle and sheep farms sample (superimposed histograms)

When looking at the efficiency of labour use for traditional outputs – livestock and livestock products (Figures 3-6), results across models are less differentiated between the CRS and VRS cases (still higher for the latter). Scores for all inputs, and assets, intermediate consumption and land area run separately show similar trends and values across cattle and sheep models. Intermediate consumption shows the highest average efficiency scores, followed by total assets, unpaid labour, land and paid labour.

Again, as in the case of environmental/diversification models, there is a strong difference between how efficiently paid and unpaid labour are used for creation of livestock outputs in both CRS and VRS models, with unpaid labour scores four (CRS) to seven times (VRS) higher than paid labour scores in the cattle models, and respectively three (VRS) to four times (CRS) higher in the sheep models.

This is, again, consistent with the current discussion on distribution of paid and unpaid labour across these types of farms – even more evident in the context of events leading up to, and particularly following, Brexit.

The efficiency of unpaid labour in creation of traditional livestock products as compared to environmental/diversification is, as expected, lower. It is less surprising that, compared to all other inputs, the use of unpaid labour is the most efficient for creation of environmental outputs, than it is the fact that unpaid labour is still highly efficient for creation of traditional livestock products, e.g., higher than land area and paid labour.

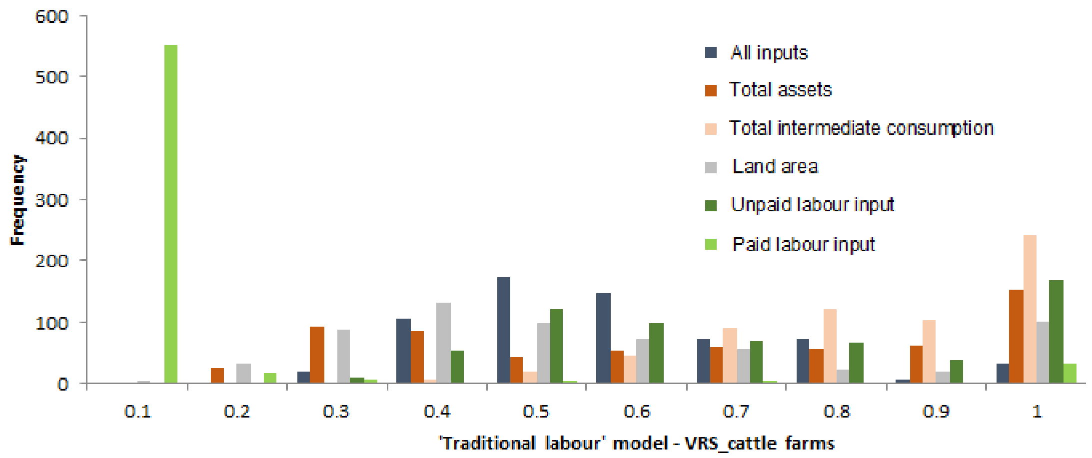

Figure 3. 'Traditional labour' model_VRS_efficiency scores_cattle farms sample (superimposed histograms)

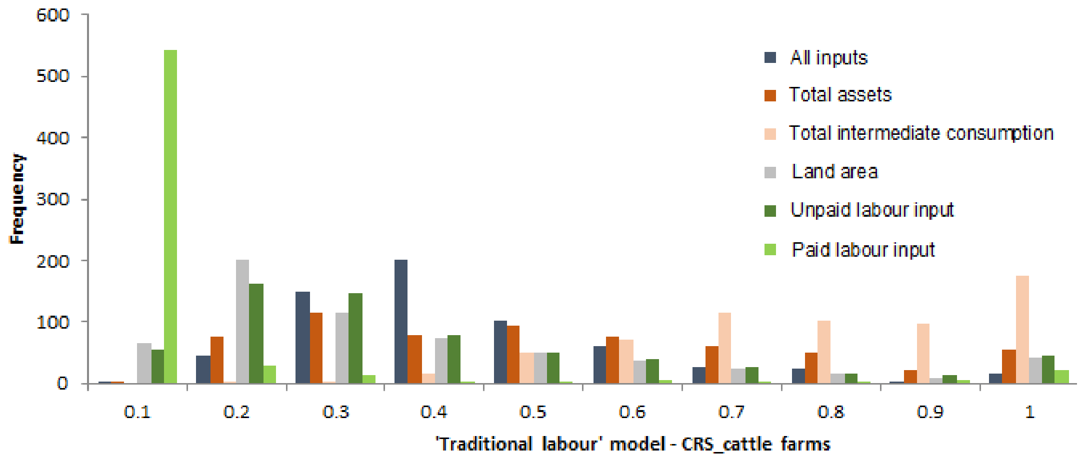

Figure 4. 'Traditional labour' model_CRS_efficiency scores_cattle farms sample (superimposed histograms)

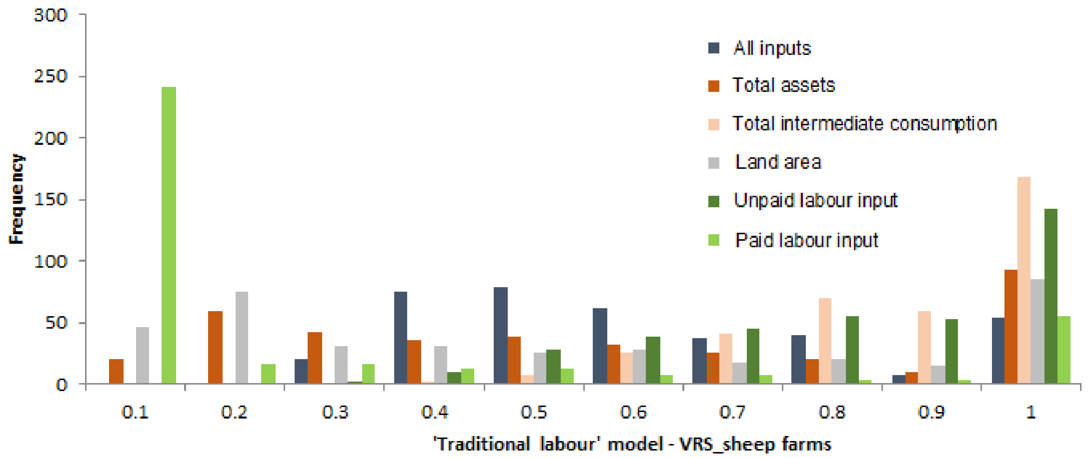

Figure 5. 'Traditional labour' model_VRS_efficiency scores_sheep farms sample (superimposed histograms)

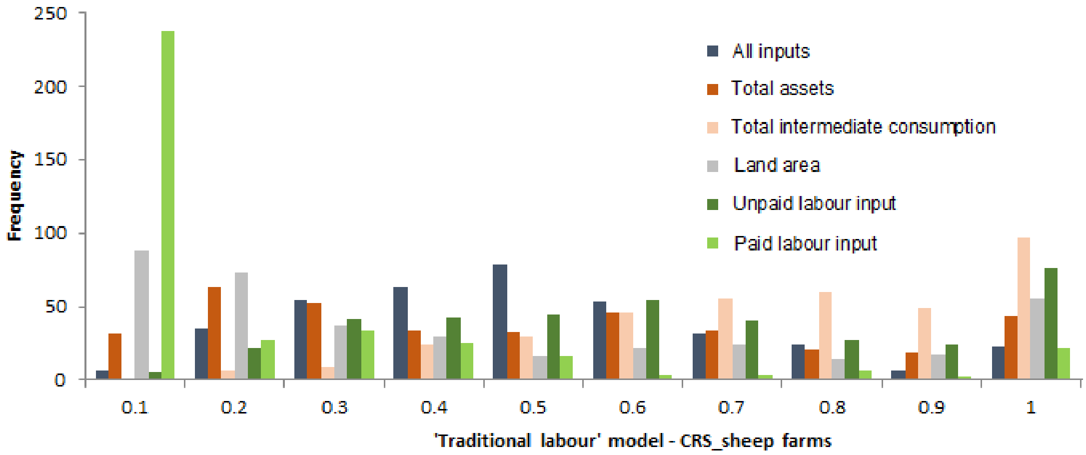

Figure 6. ‘Traditional labour’ model_CRS_efficiency scores_sheep farms sample (superimposed histograms)

We run tests to determine significant differences by LIFT typology variables – ‘high input vs low input’ and ‘high integration vs low integration’ - for all models (Table 1 and Table 2). As expected, there are no significant differences for the environmental labour models (except for the CRS paid labour model) due to the similarity between the environmental/diversification profile of the farms and the nature of the typology variables.

However, there are significant differences under both typology variables for most ‘traditional labour’ models (similar in both CRS and VRS), with only a few exceptions, mostly linked to models run on the cattle farms sample for the ‘high input vs low input’ typology.

We regressed (controlling robustness) the efficiency scores on variables identified in the literature as potentially influencing factors. Table 3 presents regressions for all models focussing on all inputs, unpaid labour, and paid labour efficiency scores as dependent variables, with environmental and other subsidies, organic farm status, and LIFT typology scores as regressors.

In the ‘environmental labour’ models, similar to the testing findings above, LIFT typology variables have a significant effect only on paid labour scores (CRS), with other subsidies being the only regressor with a significant effect on unpaid labour scores (both CRS and VRS models) and on ‘all inputs’ scores (VRS).

In the ‘traditional labour’ models, environmental and other subsidies, together with the LIFT integrated typology score have a significant effect in most cattle models, while LIFT low input typology and organic farm status significantly influencing ‘all inputs’ and unpaid labour scores (both VRS).

In the ‘traditional labour’ models run on the sheep farms sample, the LIFT integrated typology score have a significant effect in all models, organic status is significant in almost all models, with environmental and other subsidies with a significant effect in more than half of the models. The findings support the issues presented in the case study description on subsidies dependence and differences between types of labour. The relationship between farm organic status and efficiency scores of labour used for both ‘traditional’ and ‘diversification’ outputs emphasise that organic production is not only environmentally oriented but has a clear economic reasoning.

Conclusions

In accordance with key elements shaping the current and future situation of the Scottish cattle and sheep farms e.g., transitions in labour use and access to subsidies following Brexit and other shocks to markets, the analysis focused on the efficiency of labour used for creation of both environmental and traditional outputs on cattle and sheep farms using efficiency models allowing for better discrimination at the level of specific inputs and outputs.

There is a strong difference between how efficiently paid and unpaid labour are used for creation of both environmental/ diversification and livestock outputs, with unpaid labour scores consistently higher than paid labour scores.

The efficiency of unpaid labour in creation of traditional livestock products as compared to environmental/diversification is, as expected, lower. Both paid and unpaid labour are more efficiently used on sheep farms than cattle farms to produce livestock outputs. It is less surprising that, compared to all other inputs, the use of unpaid labour is the most efficient for creation of environmental outputs, than it is the fact that unpaid labour is still highly efficient for creation of traditional livestock products, e.g., higher than land area and paid labour. This is consistent with the current discussion on distribution of paid and unpaid labour across these types of farms – even more evident following the period of analysis due to recent developments e.g., Brexit.

While there are mostly no significant differences by LIFT typologies for the environmental labour models, scores are significantly differentiated under both typology variables for most ‘traditional labour’ models.

Regression findings show subsidies and organic status as consistently significant in a majority of environmental and traditional models, which supports the issues presented in the case study description on subsidies dependence and differences between types of labour. The relationship between farm organic status and efficiency scores of labour used for both ‘traditional’ and ‘diversification’ outputs emphasise that organic production is not only environmentally oriented but has a clear economic reasoning.

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Table 1. Test of differences of mean scores by variable (p-values) – 'environmental labour' models

	All inputs	Total assets (euro)	Total intermediate consumption (euro)	Unpaid labour input (hours)	Paid labour input (hours)
			Constant returns to scale (CRS)		
Cattle and sheep					
High input vs low input	0.15	0.26	0.27	0.49	**0.01**
High integration vs low integration	0.07	0.14	0.08	0.19	**0.02**
			Variable returns to scale (VRS)		
Cattle and sheep					
High input vs low input	0.23	0.21	0.42	0.91	0.08
High integration vs low integration	0.18	0.18	0.32	0.78	0.08

Note: Bold figures indicate that the difference is statistically significant at 95%.

Table 2. Test of differences of mean scores by variable (p-values) - 'traditional labour' models

	All inputs	Total assets (euro)	Total intermediate consumption (euro)	UAA (ha)	Unpaid labour input (hours)	Paid labour input (hours)

			Constant returns to scale (CRS)			
Cattle						
High input vs low input	0.14	0.82	**0.00**	**0.00**	0.09	0.59
High integration vs low integration	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Sheep and goat						
High input vs low input	**0.00**	**0.00**	0.09	**0.00**	**0.00**	**0.05**
High integration vs low integration	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
			Variable returns to scale (VRS)			
Cattle						
High input vs low input	0.46	0.15	**0.00**	**0.00**	0.96	0.52
High integration vs low integration	**0.00**	**0.02**	0.24	**0.00**	**0.03**	**0.00**
Sheep and goat						
High input vs low input	**0.00**	**0.00**	**0.02**	**0.00**	**0.02**	0.21
High integration vs low integration	**0.00**	**0.00**	0.99	**0.00**	**0.00**	**0.00**

Note: Bold figures indicate that the difference is statistically significant at 95%.

Table 3. Regression of efficiency scores against explanatory variables

Model type	Explanatory variable name	Estimated coefficient	Standard error	T-ratio	P-value
'Environmental labour' models					

CRS efficiency score IO - **All inputs**	Subsidies_environment_euro	-4.82E-06	2.51E-06	-1.925	0.058
	Organic	-4.40E-02	7.32E-02	-0.6015	0.549
	Low input score	-3.87E-02	3.74E-02	-1.037	0.303
	Integrated score	7.21E-02	4.67E-02	1.545	0.126
	Total subsidies excl. environment	6.94E-07	4.51E-07	1.538	0.128
	CONSTANT	0.1245	4.52E-02	2.756	0.007
CRS efficiency score IO - **Unpaid labour input**	Subsidies_environment_euro	-5.02E-06	3.40E-06	-1.474	0.144
	Organic	-9.30E-02	0.1043	-0.8916	0.375
	Low input score	-1.70E-02	4.76E-02	-0.3568	0.722
	Integrated score	6.27E-02	5.37E-02	1.168	0.246
	Total subsidies excl. environment	1.24E-06	6.05E-07	2.051	**0.043**
	CONSTANT	0.12948	5.61E-02	2.309	0.023
CRS efficiency score IO - **Paid labour input**	Subsidies_environment_euro	-2.66E-06	1.69E-06	-1.578	0.118
	Organic	1.56E-02	3.25E-02	0.4805	0.632
	Low input score	-8.64E-02	2.88E-02	-2.998	**0.004**
	Integrated score	8.82E-02	4.40E-02	2.005	**0.048**
	Total subsidies excl. environment	3.14E-07	3.29E-07	0.9524	0.344
	CONSTANT	6.67E-02	3.58E-02	1.861	0.066
VRS efficiency score IO - **All inputs**	Subsidies_environment_euro	4.75E-07	5.36E-06	8.86E-02	0.93
	Organic	-0.11974	8.60E-02	-1.393	0.167

	Low input score	-4.78E-02	4.85E-02	-0.9873	0.326
	Integrated score	4.90E-02	5.12E-02	0.957	0.341
	Total subsidies excl. environment	1.15E-06	4.31E-07	2.68	**0.009**
	CONSTANT	0.34915	5.90E-02	5.916	0
VRS efficiency score IO - **Unpaid labour input**	Subsidies_environment_euro	-1.34E-06	5.05E-06	-0.266	0.791
	Organic	-4.58E-02	0.1116	-0.41	0.683
	Low input score	-2.43E-02	5.38E-02	-0.4528	0.652
	Integrated score	8.44E-03	5.32E-02	0.1586	0.874
	Total subsidies excl. environment	1.59E-06	4.09E-07	3.893	**0**
	CONSTANT	0.5312	5.87E-02	9.052	0
VRS efficiency score IO - **Paid labour input**	Subsidies_environment_euro	1.85E-06	6.69E-06	0.2762	0.783
	Organic	-4.32E-02	9.67E-02	-0.4465	0.656
	Low input score	-7.94E-02	5.33E-02	-1.491	0.14
	Integrated score	9.68E-02	6.21E-02	1.561	0.122
	Total subsidies excl. environment	5.66E-07	6.10E-07	0.9271	0.357
	CONSTANT	7.11E-02	7.03E-02	1.011	0.315
'Traditional labour' models – cattle					
CRS efficiency score IO - **All inputs**	Subsidies_environment_euro	-1.90E-06	6.54E-07	-2.901	**0.004**
	Organic	-8.95E-03	6.80E-02	-0.1315	0.895
	Low input score	1.64E-02	1.44E-02	1.143	0.254

	Integrated score	0.10889	1.42E-02	7.684	**0**
	Total subsidies excl. environment	5.77E-07	1.40E-07	4.13	**0**
	CONSTANT	0.29623	1.59E-02	18.6	0
CRS efficiency score IO - **Unpaid labour input**	Subsidies_environment_euro	-2.65E-06	8.86E-07	-2.992	**0.003**
	Organic	-3.82E-02	7.81E-02	-0.4893	0.625
	Low input score	-4.89E-03	2.08E-02	-0.2345	0.815
	Integrated score	0.12004	2.06E-02	5.837	**0**
	Total subsidies excl. environment	1.64E-06	1.84E-07	8.909	**0**
	CONSTANT	0.18295	2.27E-02	8.051	0
CRS efficiency score IO - **Paid labour input**	Subsidies_environment_euro	-1.54E-06	6.75E-07	-2.287	**0.023**
	Organic	0.11128	0.102	1.091	0.276
	Low input score	2.44E-02	1.76E-02	1.389	0.165
	Integrated score	5.86E-02	1.72E-02	3.41	**0.001**
	Total subsidies excl. environment	5.31E-07	2.04E-07	2.61	**0.009**
	CONSTANT	2.27E-03	1.79E-02	0.127	0.899
VRS efficiency score IO - **All inputs**	Subsidies_environment_euro	-1.37E-06	7.16E-07	-1.907	0.057
	Organic	9.11E-02	6.26E-02	1.455	0.146
	Low input score	5.11E-02	1.46E-02	3.491	**0.001**
	Integrated score	8.28E-02	1.43E-02	5.81	**0**

	Total subsidies excl. environment	-7.74E-07	1.56E-07	-4.968	**0**
	CONSTANT	0.52971	1.61E-02	32.94	0
VRS efficiency score IO - **Unpaid labour input**	Subsidies_environment_euro	-7.97E-08	1.30E-06	-6.15E-02	0.951
	Organic	0.18449	8.11E-02	2.275	**0.023**
	Low input score	3.41E-02	1.93E-02	1.766	0.078
	Integrated score	5.44E-02	1.94E-02	2.802	**0.005**
	Total subsidies excl. environment	-1.26E-06	2.07E-07	-6.079	**0**
	CONSTANT	0.71253	2.24E-02	31.88	0
VRS efficiency score IO - **Paid labour input**	Subsidies_environment_euro	-1.79E-06	6.53E-07	-2.736	**0.006**
	Organic	6.46E-02	0.1008	0.6407	0.522
	Low input score	3.96E-02	2.10E-02	1.884	0.06
	Integrated score	8.73E-02	2.01E-02	4.353	**0**
	Total subsidies excl. environment	5.68E-07	2.14E-07	2.656	**0.008**
	CONSTANT	-1.35E-02	1.97E-02	-0.6862	0.493
'Traditional labour' models – sheep					
CRS efficiency score IO - **All inputs**	Subsidies_environment_euro	-2.03E-06	9.97E-07	-2.041	**0.042**
	Organic	0.10448	3.55E-02	2.948	**0.003**
	Low input score	-5.90E-02	2.59E-02	-2.278	**0.023**
	Integrated score	0.16558	2.55E-02	6.497	**0**

	Total subsidies excl. environment	1.21E-06	2.72E-07	4.445	**0**
	CONSTANT	0.30424	2.84E-02	10.7	0
CRS efficiency score IO - **Unpaid labour input**	Subsidies_environment_euro	-1.96E-06	1.25E-06	-1.576	0.116
	Organic	0.1055	3.70E-02	2.848	**0.005**
	Low input score	-2.48E-02	2.94E-02	-0.8428	0.4
	Integrated score	0.19995	2.95E-02	6.789	**0**
	Total subsidies excl. environment	2.66E-06	2.73E-07	9.772	**0**
	CONSTANT	0.27724	3.36E-02	8.256	0
CRS efficiency score IO - **Paid labour input**	Subsidies_environment_euro	-1.57E-06	1.38E-06	-1.143	0.254
	Organic	0.11291	5.15E-02	2.191	**0.029**
	Low input score	-2.25E-02	3.36E-02	-0.6707	0.503
	Integrated score	8.43E-02	3.20E-02	2.631	**0.009**
	Total subsidies excl. environment	1.61E-06	3.99E-07	4.03	**0**
	CONSTANT	-1.70E-03	3.50E-02	-4.87E-02	0.961
VRS efficiency score IO - **All inputs**	Subsidies_environment_euro	-3.18E-06	1.06E-06	-3.001	**0.003**
	Organic	8.95E-02	4.10E-02	2.183	**0.03**
	Low input score	-2.29E-02	2.69E-02	-0.8514	0.395
	Integrated score	0.12093	2.78E-02	4.351	**0**

	Total subsidies excl. environment	-1.16E-07	3.06E-07	-0.3799	0.704
	CONSTANT	0.5348	3.42E-02	15.63	0
VRS efficiency score IO - **Unpaid labour input**	Subsidies_environment_euro	-2.01E-06	1.48E-06	-1.355	0.176
	Organic	0.10802	3.54E-02	3.05	**0.002**
	Low input score	-8.95E-03	2.39E-02	-0.3749	0.708
	Integrated score	7.13E-02	2.46E-02	2.897	**0.004**
	Total subsidies excl. environment	-2.16E-07	2.48E-07	-0.8683	0.386
	CONSTANT	0.76503	3.12E-02	24.5	0
VRS efficiency score IO - **Paid labour input**	Subsidies_environment_euro	-4.61E-06	1.62E-06	-2.848	**0.005**
	Organic	5.48E-02	6.34E-02	0.8645	0.388
	Low input score	4.46E-02	4.48E-02	0.9965	0.32
	Integrated score	0.16424	4.50E-02	3.651	**0**
	Total subsidies excl. environment	1.61E-06	5.04E-07	3.199	**0.001**
	CONSTANT	8.59E-03	5.64E-02	0.1522	0.879

Note: Bold figures indicate statistically significance at 95%.

Table 4. Variables included in the efficiency and regression analyses (Table 5 in Appendix presents descriptive statistics).

Model	FADN code	Description

total_assets_euro defl - Agricultural land Closing value	Environmental labour/ Traditional labour	SE436-ALNDAGR_CV	Fixed assets (valuation of land, farm buildings and forest capital, machinery and equipment and breeding livestock) and current assets (non-breeding livestock, stocks of agricultural products and other circulating capital)
total_intermed_cons_euro defl	Environmental labour/ Traditional labour	SE275	Specific costs including inputs produced on the holding and overheads arising from production in the accounting year
uaa_ha	Traditional labour	SE025	Land area owned and/or rented by farm
unpaid_labour_input_hours	Environmental labour/ Traditional labour	SE016	Total number of hours worked on farm in year unpaid
paid_labour_input_hours	Environmental labour/ Traditional labour	SE021	Total number of hours worked on farm in year paid
total_livestock output_euro defl	Traditional labour	SE206	Sales and use of livestock products and livestock plus changes in any product stocks / purchases of livestock
Diversification activities (renewable energy, tourism, forestry) Sales_Euro defl	Environmental labour	ONRGPRD_SV + OTRISM_SV + CTOTALFOREST_SA	Sales of outputs from non-agricultural activities (renewable energy, tourism, forestry)
subsidies_environment_euro defl	Regression	SE621	Environmental subsidies

ORGANIC	Regression	SE436	Code indicating whether farm is fully organic, partly organic, or in conversion
score_livestock_lu_weighted_quant_two	Regression	N.A.	Low input score (LIFT FADN Protocol)
score_livestock_integrated_weighted_quant_two	Regression	N.A.	Integrated score (LIFT FADN Protocol)
subsidies_euro defl (excl. environment)	Regression	SE605 - SE621	Total subsidies (livestock, environment, LFA, RDP, SFP) minus environmental subsidies

Appendix

Table 5. Descriptive statistics for the variables included in the ‘environmental labour’ efficiency models (and associated regression)

	Descriptive Statistics			
	Minimum	Maximum	Mean	Std. Deviation
total_assets_euro defl - agricultural land closing value	187134.10	3262067.43	866848.5954	542857.17401
total_intermed_cons_euro defl	61319.98	763791.78	227779.0033	145515.90001
unpaid_labour_input_hours	720.00	9340.00	4241.0337	1947.83438
paid_labour_input_hours	.00	7850.00	1753.1798	1936.05559
diversification activities (renewable energy, tourism, forestry) sales_euro defl	76.39	81902.22	12943.8518	14125.12807
subsidies_environment_euro defl	.00	27155.59	2818.8978	5640.87888
ORGANIC	1.00	3.00	1.0674	.29379
score_livestock_lu_weighted_quant_two	17545.20	233579.07	90191.4798	53630.06325
score_livestock_integrated_weighted_quant_two	187134.10	3262067.43	866848.5954	542857.17401
subsidies_euro defl (excl. environment)	61319.98	763791.78	227779.0033	145515.90001

Table 6. Descriptive statistics for the variables included in the ‘traditional labour’ efficiency models (and associated regression)

	Descriptive Statistics			
	Minimum	Maximum	Mean	Std. Deviation
Cattle farms model				
total_assets_euro defl - agricultural land closing value	119956.62	4541622.88	1191707.2207	871933.67346
total_intermed_cons_euro defl	35763.93	763791.78	171864.7408	117271.21996
uaa_ha	40.10	2695.53	209.9250	236.51221
unpaid_labour_input_hours	450.00	10300.00	3836.5492	1645.10261
paid_labour_input_hours	.00	11294.00	1029.1000	1680.44651
total_livestock output_euro defl	17542.59	1038141.94	158332.3470	135662.19208
subsidies_environment_euro defl	.00	92473.63	2807.8259	7277.39437
ORGANIC	1.00	3.00	1.0111	.11910
score_livestock_lu_weighted_quant_two	10783.04	279725.04	67203.4151	47109.27680
score_livestock_integrated_weighted_quant_two	119956.62	4541622.88	1191707.2207	871933.67346
subsidies_euro defl (excl. environment)	35763.93	763791.78	171864.7408	117271.21996
Sheep farms model				
total_assets_euro defl - agricultural land closing value	110534.73	5821161.01	1079168.0638	965717.36404
total_intermed_cons_euro defl	39361.68	507092.09	159623.4590	84622.75224
uaa_ha	72.50	7939.00	923.8677	1155.70711
unpaid_labour_input_hours	200.00	9304.00	3939.7500	1615.66474

paid_labour_input_hours	.00	8408.00	1365.4521	1554.68621
total_livestock output_euro defl	7576.97	456591.13	130245.1337	90408.12204
subsidies_environment_euro defl	.00	62325.24	4961.5565	8683.56688
ORGANIC	1.00	3.00	1.0931	.29996
score_livestock_lu_weighted_quant_two	5888.72	242649.61	79556.1444	40819.60889
score_livestock_integrated_weighted_quant_two	110534.73	5821161.01	1079168.0638	965717.36404
subsidies_euro defl (excl. environment)	39361.68	507092.09	159623.4590	84622.75224