Determinants of off-farm work and its effect on agricultural input intensity

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Abstract

Off-farm work is a common phenomenon among farm household members in industrialised nations. In Scotland, it is expected to grow partly due to Brexit induced uncertainty in agricultural policy and markets. Previous research has linked the phenomenon to farmers' production choices with some research findings suggesting that it increases the uptake of low input intensity pro-environmental farming methods but the overall evidence is mixed. An understanding of the influence of the expected growth in off-farm work on farmer production choices and its impact on the intensity of input use is of interest given the increasing policy emphasis being given to supporting sustainable agricultural production methods. Using Scotland's Farm Accounts Survey data, we examine the determinants of off-farm work and investigate its effects on two measures of agricultural intensity namely fertiliser and crop protection expenditures per hectare. We find that tenanted farmers managing relatively small farms are more likely to be involved in off-farm work. We also find that farmers with very high levels of off-farm work are significantly less intensive in the use of fertilisers but there is no evidence of any impact of off-farm work on their intensity of use of crop protection products. It follows that an increase in the proportion of farmers with off-farm work brought about by Brexit may have the unintended (positive) consequence of reducing the intensity of inorganic fertiliser use in agriculture, thereby making the sector more environmentally sustainable.

Keywords: Off-farm work; Fertiliser; Crop protection; Input intensity; Environment

1 Introduction

Participation in off-farm work is a common phenomenon among UK farm household members and may be set to increase as a result of Brexit induced uncertainty in agricultural policy and markets. Unlike other forms of farm income diversification, off-farm work requires little to no capital investment. For individual farmers, it is a way of using their under-exploited time and labour resource in ways that enhance their levels of farm and/or household incomes (see e.g. Hansson, Ferguson, Olofsson, & Rantamäki-Lahtinen, 2013; Olfert, 1992). Additional motives for off-farm work include reduction of income risk and uncertainty (see e.g. Barbieri & Mahoney, 2009; Hansson et al., 2013; Mishra & Goodwin, 1997; Northcote & Alonso, 2011), motives associated with lifestyle choices (see e.g. Barbieri & Mahoney, 2009; Hansson et al., 2013; Northcote & Alonso, 2011; Vik & McElwee, 2011) and changes in societal attitudes towards female participation in paid work (see e.g. Mishra, El-Osta, Morehart, Johnson, & Hopkins, 2002). At a (rural) community level, increased participation of farmers in off-farm jobs may lead to the development of (new) rural services, and, in turn, in-migration and rural economic growth.

Previous studies have suggested that off-farm work directly influences farmers' on-farm production choices and can have significant implications for the environment, farm output performance and efficiency. The mechanism through which this occurs has been debated. Smith (2002) suggests that the reduction in on-farm time associated with off-farm work inhibits adoption of time intensive pro-environment farming techniques such as integrated pest management, soil testing and precision farming. The result of this may be high input intensities and low on-farm efficiencies. Gasson (1988) on the other hand argues that income from off-farm work can facilitate farmers' adoption of pro-environment low input intensity farming practices. Production practices with high input intensities have been shown to damage wildlife and habitats, cause surface and groundwater pollution and other environmental damages (see e.g. Falconer, 1998; McLaughlin & Mineau, 1995; Skinner et al., 1997).

In Scotland, as elsewhere, agricultural policy is increasingly focused on encouraging a shift from high input conventional agriculture to agricultural concepts such as 'conservation agriculture' (Knowler & Bradshaw, 2007), 'agro-ecological intensification' (Milder, Garbach, DeClerck, Driscoll, & Montenegro, 2012) and 'sustainable intensification' (Barnes, 2012; Pretty & Bharucha, 2014). These agricultural management concepts may have differences in the practices advocated, but all centre on the proposition that agriculture and the environment are co-dependant and a careful management of the two (e.g. through low agrochemical input intensities) leads to long term sustainability. The linkage between farmers' degree of engagement in off-farm work and how that influences their on-farm production practices and the resultant effects of those practices on agricultural and environmental sustainability is therefore of considerable policy interest. If off-farm work encourages less intensive pro-environment farming practices, then an increase in off farm work arising from Brexit would be complementary with post CAP UK agricultural policy encouraging pro-environmental practices. Otherwise, increase in off-farm work may have counterbalancing and negative implications for the environment. Further, it is important to understand the determinants of off-farm work in order to facilitate better policy targeting of farmer cohorts.

The aim of this paper is two-fold; to examine the determinants of off-farm work and to further investigate its effect on agrochemical input intensities and associated implications for the environment. We study a representative sample of Scotland's farmers, with a focus on the farmer rather than the spouse or other household members. The decision to focus on the farmer is partly driven by data considerations, but is also consistent with the findings of other studies which observe that farmers have the greatest influence on farm production choices (see e.g. Coughenour & Swanson, 1983; Meyer & Lobao, 1997).

The paper contributes to the literature in a number of ways. First, the dual approach (i.e. examining first the determinants of off-farm work and second, its effects on input intensity) ensures a better understanding of the causes and consequences of off-farm work and the implications for contemporary and future agricultural and rural development policy in Scotland. Second, the paper provides specific and contemporary evidence of the impact of off-farm work on agricultural intensity in Scotland using recent available data on Scotland's farmers. The evidence provided is timely against the backdrop of Brexit, and would potentially inform contemporary and future agricultural and rural development policy in Scotland. Third, the estimation procedure used to examine the determinants of off-farm work accounts for potential endogeneity between off-farm work and farm production decisions as failure to do so may cause bias in estimates. Endogeneity has been ignored in many previous papers.

The paper is organised as follows. In Section 2, we review the literature on the determinants of off-farm work and its effects on farming intensities, performance and efficiency. In Section 3, we discuss the methodology used for our study. In Section 4, we introduce our data. Section 5 presents our results and Section 6 concludes our paper with a discussion of the implications of our findings for agricultural and rural development policy in Scotland.

2 Literature review

Below, we summarise previous studies on off-farm work in relation to its determinants and effects on production intensity, farm output performance and efficiency.

2.1 Determinants of off-farm work

A wide range of approaches and disciplines have examined the determinants of off-farm work with many studies drawing from the theory of the farm household which allows the farm household to be explicitly modelled as an optimising unit, considering household time allocations for on-farm work, off-farm work, and leisure (see e.g. Becker & Becker, 2009; F. Ellis, 1993; Nakajima, 2012; Phimister, 1993; Singh, Squire, & Strauss, 1986). Key determinants of off-farm work include farm and/or household financial circumstances and the frequency and levels of agricultural subsidies received. Weersink, Nicholson, and Weerhewa (1998) for example find that dairy farm families in New York State and Ontario were significantly motivated by their financial circumstances to engage in off-farm work. Ahearn, El-Osta, and Dewbre (2006) and Mishra and Goodwin (1997) on the other hand find that amongst US farmers, the additional income provided by farm subsidies reduced the need for farmers to engage in off-farm work. The opposite finding is reported by Hennessy and Rehman (2008) where it is shown that decoupled subsidy payments increased the incentive for Irish farmers to engage in off-farm work, suggesting that the influence may depend on the type of subsidy being provided. In contrast, government subsidies have been shown not to impact Dutch farmers' off-farm work choices (see Woldehanna, Lansink, & Peerlings, 2000).

Farmer characteristics (e.g. gender, age, marital status, education, experience), household demographics (e.g. presence of a spouse/partner, children) and farm spatial placement have also been evidenced to significantly determine farmers' off-farm work choices. Goodwin and Mishra (2004) and Mishra and Goodwin (1997) for example show that where children are present, farmers are significantly less likely to engage in off-farm work. Ahituv and Kimhi (2006), Huffman (1980), Lien et al. (2006), Lien, Kumbhakar, and Hardaker (2010) and Serra, Goodwin, and Featherstone (2005) show that farmer individual characteristics significantly determined off-farm work choice whilst Benjamin and Kimhi (2006) and Lass, Findeis, and Hallberg (1989) amongst others show that farm geographic placement in relation to adjoining towns and regions significantly determined farmers' off-farm work choices. We consider, and where possible, include the above determinants in our estimation of the determinants of off-farm work in Scotland.

2.2 The effects of off-farm work on agricultural input use

The effect of off-farm work on input intensity has been variously examined in the literature although the overall evidence is mixed. Smith (2002) hypothesised that increased off-farm work encourages adoption of time-saving farming practices involving high agrochemical input applications that harm the environment, and may have decreasing effect on farm performance and efficiency over the long run due to soil carbon and nutrient depletion. This hypothesis has been evidenced in the work of Phimister and Roberts (2006) who find that greater off-farm work participation significantly increased farmers' use of pesticides and other agrochemicals intended for crop protection (but not fertiliser). Gasson (1988) however hypothesised that income from off-farm work can facilitate farmers' adoption of farming practices with a focus on lower agrochemical input applications that benefit the environment, and may have increasing farm performance and efficiency effects over the long run due to soil carbon and nutrient gains. This hypothesis has been evidenced in Ellis, Heal, Dent, and Firbank (1999) who find amongst lowland farms in the Grampian region of Scotland that farmers engaged in off-farm work are likely to farm less intensively. Our purpose in this paper is to examine the effects of off-farm work on two measures of agrochemical input intensity i.e. fertiliser and crop protection inputs per hectare as these arguably have the greatest implications for agricultural and environmental sustainability.

3 Methodology

We use the Scottish Farm Accounts Survey (FAS) data which is collected annually under the EU Farm Accountancy Data Network (FADN) system (European Union, 2017). Our variable of interest is farmers' 'off-farm work hours'. Only about 7.53% of our sample observations involve positive off-farm work hours. 'Off-farm work hours' is therefore a limiting variable in the sense that it severely restricts the number of usable observations in our data. This limitation raises an econometric estimation issue known as the non-random sample selection problem, where only a small percentage of the population is selected or eligible for estimation due to the restrictions implied by the limiting variable. This problem can lead to biased and inconsistent results in some instances, but can be ignored in other instances. In instances where biased and inconsistent estimates result, sample selection corrections are required in order to make estimations unbiased, consistent and valid.

3.1 Estimating the determinants of off-farm work

In our first estimation procedure, we examine the determinants of off-farm work, where 'off-farm work hours' is the dependent variable. Since the estimation sample is determined by the dependent variable in this case, the data restriction implied by this 'limiting' dependent variable raises an instance of 'endogenous sample selection' problem where sample selection bias and inconsistency in estimates result unless sample selection corrections are effected (Wooldridge, 2015). We use the sample selection correction procedure introduced by Wooldridge (2015) which adapts the methods of Heckman (1976) and Chamberlain (1982). This procedure accounts for any endogeneity between farm production choices and 'off-farm work hours'. Many studies have ignored this issue, which as stated, may lead to bias (see Lass, Findeis, & Hallberg, 1991 for a review). The procedure also accounts for unobserved heterogeneity between farms. Let i represent individual farms and t represent time periods in our panel data. The sample selection model is presented as follows (Wooldridge, 2015);

1. $y_{it} = x'_{it}\beta + \mu_i + d_t + v_{it}$
2. $s_{it} = z'_i\delta_t + u_{it}$

where equation (1) is the main equation with y_{it} being the dependent variable 'off-farm work hours', x'_{it} represents a vector of independent variables hypothesised to determine 'off-farm work hours', μ_i represents time invariant farm and farmer characteristics, d_t represents time period dummies and v_{it} represents idiosyncratic errors. Equation (2) represents the participation equation where s_{it} is a binary variable indicating whether or not a farmer participates in off-farm work, z'_i represents a vector of independent variables also hypothesised to determine off-farm work hours and u_{it} represents idiosyncratic errors. To account for exclusion restrictions, the vector of independent variables in the main equation x'_{it} is made a strict subset of the vector of independent variables for the selection equation z'_i, where the extra variables in z'_i are strictly exogenous. Consistent with the literature, we include, as appropriate and where available in our data, variables characterising farm and farmers' characteristics and financial indicators in both vectors x'_{it} and z'_i.

Let n represent the total sample of observations of off-farm workers (i.e. where off-farm work hours greater than zero) and non-off-farm workers (i.e. where off-farm work hours is zero). The two step sample selection correction procedure introduced by Wooldridge (2015) is conducted as follows. In step 1, all n observations are used to estimate the participation equation by Probit estimator for each period. Mills ratios for each period are then generated. In step 2, the main equation is estimated using the sample of off-farm workers only. The estimation is by a pooled (robust) ordinary least squares estimator with the estimated Mills ratios included as independent variables.

Due to the severe restriction of the sample for step 2, a parsimonious specification is preferred. We therefore include in the vector x'_{it} variables capturing farmer age, land tenure, farm size, labour units, farm net worth and levels of subsidies received. We also include time dummies d_t to capture the effects of macroeconomic shocks that uniformly affects all farms e.g. changing relative prices (see e.g. Gilchrist & Himmelberg, 1995; Phimister & Roberts, 2006), as well as the Mills ratios formed in Step 1. In vector z'_i for estimation of the selection equation in step 1, we include the variables in x'_{it} (excluding the Mills ratios) and additional variables capturing farms' less favoured area status, whether or not they are arable and whether or not they are low-ground farms. These additional variables account for exclusion restrictions.

3.2 Estimating the effects of off-farm work on agrochemical input intensity

In our second estimation procedure, we examine the effects of off-farm work on the intensity of agrochemical input use, specifically 'fertiliser expenditure per hectare' and 'crop protection expenditure per hectare'. These two indicators of agricultural intensity are the dependent variables and are observed for most farms. The limiting variable 'off-farm work hours' is included as an independent variable. In this instance however, the data restrictions arising from the inclusion of the limiting variable 'off-farm work hours' as an independent variable does not cause sample selection bias or inconsistency in estimates. This is known as 'exogenous sample selection' (Wooldridge, 2015), where sample selection corrections are not required.

Accordingly, we focus on use of linear panel data models of which some are more appropriate to our data and setting than others. Specifically, ours is an unbalanced short panel (i.e. many farms, few time periods), with the most appropriate models to consider being the 'fixed-effects' (FE) model and the 'random-effects' (RE) model. Consider the following generic model;

3. $y_{it} = x'_{it}\beta + \alpha_i + d_t + \varepsilon_{it}$

where y_{it} is the dependent variable 'fertiliser expenditure per hectare' or 'crop protection expenditure per hectare', x'_{it} is a vector of independent variables (including 'off-farm work hours'), α_i are random individual specific effects and ε_{it} represents idiosyncratic errors. The fundamental distinction between the FE and RE models lies in assumptions about the nature of the individual specific effects α_i (Cameron & Trivedi, 2010).

In the FE model, a limited form of endogeneity is allowed by permitting α_i to be correlated with the independent variables x'_{it}. The model decomposes to the following;

4. $y_{it} = x'_{it}\beta + \alpha_i + d_t + u_{it}$
5. $u_{it} = \alpha_i + \varepsilon_{it}$

where x'_{it} is correlated with the α_i of the composite error term u_{it} but not its idiosyncratic error term. Although it is possible to estimate the FE model by estimating α_i for all farmers (in addition to the slope parameters β), asymptotic theory depends on large N and because N is large for short panels, this leads to an estimation of a large number of parameters, leading to the incidental parameters problem. To avoid this problem, a mathematical transformation of equation (3) is implemented by the FE estimator such that α_i is absorbed by the intercept. The attraction of the FE model is its accommodation of the endogeneity arising from the correlation between x'_{it} and α_i (Cameron & Trivedi, 2010; Kohler & Kreuter, 2005).

In the random effects model, α_i is assumed to be random and uncorrelated with the vector of independent variables x'_{it}. This assumption is strong, with the inherent disadvantage of the RE model being that results may be inconsistent if the assumption is incorrect. The attraction of the RE model however is that it allows explicit estimation of the coefficients of α_i (Cameron & Trivedi, 2010; Kohler & Kreuter, 2005) such as farmer and farm characteristics for which we want an indication of effect on production intensity. The RE model is also preferred in instances where it is believed that α_i differences across farms have direct influence on the dependent variable (Torres-Reyna, 2007). α_i (e.g. geographic location/region of farm) has indeed been empirically evidenced to impact farmer production choices and outcomes (Lien et al., 2010). RE models are also more appropriate in instances where within cluster variation is minimal and/or time varying variables are slow changing over time (Torres-Reyna, 2007), both of which are features of our data for our key variables 'off-farm work hours', 'fertiliser expenditure per hectare' and 'crop protection expenditure per hectare'. Finally, empirical evidence shows that 'off-farm work hours' are not endogenous with some indicators of production intensity including 'fertiliser expenditure per ha' (Phimister & Roberts, 2006) in which case use of RE models provide consistent estimates. Given these observations and data considerations, we use the RE model for our estimations of the effect of off-farm work hours on agrochemical input intensity.

4 Data

We use the FAS data which contains an annual sample of about 500 farms that are representative of commercial farms in Scotland; and provides information on inputs, outputs and socio-economic data on the surveyed farms. Data is collected annually under the EU FADN quality guidelines, allowing for long term analysis of changes and trends in Scotland's agriculture. Due to attrition bias resulting from farms leaving the industry and/or undergoing significant restructuring, the data is unbalanced. However the level of attrition is low (Brien & Hennessy, 2006). To limit the influence of attrition bias and meet minimum considerations for our estimation models, we exclude farms that did not have at least 2 consecutive years within the data.

Although the FAS data is available from 1989, the consistent collection of data on farmers' 'off-farm work hours' that is suitable for our estimation models have been collected since 2010 only. We therefore limit our analysis to the 6 year period between 2010 and 2015. Only farms with full information on 'off-farm work hours' and fertiliser and crop protection expenditures within this period were retained for use in our estimations. As extreme outliers are common in ratio data, we follow convention to exclude those observations where fertiliser and crop protection expenditure intensities were above the 98th percentile (Abdul-Salam & Phimister, 2017; Gilchrist & Himmelberg, 1995; Phimister & Roberts, 2006). All expenditure data were deflated with relevant price indices so that changes reflect quantity rather than prices (Abdul-Salam & Phimister, 2017). Our final panel data consisted of 556 farms of which 43 farms were observed over 2 years, 35 farms over 3 years, 40 farms over 4 years, 36 farms over 5 years and 402 farms over 6 years. The total number of observations in the panel was 2894, with 218 observations for off-farm workers (i.e. 7.53%) and 2676 observations for non-off-farm workers. Table 1 shows some descriptive statistics of the variables of interest in the final data for our estimation models.

Table 1: Descriptive statistics of variables in final dataset

	Zero off-farm hours	Positive off-farm hours
Off-farm hours		
Annual farmer off-farm hours	-	815.21
0 hours	100%	-
> 0 and ≤ 200 hours	-	32.57%
> 200 and ≤ 1600 hours	-	46.33%
> 1600 hours	-	21.10%
Farmer characteristics		
Male	97.83%	98.62%
Age	57.51	52.48
≤ 45 years	12.37%	22.02%
> 45 and ≤ 65 years	63.04%	70.64%
> 65 years	24.59%	7.34%
Farm characteristics		
Owner occupied	44.62%	43.58%
Small	34.87%	50.00%
Medium	19.77%	16.97%
Large	45.37%	33.03%
Arable	23.36%	19.27%
Mixed	14.99%	15.14%
Low ground cattle and sheep	5.83%	4.13%
LFA cattle and/or sheep	45.37%	57.34%
Dairy	10.46%	4.13%
Organic	3.10%	10.09%
Area, ha	151.878	155.272
Labour units	1.99	1.71
Grazing livestock units	149.61	119.08
Stocking density (livestock units per ha)	1.26	0.98
Degree of livestock specialisation	0.74	0.74
Farm finance		
Net worth, £	1,396,688.80	1,246,107.56
Total grants, £	57,416.59	56,793.79
Total livestock revenues, £	108,646.53	87,907.19
Total crop revenues, £	61,580.89	51,321.02
Intensity		
Fertiliser expenditure, £ per ha	145.64	114.55
Pesticide expenditure, £ per ha	37.84	31.47
Number of observations	**2676**	**218**
Number of farmers	**495**	**61**

Average annual hours for farmers engaged in off-farm work is 815 hours, with 33% of these farmers doing up to 200 hours, 46% doing between 200-1600 hours and 21% doing over 1600 hours. Consistent with previous studies including Lass et al. (1991) and Phimister and Roberts (2006), farmers engaged in off-farm work tend to be younger and manage small farms. Conversely, a larger majority of non-off-farm workers (about 45%) manage large farms This is consistent with previous studies including Hill (1999) and Phimister and Roberts (2006). For livestock farmers the proportion of LFA cattle and/or sheep farmers engaged in off-farm work is greater. To the contrary the proportion of dairy and low-ground livestock farmers engaged in off-farm work is lower, consistent with the findings of Phimister and Roberts (2006) and indicative of the intensity of the higher labour demands of these farming types.

Stocking density is a continuous variable, defined as the ratio of grazing livestock units to forage area. It is a proxy for the intensity of livestock production. The average stocking density for non-off-farm workers is significantly greater than that of off-farm workers, perhaps indicating that intensive production methods inhibit off-farm work. Degree of livestock specialisation is also a defined variable, calculated as the ratio of livestock revenues to total farm revenue (i.e. livestock and crops). Higher scores in this range indicate higher specialisation in livestock production rather than crop production, and vice versa. Finally, significant differences exist in fertiliser and crop protection expenditures for farms with and without off-farm work. Both fertiliser and crop protection expenditure intensities are higher on average in farms without off-farm work, which is consistent with our a priori conjecture about the relationship between off-farm work and production intensities.

5 Results

5.1 Determinants of off-farm work

Table 2 shows our estimation results for the determinants of off-work, with the sample selection model in column 2 showing our base results. The sample selection result is closely reflected in signage by the robust OLS estimation in column 3 hence indicating the stability and robustness of our results. Age of farmer was expected, a priori, to be a significant determinant of off-farm work with negative signage so that increasing age reduced propensity for working off-farm. This would have reflected the hypothesis that younger farmers are more eager to do more work beyond the farm in order to expand their incomes and accumulate future wealth, in line with the life cycle hypothesis of Modigliani (1986). It would have also reflected the notion that age is a proxy for experience at least to the extent that farmers learn by doing, so that older more experienced farmers are more efficient at farm production hence have less need to supplement their incomes with off-farm work. However, the evidence shows that although age decreased propensity for off-farm work, the effect was not statistically significant amongst Scotland's farmers.

Land tenure is found to be a significant and negative determinant of farmers' off-farm work participation choices. Compared to farmers who own their own land, tenant farmers are more likely to engage in off-farm work. The explanation could be that tenant farmers have higher motives for accumulating income hence have a greater propensity to engage in off-farm work.

Similar to land tenure, the area used for agriculture is a significant and negative determinant of farmers' off-farm work choices. Farmers who manage larger farms are less likely to engage in off-farm work. This is consistent with the findings of Benjamin and Kimhi (2006), Lass et al. (1991), Mishra and Goodwin (1997) and Serra et al. (2005). The reason for this is somewhat related to the profit focus of larger commercial farms, where there is likely potential benefits in the form of returns to scale.

As expected, our results also show that farmers managing more labour intense farms (i.e. family and hired labour, excluding farmer labour) are significantly less likely to engage in off-farm work. This is somewhat self-evident, as labour intense farms naturally inhibit farmer participation in non-off-farm activities. However, contrary to expectations we also find that farmers with higher net worth are significantly more likely to engage in off-farm work. One possible explanation for this is that such farmers are more efficient and hence are able to afford spare time for work off-farm. Another plausible explanation is that these farmers are more educated and hence are likely skilled in other higher paying sectors with demand for their labour. Given a higher marginal return for their labour in off-farm work, and given perfect substitution of their own-labour for hired-labour, they are able to work off-farm for the higher income. Although net worth and area used for agriculture might appear to be highly correlated, we find that their degree of correlation is less than 50% hence multicollinearity is unlikely to be an issue hence justifying their inclusions. Finally, our results show that government subsidies do not significantly determine Scotland's farmers' off-farm work choices. A priori, it was expected that higher (decoupled) CAP subsidies as received by Scotland's farmers would likely increase their propensity for off-farm work, as evidenced by Hennessy and Rehman (2008) in a different setting. Although the signage is positive and consistent with this hypothesis, the lack of significance may be a consequence of the limited variability in the subsidies received by the farmers in our sample. Our findings with respect to subsidies is consistent with the findings of Lien et al. (2010) and Woldehanna et al. (2000), although it is at variance with the findings of Ahearn et al. (2006) and Mishra and Goodwin (1997). The insignificant Mills ratios suggest that sample selection is not a significant driver of the results. Compared to 2010, farmers were significantly less likely to engage in off-farm work in years 2011-2013, perhaps hinting some period specific factors pertaining to those years.

Table 2: Determinants of off-farm work using a sample selection correction model, and an OLS model for robustness checks

		Sample selection correction model	Robust OLS model
	log (age of farmer)	-0.85	-1.22
		(1.36)	(1.23)
	Tenure (owner = 1; tenanted = 0)	-1.03**	-0.74*
		(0.49)	(0.42)
	log (area used for agriculture)	-0.47***	-0.49***
		(0.16)	(0.17)
	log (labour units)	-2.12***	-1.45***
		(0.60)	(0.41)
	log (net worth)	0.69**	0.51*
		(0.30)	(0.27)
	log (subsidies received)	0.55	0.25
		(0.50)	(0.38)
Reference period: 2010	2011.period	-0.78*	-0.29*
		(0.40)	(0.17)
	2012.period	-1.03**	-0.14
		(0.48)	(0.24)
	2013.period	-0.89*	0.03
		(0.52)	(0.26)
	2014.period	-0.60	0.35
		(0.55)	(0.24)
	2015.period	-1.23	-0.08
		(0.79)	(0.34)
	Mills ratio (Period 1)	-0.56	
		(0.57)	
	Mills ratio (Period 2)	-0.27	
		(0.54)	
	Mills ratio (Period 3)	-0.06	
		(0.58)	
	Mills ratio (Period 4)	0.01	
		(0.56)	
	Mills ratio (Period 5)	0.00	
		(0.45)	
	Mills ratio (Period 6)	0.15	
		(0.39)	
	Constant	-1.52	4.47
		(7.92)	(6.87)
	N	181	218
	R-squared	0.34	0.26
	AIC criterion	689.75	810.54
	BIC criterion	747.32	851.15

5.2 The effects of off-farm work on agricultural input intensity

The distribution of 'off-farm work hours' data is skewed and lumpy, in part due to the retrospective collection of the data from farmers making it subject to recall bias (Dex, 1995). To limit lumpy 'off-farm work hours' effects and recall bias, we follow Phimister and Roberts (2006) to cast 'off-farm work hours' as dummy variables capturing ranges of the extent of farmers' off-farm work participation. Table 3 shows our estimation results for the effects of 'off-farm work hours' on fertiliser and crop protection expenditure intensities.

Our main interest in the results is the effects of off-farm work on fertiliser and crop protection expenditure intensities. The results show that farmers who annually work up to 1600 hours off-farm are not significantly different from farmers who do not work off-farm in terms of their fertiliser and crop protection expenditure intensities. This is also true of farmers who work more than 1600 hours off-farm in terms of their crop protection expenditure intensities. For fertiliser expenditures however, farmers who work more than 1600 hours annually off-farm are significantly less intensive compared to farmers who do not work off-farm. This result is consistent with previous studies (see e.g. Davies & Dalton, 1993; Ellis et al., 1999; Gasson, 1988; McNally, 2002; Phimister & Roberts, 2006). A plausible explanation for this effect is that for farmers who work significant hours off-farm (i.e. more than 1600 hours annually), farm management is simplified where the emphasis is on the use of lower time, labour and financial resources through lower fertiliser applications. Spending significantly more time off-farm therefore appears to facilitate a less intensive production regime. For farmers who do not work off-farm however, and for whom reliance is mostly on farm income, farm management may be more aimed towards maximisation of fertiliser input applications in order to maximise profits.

Other results show that fertiliser and crop protection expenditure intensities are significantly higher on arable farms and on livestock farms with high stocking densities. In the case of arable farms, this is a natural consequence of higher use of agrochemicals for arable crop production than on livestock farms for grass production. In the case of livestock farms with high stocking densities, this is also expected due to greater use of techniques such as reseeding. Further, fertiliser and crop protection expenditure intensities are significantly higher on large net worth farms, farms receiving large amounts of subsidies and farms using greater labour inputs. On the contrary, fertiliser and crop protection expenditure intensities are significantly lower on owner occupied, organic and high specialisation farms.

Table 3: Effects of off-farm hours on fertiliser and crop protection expenditure intensity using a RE model

		Fertiliser expenditure per ha	Crop protection expenditure per ha
	Off-farm hours		
Ref: 0 hours	> 0 and ≤ 200 hours	0.01	0.06
		(0.07)	(0.14)
	> 200 and ≤ 1600 hours	0.01	-0.05
		(0.06)	(0.11)
	> 1600 hours	-0.35**	-0.30
		(0.14)	(0.29)
	Age		
Ref: > 65 years	≤ 45 years	0.03	0.17**
		(0.04)	(0.08)
	> 45 and ≤ 65 years	0.04	0.06
		(0.03)	(0.06)
	Owner occupied (Owner = 1)	-0.06*	-0.15**
		(0.03)	(0.06)
	Organic (Organic = 1)	-1.02***	-0.53***
		(0.08)	(0.18)
	Arable only	0.19***	0.22***
		(0.05)	(0.08)
	Non grant improvements (Yes = 1)	0.02	-0.05
		(0.02)	(0.03)
	Stocking density	0.14***	0.09***
		(0.01)	(0.02)
	Degree of specialisation	-0.59***	-2.65***
		(0.07)	(0.13)
	Log (Area)	-0.39***	-0.39***
		(0.03)	(0.06)
	Log (Labour units)	0.20***	0.17**
		(0.04)	(0.07)
	Log (net worth)	0.08***	0.19***
		(0.02)	(0.04)
	Log (Subsidies and grants)	0.29***	0.34***
		(0.04)	(0.08)
Ref: period 2010	2011.period	-0.16***	-0.12***
		(0.02)	(0.04)
	2012.period	-0.01	-0.08*
		(0.02)	(0.04)
	2013.period	0.06**	-0.08
		(0.03)	(0.05)
	2014.period	0.08***	-0.03
		(0.03)	(0.05)
	2015.period	0.03	0.23***
		(0.03)	(0.05)
	Constant	2.77***	0.09
		(0.40)	(0.79)

Number of observations	2825.00	2537.00
R-squared		
r2_o	0.47	0.58
r2_b	0.57	0.66
r2_w	0.10	0.03

6 Conclusions

In this paper, we used a dual study approach and recent Scotland data to first examine the determinants of off-farm work and second, its impact on agricultural input intensity, focusing on fertiliser and crop protection inputs. Focus on these inputs has implications for agricultural and environmental sustainability which are key policy goals in Scotland and the UK. The dual approach we use allows an understanding of the causes and consequences of the off-farm work phenomenon, providing timeous evidence for policy consideration as the UK prepares to exit the EU.

In the first part of our dual study approach, we find that tenanted farmers managing relatively small farms with lower labour requirements are more likely to be engaged in off-farm work, as are farmers with higher levels of net worth. Tenanted farmers have a higher motive for wealth accumulation which perhaps explains their tendency for off-farm work. Farmers managing small farms with lower labour requirements may use off-farm work as a way of deploying their under-exploited time and labour resource in ways that enhance their levels of farm and/or household incomes. It is not clear why high net worth farmers are more likely to engage in off-farm work. One possible explanation could be that these are highly educated farmers whose education allows them to find higher paying off-farm for which they substitute with family or hired on-farm labour. In the second part of our dual study approach, we find that farmer participation in off-farm work reduces intensity of fertiliser applications but not the use of crop protection products. This would imply that an increase in farmer participation in off-farm work may have the unintended (positive) consequence of reducing the intensity of inorganic fertiliser use in agriculture, thereby making the sector more environmentally sustainable. This would however possibly have adverse implications for agricultural output in the short run as inorganic fertiliser input is reduced, but possibly positive output implications in the long run as soil fertility and resilience is enhanced due to less inorganic fertiliser input intensity.

Our findings have important implications for agricultural and rural development policies in Scotland and the UK. Most obviously, they suggest that the effect of an increase in the proportion of farmers uptaking off-farm work is consistent and complimentary with policies aiming for greater pro-environmental farming practices.

Our analysis was limited by the lack of socio-economic variables in the data set and further qualitative research is required to understand better the factors which influence off farm work participation, off-farm work hours and the reasons why this then impacts fertiliser use but apparently not other agrochemical use. The panel dataset also allows analysis of transitions into and out of off farm work and follow up research will explore how this impacts farm management decision.

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