REFEREED ARTICLE

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Economic factors affecting concentrate usage on Irish sheep farms

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ABSTRACT

While comprehensive farm level models for the dairy, beef and cereal sectors have previously been developed, to date, relatively little research has been conducted on the economics of the sheep sector at farm level. Nationally representative farm level data from Teagasc's National Farm Survey (NFS) is used to develop a model examining the economic factors of concentrate usage on Irish sheep farms informed by the current body of literature on pastoral based production systems research. Results from a 2 step random effects panel regression of a demand function for concentrate use with log linear functional form support the established production literature. The demand for concentrates on Irish sheep farms was found to be elastic and thus sensitive to price changes. Farm labour input, fertiliser application, subscription to an extension and research provider and date of lambing were found to be significantly associated with concentrate demand on sheep enterprises. Results from a second model specification indicate the presence of spatially heterogeneous effects of lambing on concentrate demand across regions.

KEYWORDS: Random Effects Model; Concentrate demand; Sheep production

1. Introduction

The evolution in agricultural policy has altered producer priorities in terms of farm structure and consequently farm management practices. Over the past 30 years, high product prices in the EU have encouraged systems with high inputs of concentrate feeds, fertiliser, machinery and associated labour inputs, particularly in the beef and dairy sectors (Dillon, 2007). Sheep production has in general continued to remain relatively extensive in its nature. With successive CAP reforms and GATT agreements, production systems have been required to account for, on the one hand, environmental concerns, particularly in the context of hill sheep farming on commonages (Buckley *et al.*, 2008) and on the other, reduced product prices. This has led to a growing emphasis on production efficiency per unit of output. Thus, to improve profitability on sheep farms, production costs must be examined as closely as flock performance (Flanagan, 2001). In this regard, Irish conditions for biomass production have been identified as having the potential to afford producers a competitive advantage (O'Donovan *et al.*, 2011).

While climatic conditions and thus grass growth vary widely within Ireland, grass has been shown to grow more regularly from spring to autumn in Western Europe (UK, Ireland, Normandy in France) relative to other European regions where grass growth is limited in summer or the grazing season is quite short due to long cold winters (Brereton, 1995; Dillon, 2007; Drennan *et al.*, 2005). As with dairy and beef, systems of Irish sheep production have been developed to exploit this natural advantage with the aim of increasing profitability by reducing costs through increased pasture utilization in the diet of the ewe. Consequently, mid season lowland production is the predominant system on Irish sheep farms with most sheep lambing in the spring to target grazed grass input as the cheapest source of nutrition. Maximising grass utilisation and minimising concentrate input can enhance the competitiveness of pasture-based systems of production, whilst also preserving the rural landscape and promoting a clean, natural, image (Dillon, 2007; Gottstein, 2007; O'Donovan *et al.*, 2011; Teagasc, 2012a).

Results from Teagasc's eProfit Monitor Programme and the National Farm Survey clearly show that sheep production enterprises with well-developed grassland management practices can return gross margins that compare very favourably with other drystock enterprises (Teagasc 2012a, 2012b) Other important empirical findings highlight the number of lambs reared per ewe joined, stocking rate, and the level of concentrate feeding to ewes and lambs (endogenously linked to grassland management) are key drivers of profitability and technical efficiency on Irish sheep farms (Diskin *et al.*, 2011).

With the general trend of sheep output and associated financial returns in decline since the early nineties, there is a growing focus on cost reduction strategies in order to maintain viable producer incomes. In this regard, the low cost of grazed grass relative to silage and/or

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concentrates is of central importance to maintaining and improving profit margins.

This paper seeks to identify the underlying factors affecting concentrate usage on Irish farms in terms of price effects and management practice, including seasonality of production and farm environmental factors so as to better describe the economic behaviour of agents through the actual choices made on Irish farms. An important part of this analysis is an investigation of whether concentrate use varies depending on the choice of breeding cycle and whether these seasonality of production effects vary across regions. To do this a 2 step (Heckman) Random Effects panel data model of concentrate use is specified using NFS variables and log linear functional form based on production theory. A second model specification is proposed to investigate whether there are significant differences in concentrate demand across regions.

The following section highlights the importance of the grazing resource for pastoral based Irish sheep production.

The grazing resource

Past research has highlighted that stocking rates on Irish grassland farms are low considering the high growth potential, whilst there is an associated overreliance on expensive supplementary feeding (Connolly, 1998; NFS, 2012). There exists significant potential to increase output per ha by improving technical performance (Connolly, 1998). Higher stocking rates and consequently higher output is possible by increasing herbage yield/grass growth through greater and/or more efficient use of fertilizers. Evidence based research points to the potential of farm management practices that maximise grazed grass in the diet of the ruminant and thus minimise concentrate use to increase farm profitability and sustainability.

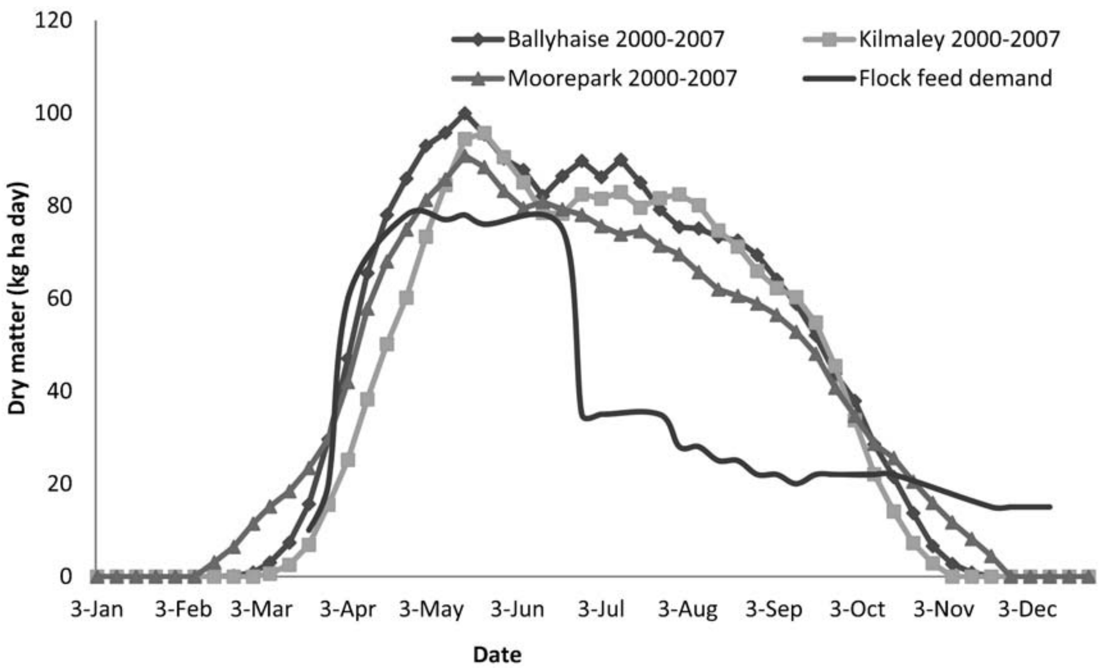
Figure 1 below charts both the nutritional supply of grass and the flock demand for a lowland mid-season farm for a production season. The supply and demand curves visualise the degree to which two key elements of ruminant nutrition interact throughout the year on a 'normal' March lambing mid-season lowland sheep farm. Pasture growth curve measurements are recorded in kilograms of dry matter per hectare for three Teagasc research farms averaged over an eight year period (2000–2007). Moorepark is located in the South, Kilmaley in the West and Ballyhaise in the North of the country.

The typical pattern is low or no growth over the winter months, with significant growth commencing in February or March depending on location and accelerating rapidly up to peak growth rates of approximately 100 kg DM/ha per day and nutritional surplus (Grennan, 1998) in May. In line with grass growth models (Brereton, 1995; Drennan *et al.*, 2005; O' Mara, 2008) figure 1 highlights how both dry matter production potential and the grass growing season varies considerably depending on farm location.

Figure 1 encapsulates many of the dynamics that explain pastoral sheep management and the associated economics of the production system. Accordingly, for any given farm the relationship of the two distributions (grass supply to total nutritional demand) is a key determinant of the firm level production function, expressing as they do combinations of inputs according to a technological relationship (explicitly, the distribution of grass input given grassland management technology and, implicitly, supplementary concentrate input that is required to balance the nutrition demand of the flock given the chosen flock production system).

Initial research involved building a profile of Irish sheep production systems using NFS data with reference to the body of past experimental production and economic research to inform the model of concentrate

Figure 1: Grass growth and feed demand for a midseason lambing flock



demand developed in this paper. The NFS dataset used in this paper is introduced in the following section.

2. Data

The NFS is an unbalanced panel dataset that annually surveys Irish farmers with the aim of: (a) determining the financial situation on Irish farms across the spectrum of farming systems and sizes, (b) providing data on Irish farm output, costs and incomes to the EU Commission in Brussels as part of the Farm Accountancy Data Network (FADN).

The NFS is a random, nationally representative sample selected each year in conjunction with the Central Statistics Office (CSO). Each farm, of which on average approximately 1,000 are surveyed, (922 for the 2012 NFS) is assigned a weighting factor so that the results of the survey are representative of the national population of farms. Utilising the NFS means that data with respect to farm types, their locations and production activities is readily available.

Data cleaning involved the identification of suitable variables within the NFS to accurately capture animal demographic data. Extracting NFS raw data 'check tables' gives a detailed monthly breakdown of animal stocks by age class. 'Notes data' per month for lamb births, deaths, transfers, sales, purchases, etc., which are used to build up reported aggregated NFS variables, was extracted and cleaned into a usable dataset. This data has not in the past been directly manipulated for research purposes and is required here to capture lamb birth dates on Irish sheep farms.

3. Methods and Procedures

This paper uses panel data methods to model concentrate use on Irish sheep farms over time by employing National Farm Survey data on 710 farm observations for a three year period, 2008–2010. While NFS data is available dating back to 1975, the detailed monthly animal demographic breakdowns used in this paper are available since 2008. Using a subsample of the NFS means that the dataset employed is a short panel with relatively few time periods and many individual farms (N=710, T=3). Most farms have multiple observations/years and thus the number of farms is substantially less than 710. Use of NFS panel data enables issues of heterogeneity and omitted variables, measurement error, dynamics and causality under certain conditions to be addressed (S. Hynes, Dillon, E., Hennessy, T., Garvey, E, 2007).

This study can be characterised as an input demand study based on production theory following the typology developed by Burrell (Burrell, 1989). Consequently, demand for an input, in this case supplementary concentrate feed, is regressed on its own and cross prices and other shift variables, with the results interpretable as Marshallian elasticities of demand. Implicit in this single equation input demand model is an underlying assumption of the profit maximising behaviour of producers (J. Breen *et al.*, 2012; Burrell, 1989). Having constructed a 3-year unbalanced panel of sheep farms, a random effects model of concentrate feed is estimated after first addressing the issue of sample selection bias.

The list of variables specified in this model of concentrate feed use is presented in Table 1 and builds upon previous input demand studies and the current production literature previous NFS research (Connolly, 1998, 2000; NFS, 2012). The dependent variable of choice is concentrate use per sheep livestock units. The NFS concentrates variable captures the quantity of supplementary concentrate fed to sheep livestock per year. In this study livestock units relate to the number of sheep livestock units on farms. As highlighted in the summary statistics of Table 3, a number of farms are shown to purchase no supplementary concentrate feed and are thus completely dependent on forage as a source of nutrition. In this context the dependent variable is censored with a concentration of observations at zero values. Failing to correct for this issue results in biased parameter estimates.

In the following section this paper proposes a two stage estimator to address this selection bias in line with the procedure first proposed by (Heckman, 1976). This approach involves estimation of a probit model for selection, followed by the inclusion of a correction factor in the model of interest. Specifically the Inverse Mills ratio is calculated from a probit selection model and included as an explanatory variable in the subsequent Random effects model of concentrate use.

Correcting for Sample Selection Bias - Heckman 2 Step Procedure

Step 1 - Selection Equation

With their differentiable production systems, some of which are more extensive in nature, it is evident that a subset of farms within the sample makes the production decision not to feed concentrates. In the context of this study, farms that feed concentrates thus represent a non-randomly selected sample (649 obs) from the full set of 710 obs over the period 2008–2010. Modelling the factors that affect concentrate demand by drawing solely on this subset of farms fails to take into account the characteristics of those farms which choose not to feed concentrates, and which may potentially exhibit an alternative preference structure. Accordingly, the dependent variable is censored with a concentration of observations around 0. In order to correct for self-selection a selection equation must first be estimated using the inverse mills ratio (equation 1.2).

The first stage selection equation for this study can be represented as follows:

$$\mathrm{Prob}(D_i = |Z_i) = \Phi(Z_i\gamma) \qquad \text{(eq1)}$$

$$\text{where}: \; D_i = (0 \text{ if } Z_i\gamma + \upsilon_i \leq 0; \text{ if } Z_i\gamma + \upsilon_i > 0) \qquad \text{(eq1.1)}$$

Equation one represents a probit regression where D is an indicator for positive concentrate use. Z is a vector of explanatory variables for concentrate use, γ is a vector of unknown parameters, and Φ is the cumulative distribution function of the standard normal distribution and υ_i are unobservable sources of variation in D_i. Sample selection bias exists because $E[\varepsilon_i|Z_i, D_i=1]\neq 0$. Consequently, the conditional mean for concentrate use is being misspecified (Vella, 1998). The assumptions

Table 1: Description and summary statistics for model of concentrate use

Variable	Description	Obs	Mean or Proportion*	Std Deviation	Min	Max
Concentrate use per livestock unit	Concentrate use per sheep livestock unit	710	6.82	6.76	0	57.38
Concentrate price	Price of purchased concentrate per tonne (€)	710	237.73	83.68	0	400
Weaning rate	Number of lambs per ewe mated to ram	710	1.11	0.44	0	2.5
Labour intensity	Total labour units divided by farm forage area (lu per acre)	710	0.034	0.024	0.003	0.339
Fertiliser application rate	Rate of compound chemical fertiliser applied to total farm area (kgs per ha)	710	101.45	79.83	0	455.73
Reps participation	0; Not a REPs participant farm 1; A REPs Participant farm	710	0.545	0.498	0	1
Off-farm job	0; Farmer has no off farm employment 1; Farmer has off farm employment	710	0.255	0.436	0	1
Teagasc advisory client	0; No subscription to Teagasc service 1; Subscription to Teagasc service	710	0.585	0.493	0	1
Sheep numbers	Number of sheep in Lu equivalents	710	24.250	30.127	0.02	380.36
Farm Size	Forage Area measured in acres	710	18.280	30.002	0.02	346.3
Lambing date	Percentage of lamb crop born per month					
January		710	0.096	0.221	0	1
February		710	0.207	0.302	0	1
March		710	0.413	0.365	0	1
April		710	0.187	0.296	0	1
May–Dec		710	0.021	0.077	0	.722
Region	Farms belong to one of 8 geographic regions 1–8; see Table 3 for expanded regional breakdown.					
1	Border	710	0.24	0.43	0	1
2	Dublin	710	0.01	0.11	0	1
3	East	710	0.17	0.37	0	1
4	Midlands	710	0.11	0.31	0	1
5	Southwest	710	0.05	0.22	0	1
6	Southeast	710	0.13	0.33	0	1
7	South	710	0.12	0.33	0	1
8	West	710	0.18	0.38	0	1

*Proportion for dummy variable expressed as a percentage of sample where dummy equals 1.

must be made that εi and υ_i are independent and identically distributed and independent of Z_i. Thus a probit model is used to regress Z_i on D_i and to estimate:

$$E[\varepsilon_i|Z_i, D_i = 1] = \frac{\vartheta(Z_i'\gamma)}{\Phi(Z_i'\gamma)} \qquad \text{(eq1.2)}$$

Where φ(.) and Φ(.) denote the probability and cumulative distribution functions of the standard normal distribution. The term on the right hand side of (equation 1.2) is known as the Inverse Mills Ratio (IMR). Calculation of the IMR is the first step in the two step model. The second step involves calculating a random effects model of concentrate demand corrected for selection bias through inclusion of the IMR as an explanatory variable in the vector of explanatory variables X_{it}.

The variables contained in the vector of explanatory variables for the selection equation Z_i (equation1.2) and those of the second stage random effects model X_{it} (equation 2,) are overlapping but not identical. X_{it} includes the IMR which accounts for selection bias as specified in (equation 1.2). Z_i on the other hand contains a variable for weaning rate, which is not in X_{it}. Given the production system most likely employed by those 'non using' sheep farms, i.e., farms which do not use concentrate feed, the derived variable weaning rate is used as an identifier for the selection equation. Farms with productive ewe flocks can be guaranteed to witness seasonal surges in nutritional requirements. Farms with alternative production systems, on the other hand, such as farms which may have a significant hogget rearing enterprise, are expected to have low weaning rates and be more extensive with lower concentrate demand (Hoyne, 2001). The weaning rate therefore is proposed to mostly impact upon the first stage decision rather than the second stage. This inclusion of an extra variable in the first step acts as an exclusion restriction and helps to avoid collinearity problems between the IMR and other independent variables in X_{ij} (Greene, 2003).

Step 2 - Demand equation - Random Effects Panel Model corrected for selection bias

To estimate the demand equation for concentrates the following random effects model specification was employed:

$$Y_{it} = \beta_o + \beta X_{it} + (U_{it} + \varepsilon_{it}), \quad \text{(eq2)}$$

Where Y_{it} is the dependent variable, the quantity of concentrate used per livestock unit per farm i in year t (t=08, 09, 10). X_{it} is a vector of explanatory variables which includes the IMR from the selection equation. (U_{it}+ε_{it}) represents the composite error term (V_{it}). U_{it} is an idiosyncratic fixed effect which takes into account differences in unobservable time invariant characteristics of the farms (Between-entity error term), ε_{it} is the within-entity error term.

From equation 2 concentrate use intensity per farm can be expressed as a function of

$$C = f(P, Z, D)$$

Where the farm level demand for supplementary concentrates feed (C) is a function of the price of concentrates (P), other farm specific variables (Z) and correction for selection IMR (D).

Exploiting the panel nature of the National Farm Survey, this paper estimates a panel data random effects model (Howley, 2012). In terms of the choice of panel estimator, fixed effects allow the individual component to enter through the intercept whereas random effects have the individual component entering through the error term (U_{it} the idiosyncratic error term). Thus a panel rather than a pooled specification is preferable, as the error component for individual farms in the NFS is correlated across years.

The fixed effects estimator uses within group variation in estimation. However, in practice, within group variation may be limited given the nature of the dataset, where there is often very little variability in relevant variables for individual observations (farms) over time. The random effects estimation, on the other hand, weights within and between group variation according to where the variation in X and the variation in the error term lie. Given the structure of the NFS, where there are a lot more individuals than years, a random effects model is most appropriate. While a Hausman test suggests using a fixed effects model, doing so causes observations to drop out of the sample due to this lack of variability across years (S. Hynes *et al.*, 2009). The choice of random effects estimator in this study of NFS data is thus in line with the rationale developed in S. Hynes, Dillon, E., Hennessy, T., Garvey, E (2007). Accordingly, it assumes the unobserved individual effect is uncorrelated with the regressors in the model.

A second model specification is subsequently proposed to examine heterogeneous between group effects on concentrate use. Specifically, model 2 extends the analysis to examine across region differences in lambing and concentrate demand. It is proposed that there is an expectation of variation in supplementary concentrate demand across regions for farms with similar seasons of production. To control for these across regional differences model 2 includes additional interaction terms of Region interacted with Monthly Lambing Percentage (Jan–Apr). The Results of Model 2 are proposed to better inform regional differences in lambing and concentrate usage.

Summary Statistics of Concentrate Model Variables

Summary statistics for variables used in specifying a random effects model of concentrate use on Irish sheep farms are presented in Table 1. The dependent variable of choice is concentrate use per sheep livestock unit. The NFS concentrates variable captures the quantity of supplementary concentrate fed to sheep livestock per year. The dependent variable thus captures the intensity of supplementary feeding on a per livestock basis. In order to estimate the price elasticity of demand for concentrates, the price per tonne of concentrate is included as an explanatory variable. Note that the mean price per tonne of concentrate feed reported in Table 1 is based on all farms in the sample. However, as previously noted, a number of farms do not feed concentrates and are completely dependent on forage as a source of nutrition. To determine the true mean price per tonne of concentrates paid over the period 2008–10 it is necessary to look at the subsample of farmers who fed concentrates. For the observed farms who fed concentrates over the 3 year period 2008–10, the mean price paid for concentrates was €[4]260/tonne. The mean price for concentrates across all farms, i.e., including those farms which do not feed concentrates, is €237.73, which is the average across all farms.

More technically efficient farms have been shown to place a greater emphasis on pasture expenditure rather than supplementary feed (Teagasc, 2012b). Fertiliser use on these forage based farms is for the production of grass, which is the main feed input in pastoral based ruminant production systems. Grass and grass silage is a substitute for concentrate feed and so the rate of application of inorganic fertiliser per unit area is also included as an explanatory variable in the model. Fertiliser applied is a farm level variable and farm level application rate is assumed for the sheep enterprise of mixed farms. This application rate is the sum of chemical fertiliser compounds applied in kgs divided by the total area of the farm in acres. In the model of concentrate use a second derived fertiliser variable, which relates application intensity to stocking density, is included (not included in summary statistics). This derived variable better captures the effective application intensity on a per livestock basis with the expectation that, given the substitute nature of the two inputs, there will be a negative relationship. As with concentrates, not all farmers in the sample applied chemical fertiliser.

Labour intensity per unit forage area is included as a measure of the production intensity with the expectation that increased intensity will be associated with increased input use and thus be positively correlated with the dependent variable. Labour intensity per unit area is calculated as the total number of labour units of the farm divided by the size of the farm. In this calculation for the derived variable 'Labour intensity', forage area is a farm level variable comprising the area of forage crops grown for consumption on the farm adjusted to include the area equivalent of purchased forage. Total labour units are the sum of labour units unpaid plus labour units paid, where one labour unit is equivalent to 1800 hours. No one person can be more than one labour unit even if he /she works more than the 1800 hrs

[4] In late May 2014, €1 was approximately equivalent to £0.81 and $1.37.

allocation. Persons under 18 years of age are given the follow labour unit equivalent: 16–18 years=0.75, 14–16 years=.50 units (NFS, 2012).

Farm size in terms of the enterprise level forage area variable is included as an explanatory variable and would be expected to be negatively correlated with total concentrate demand as grass is a substitute for concentrate feed. The forage area is that area of the farm dedicated to the production of grass for sheep, including rough grazing and adjusted for commonage area. Dummy explanatory variables are included for: REPs participation, off-farm job, Teagasc subscription, year and region.

REPS payments require an adherence to environmental measures as well as a ceiling on fertiliser usage and are typically associated with a lower intensity of production and output (J. Breen *et al.*, 2012). The dummy for off-farm job corresponds to 1 where the farm holder has an off-farm job and 0 where the holder has no off-farm job. There is an expectation that REPS participants and those with an off-farm job would have more extensive management practices and thus have lower input demands.

A farmer is deemed to be a Teagasc client when they have shown to make a subscription payment to the Teagasc advisory service. As a client of a farm research and extension provider, subscribers could be seen as having access to up-to-date best practice (S. Hanrahan, 2010).

A year dummy is used to control for weather, i.e., the effects of particularly severe weather, its potential effects on grass availability and, consequently, dependence on supplementary feeding.

Region dummies control for the influence of geography, associated soil conditions and production system, whether upland or lowland (Burrell, 1989).

Sheep numbers are based on farm sheep livestock units. The NFS variable sheep livestock numbers are calculated from 'check tables' (raw data files which report monthly animal stocks and flows), by multiplying actual monthly numbers by the relevant livestock unit co-efficient. January Lambing date gives the percentage of births attributable to January. 'Check tables' data were manipulated to calculate this derived variable. January lambing, together with those variables that capture the percentage of births for alternative months, are expected to highlight the influence of seasonality of production on concentrate usage for Irish sheep farms. Note that the figures reported in the summary statistics (Table 1) are for the full sample of farms, some of which do not operate a productive ewe flock. Percentages of births per month will be lower accordingly.

4. Results

Model 1

Table 2 presents the results for Model 1. Model 1 estimates concentrate demand using the natural log of concentrates per livestock unit as the dependent variable. The model is estimated by a random effects general least squares regression for three years of NFS data 2008–2010 inclusive Having previously estimated a probit to correct for sample selection bias, the IMR can be seen to enter the model as an explanatory variable.

Concentrate price has a statistically highly significant negative influence on concentrate use, in line with a priori expectations. The coefficient on concentrate price can be interpreted as a cross price elasticity of demand for concentrate given the chosen log linear functional form. (Burrell, 1989) highlights that for single equation econometric models of this type, the set of regressors chosen in specifying the model implies its own *ceteris paribus* conditions and interpretation of elasticities is thus similarly model specific. This study focuses on whether independent variables have a significant impact on the dependent variable and the direction of the sign (whether positive or negative) rather than the magnitude of the coefficient. Similarly the log of labour intensity is highly significant and positive, indicating that, *ceterius paribus*, increased labour input is associated with increased demand for concentrate feed. The Region variable exhibits a negative coefficient for Regions 1 and 4, significant at the 10% and 5% levels respectively. A detailed description of the breakdown of sheep farms across region and discussion of the regional variation in production and concentrate input use on farms is further developed in the following section.

Fertiliser application rate is significant at the 1% level and would indicate increasing concentrate use for increasing fertiliser application, although the interaction term with stocking rate is negative. The interpretation of the impact of fertiliser should be combined. For a moderately stocked farm with a stocking rate of greater than 1.1 life-stock units per hectare, concentrate use declines with increased fertiliser use, reflecting the trade-off between grass and concentrate. For lower stocked farms, the relationship is positive; perhaps reflecting more about the efficiency of those types of farms.

The coefficient for the Teagasc is significant at 10% and negative. A farmer who is shown to be a Teagasc client through subscription payments to its advisory service uses less concentrate per lu. As a client of a farm research and extension provider, subscribers have access to up-to-date farm management best practice which emphasise greater grass utilisation and reduced dependence on more expensive concentrate feed (S. Hanrahan, 2010). Both REPs and off-farm job are statistically insignificant. However, given the extensive nature of the sheep enterprise, it is unsurprising that REPs participation does not significantly impact management practice and reduce input demand intensity. Indeed an alternative input demand study Breen (2012) which looked the elasticity to demand for fertiliser for more intensive dairy production systems, also reported the coefficient on REPs participation as insignificant. Given the nature of sheep farms, which are often second enterprises on the farm, it follows that the division of labour that comes with an off-farm job has no discernible impact on the nutritional management practices of the sheep enterprise. Year dummies and the coefficient for the log of sheep livestock units are insignificant.

January Lambing is the proportion of births in January and is statistically significant at the 10% level. This coincides with a priori expectations that feed demand is higher at a time when feed supply is insufficient or in deficit, coinciding with lambing when the ewes' plane of nutrition is elevated, thus increasing the requirement for supplementary feed in the form of concentrate to meet the nutritional deficit. This is a significant result and agrees with the sheep production literature. Interpreting the coefficient, a 1 percentage point increase in the level of January lambing leads to 7.7% increase in concentrate use per sheep livestock unit. The level of February, March, April, and Later lambing births does not have a statistically significant influence on concentrate feed intensity in model 1. As previously developed, this study hypothesises that seasonality of production has significant effects on supplementary concentrate feeding.

This paper subsequently presents a second model that further develops the discussion of seasonality effects by taking into account the spatial difference across Irish sheep farms by region.

Regional differences in concentrate use on Irish sheep farms

From the initial model specification presented in Table 2, the level of lambing by month is hypothesised as having a statistically significant impact on concentrates usage. From Model 1 only the January lambing proportion has a statistically significant negative impact on concentrate use per livestock unit. This paper now turns to regional differences in lambing date to progress the story of seasonality effects on concentrate use. This paper hypothesises that in addition to seasonality of production being an important predictor, this effect will vary across regions. The justification for this investigation is based on the current production literature (Carty, 2011; Hoyne, 2001; Teagasc, 2012, C) and the results of the cross tabulation of region with month of lambing and concentrate use which indicate regional differences in lambing and concentrate usage on Irish sheep farms. These regional differences are due primarily to agronomic conditions due to weather, soil and altitude that vary substantially, with typically the South and East having better agricultural conditions. As a result optimal lambing patterns from a grass utilisation point of view will vary from region to region.

Summary Statistics for regional breakdown of season of production and concentrate use (Model 2)

Descriptive statistics in Table 3 below present mean seasonal lamb production by month and concentrate usage broken down by region. The results of the cross tabulation indicate regional differences in lambing and concentrate usage on Irish sheep farms. Summary means for monthly production/lambing are based on a subset of the full sample, representing those 657

Table 2: Results of a random effects model of supplementary concentrate feed demand

Results of Model 1 for concentrate feed demand on Irish sheep farms		
Constant	8.855***	(1.247)
Log of concentrate price	−1.115***	(0.204)
Log of labour intensity	0.261***	(0.083)
Region 1	−0.266*	(0.150)
Region 2	−0.478	(0.545)
Region 4	−0.361**	(0.181)
Region 5	−0.195	(0.218)
Region 6	−0.072	(0.168)
Region 7	−0.146	(0.176)
Region 8	−0.238	(0.160)
Log of fertiliser application rate	0.234**	(0.099)
Log of fertiliser application rate * Farm stocking density	−0.210**	(0.098)
Reps participation	0.049	(0.072)
Off-farm job	−0.053	(0.095)
Teagasc client	−0.146*	(0.082)
Log of sheep numbers	0.001	(0.046)
2009 Year	−0.008	(0.067)
2010 Year	0.028	(0.075)
January lambing	0.770***	(0.248)
February lambing	0.289	(0.211)
March Lambing	0.089	(0.203)
April Lambing	0.156	(0.234)
Later Lambing	0.009	(0.473)
Inverse Mills Ratio	−0.021**	(0.009)

Notes:
1. N 648
2. Standard errors in parentheses
3. Significance levels * $p<0.10$ ** $p<0.05$ *** $p<0.01$
4. Regions:
   1. Border - Louth, Leitrim, Sligo, Cavan, Donegal, Monaghan
   2. Dublin
   3. East - Kildare, Meath, Wicklow
   4. Midlands - Laois, Longford, Offaly, Westmeath
   5. Southwest - Clare, Limerick, Tipp North
   6. Southeast - Carlow, Kilkenny, Wexford, Tipperary South., Waterford
   7. South - Cork, Kerry
   8. West - Galway, Mayo, Roscommon

observations with productive ewe flocks over the three year period 2008–10. Similarly, the breakdown of the mean level of concentrates fed per livestock unit is based on the subsample of 649 farm observations that feed concentrates.

Notable results highlight how farm location influences the sheep production system in terms of date of lambing and concentrate usage. In line with the production literature, regions where there is a high proportion of mountain flocks such as in counties Donegal, Sligo, Wicklow, i.e., Regions 1 and 3, tend to lamb later, exhibiting a greater proportion of later lambing vis-à-vis early lambing (Carty, 2011; Hoyne, 2001; Teagasc, 2012b). Also, means of concentrate per livestock unit for the western counties of Regions 1 are below the total sample mean.

In contrast, regions 5 and 6 exhibit relatively higher percentages of early lamb births. This follows expectations whereby such farms (in particular those of region 5) are located in counties which are generally associated with earlier lambing lowland flocks. Furthermore, the means of concentrate per livestock unit for regions 5 and 6, reported in Table 3, are above the total sample mean. The lack of grass growth in winter, when the feed requirements of early lambing flocks is peaking (late pregnancy), leads to nutritional deficits. To rectify grass deficits, it is necessary to provide alternative nutritional sources such as specially sown forage crops for winter grazing or extra concentrate feeds. Either option results in considerably increased feed costs compared with mid-season production. Early season lowland production systems are thus most readily accommodated in tillage areas or areas with an early start to the growing season, i.e. more southerly counties such as those of Regions 5 and 6. On mixed farms with both tillage and sheep enterprises, competing demands for labour in spring are avoided by lambing in winter (Flanagan, 1999). Finally, Region 8 can be seen to have a high percentage of births in March and April (over 71%). The counties of Region 8 are important lowland mid-season producers and exhibit mean concentrate usage per livestock unit below the total sample mean, in line with the production literature.

Summary statistics highlight the variation in seasonal production and concentrate usage, thus motivating an investigation of the spatial difference in lambing and its effects on concentrate use. The aim of the following model is to add to the discussion on the variation in practice on Irish farms across region and production system.

Model 2

The results of Model 2 are presented in Table 4. Results are consistent for with those explanatory variables common to the specifications of both models 1 and 2. Independent variables common to both models exhibit the same degree of significance, sign and general magnitude of the coefficient when explaining concentrate demand.

In Model 2, this paper considers an alternative strategy for examining regional differences: incorporating the interaction terms of region with independent variables for seasonality of production by month (Jan–April). It is hypothesised that doing so gains a spatial difference by identifying differences in seasonal production effects, if any, across region. Only coefficients for significant interactions are presented in Table 4. Significant coefficients for a Month*Region interaction indicate the presence of spatially heterogeneous effects of lambing across regions relative to the reference dropped region.

The coefficient for January lambing*Region dummy indicates how the effect of the level of January lambing on concentrate usage differs across groups. Looking to the results in Table 4, the negative coefficient on January lambing*Region3 interaction, significant at the 10% level, is interpreted as follows: an increased percentage of flock births in the East for January results in less demand for concentrates relative to other regions. This result for the Midlands reflects a relatively small proportion of farmers with more efficient systems who lamb earlier than others in their region, reflecting agronomic considerations, as grass growth is later than for example the Southern part of the country.

The same rationale can be used for the interpretation of the other significant interaction coefficients. Looking at the results for April Lambing, the interaction is significant and negative for all regions except Regions 5 and 6. The coefficient for the regional interactions terms is thus negative and in an opposite direction to the main effect. Results signify that regions 1,3,4,7,8 use less concentrate for an increased percentage of April lamb births relative to the reference dropped regions in the South West and South East. Agronomically the South have better grass growth earlier in the season, but there is a catch up in more Northern regions into later Spring

Table 3: Regional breakdown of season of production and concentrate usage

Region (see Table 2 for key)	N*	N**	Concentrate per livestock unit (kgs)	N***	Percentage of births per month across Region					
					Jan	Feb	March	April	May–Dec	
1	168	157	6.624	151	0.064	0.200	0.469	0.236	0.031	1
2	7	5	4.441	5	0.000	0.334	0.345	0.274	0.047	1
3	119	107	7.601	116	0.047	0.179	0.402	0.332	0.040	1
4	79	67	6.501	77	0.092	0.269	0.451	0.181	0.006	1
5	36	34	9.236	34	0.183	0.371	0.394	0.031	0.021	1
6	88	84	8.617	81	0.162	0.333	0.465	0.038	0.002	1
7	86	80	8.591	81	0.111	0.243	0.356	0.242	0.049	1
8	127	115	7.037	112	0.157	0.129	0.532	0.177	0.005	1
Total	710	649	7.469	657	0.104	0.224	0.446	0.202	0.023	1

Notes: *All farms **Farms which feed concentrates ***Farms with productive ewe flocks.

and Summer. As a result it is more efficient for the southernmost counties to lamb earlier to maximise grass utilisation. Consequently those that lamb relatively later in the season require more concentrate feed. The opposite is true for the North of the country where optimally later lambing will be more efficient, reducing concentrate use relatively.

Model 2 results thus confirm the spatial difference that seasonality of production exhibits on concentrate demand across regions.

5. Conclusions

This paper proposes that a greater understanding of the factors influencing farmer decisions across the breadth of farm systems, sizes and environmental conditions, using nationally representative data, informs the actual choices being made on Irish farms and thus informs the interpretation and direction of farm management research, advisory services and dissemination. As a step towards addressing this information gap in the current research programme, this paper proposes a model of the factors affecting concentrate usage on Irish sheep farms in light of a review of farm profiles. The use of nationally representative data enables this study to analyse the actual choices being made on Irish farms and thus inform the interpretation and direction of farm management research, extension information and dissemination. Results from this paper show that the seasonality of production affects concentrates demand and that a spatial difference exists across regions.

An important feature of the paper is that it combines new information on farmer's actual management choices in terms of lambing date and estimates the effect of seasonality of production on concentrate usage. The approach employed uses NFS panel data to take into account the national distribution of farms across the range of farm systems, sizes and environmental conditions. Results highlight that farmer behaviour is consistent with the current animal science production literature. The demand for concentrates on Irish sheep farms was found to be elastic and thus sensitive to price changes. Farm labour input, fertiliser application, subscription to an extension and research provider and date of lambing were found to be significantly associated with concentrate demand on sheep enterprise. Significant results for the interaction of farm location with seasonal production indicates the presence of spatially heterogeneous effects of lambing on concentrate demand across regions.

There is potential to further develop the study in terms of the cost saving potential of better utilisation of grass relative to concentrate feeding. Results for the models proposed in this paper agree with a priori expectations and point towards the substitutable nature of grass and concentrates. Practices that can be shown to decrease concentrate demand whilst increasing grass utilisation can be quantified to determine their cost saving potential. This model provides impetus for future development of a detailed model of nutrition for the national distribution of sheep farms. There is potential to augment NFS data with biological information, cost functions, and environmental weather data to determine the financial impacts of economic behaviour of rational economic agents as preliminarily described through regression analysis in this study. Much research has already being undertaken in the field of ruminant production systems to complement such developments (Finneran *et al.*, 2010). Furthermore, thanks to the recent geo coding of the NFS, developing spatial analysis data has the potential to supplement the

Table 4: Results of a random effects model of supplementary concentrate feed demand on Irish sheep farms including regional interactions

Results of Model 2 for concentrate feed demand with Regional interaction terms		
Constant	8.870***	(1.244)
Log of Concentrate price	−1.164***	(0.205)
Log of Labour intensity	0.240***	(0.084)
Log of Fertiliser Application	0.196*	(0.100)
Log of fertiliser application rate * Farm stocking density	−0.174*	(0.098)
Reps participation	0.054	(0.072)
Off-farm job	−0.087	(0.094)
Teagasc client	−0.139*	(0.082)
Log of Sheep numbers	−0.012	(0.046)
2009 Year	0.010	(0.068)
2010 Year	0.009	(0.076)
January lambing	0.871*	(0.498)
January lambing*Region 3	−1.519*	(0.795)
April Lambing	3.405**	(1.615)
April lambing*Region 1	−3.170**	(1.610)
April lambing*Region 3	−2.916*	(1.607)
April Lambing*Region 4	−3.803**	(1.648)
April Lambing*Region 7	−3.191**	(1.623)
April Lambing*Region 8	−3.916**	(1.620)
Inverse Mills Ratio	−0.020**	(0.009)

Notes:
1. N 648
2. Standard errors in parentheses
3. Significance levels * $p<0.10$ ** $p<0.05$ *** $p<0.01$
4. See Table 2 for key to regions.

current model with weather data and grass growth proxies to the farm level.

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