Systems Approach to the Economic Impact of Technical Performance in the Sheep Sector

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Abstract

This paper investigates the structure and characteristics of the full distribution of sheep farms achieving various levels of financial and technical performance. Analysing data from the Irish panel dataset, the Teagasc National Farm Survey (NFS) shows Irish sheep farms exhibit relatively low level of technical performance and that on-farm technical advances have been stagnant over the past 20 years. NFS data files not previously manipulated for research purposes are used to capture monthly animal data flows for the full sample of NFS sheep farms for the 3 year period 2008 – 2010. Utilising this data we identify and analyse key flock performance indicators including reproduction, mortality rates. These "Livestock Demographic" variables are important indicators for estimating and modelling flock dynamics and production, combining two drivers of flock performance: the biological characteristics of the stock on the farm and the farmers' flock management practices. Results indicate the potential impacts on farm output and gross margins of improved animal performance which is achievable through specific technology adoptions.

Key Words: Sheep Production; Technical Performance, Gross Margin, Random Effects, Simulation.

JEL code: Q Agricultural and Natural Resource Economics

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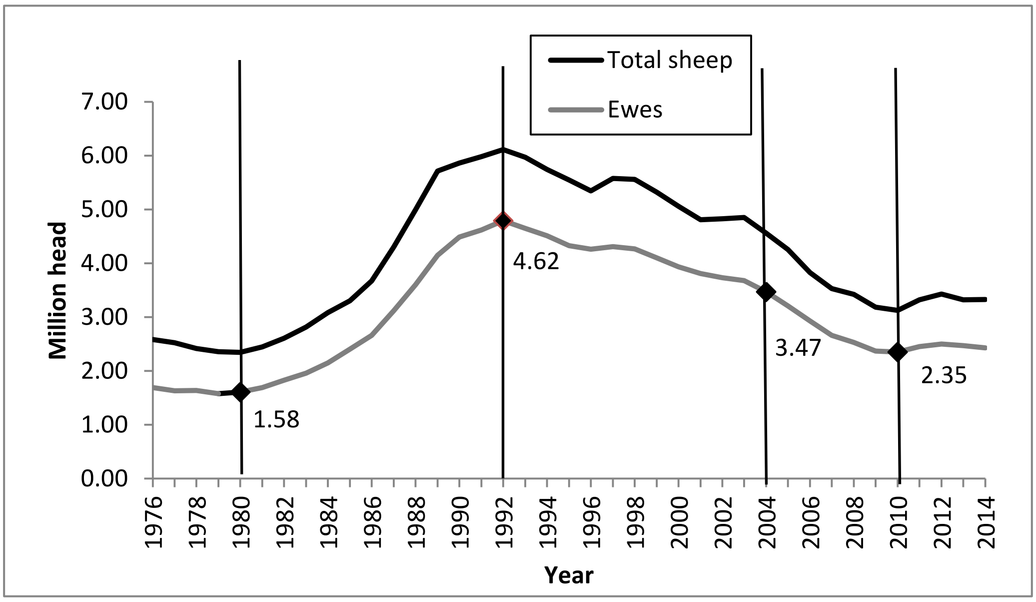
Economic Implications of Sheep Demographics

Introduction

Over the past 20 years the Irish sheep sector has been in decline reflected in falling farmer numbers, a reduction in the size of the national flock, stagnation in on-farm technical performance and profitability and ultimately a drop in sheepmeat output. Figure 1 charts the development in total sheep and breeding ewe numbers as recorded in the Central Statistics Office (CSO) December Livestock Survey for the period 1976 to 2014. From the chart it is evident that since the 1992 McSharry CAP reforms the national sheep flock has been in decline and that this decline has translated to a fall in sheep meat production and throughput in the sector (Bord Bia, 2011). As a caveat, positive growth in sheep numbers recorded in for 2009 and 2010 can be explained by improved producer confidence following positive market and government stimulus. In 2010, the national "Grassland Sheep Scheme", a coupled ewe premium scheme was introduced, funded from €54million of unused CAP modulation funds and distributed over the three year period 2010-2012.

Figure 1. Sheep Numbers - CSO December Livestock Survey 1976 – 2014



Source: Central Statistics Office (CSO) Livestock Survey (1976-2014)
*1980 First EU CMO for sheep meat implemented. Ewe numbers at low of 1.6 million head.
*1992 McSharry CAP Reforms. Sheep numbers peak at 4.88 million ewes.
*2005 De-coupling of SFP. Trend of falling sheep numbers increases following decoupling of SFP
*2010 Sheep Grassland Scheme (Coupled Ewe Premia)

Despite these negative trends sheep farming remains the second most common farm enterprise after cattle production with 34,300 sheep flocks and a national breeding ewe flock of 2.43 million ewes (CSO, 2014). Of the breeding ewe flock in Ireland, the lowland sheep sector accounts for 75% of the population and contributes approximately 85% of lamb carcass output. While there are specialist sheep farmers, sheep production on most lowland farms is a secondary enterprise to cattle production. Average flock size in Ireland is low at approximately 100 ewes, with over 68% of sheep farms holding less than 100 ewes and almost 43% 50 ewes or less.

The dry-stock sector, cattle and sheep farms, is characterised by very low profitability and smaller holdings. The small scale nature of production on many farms clearly raises significant structural constraints to the commercial viability of these flocks and the potential for improved efficiencies through technology adoptions as promoted through the production research. The average income per hectare in 2013 is estimated at €207 and with direct payments contributing 161% of income there is a clear reliance on subsidy support for many of these low profit enterprises (NFS, 2013).

Each of the successive agriculture policy reforms highlighted in Figure 1 and in particular the decoupling of direct payments in 2005 has led to the expectation of a more market orientated outlook for livestock production systems in the EU. Given that Irish farmers are considered price takers in a globally traded market with little scope to affect meat prices, any strategies to improve margins necessarily focus on increasing output volume on the one hand or cost minimisation practices on the other. Within the contemporary production research and extension advice given to sheep farmers two main technical performance parameters are highlighted as driving farm level output; increased stocking rates through improved grassland management and or increased ewe output through targeted breeding and improved animal husbandry (Connolly, 2000; Diskin et al., 2011, B; T. W. J. Keady et al., 2005). Analysing data from the Irish panel dataset the Teagasc National Farm Survey (NFS) indicates that expected changes in sheep producer priorities post decoupling have not materialised, on farm technical performance has continuing to stagnant at relatively low levels of performance while a significant reliance on subsidy payments has been maintained (Connolly, 1997a; Matthews et al., 2007; NFS, 2012).

Despite this, results from Teagasc's NFS data and published data (K. Hanrahan et al., 2013) clearly show the large differences in the profitability of sheep farms and highlight that well managed sheep production enterprises can return high levels of financial and technical performance which compare favourably with alternative drystock systems. Table 1 supports this by presenting the results for the key technical performance indicators, weaning and lambing rate and financial performance (Gross Margin (€/ha) for the Athenry sheep research flock and for the top and bottom performing lowland mid-season farms in the NFS sample. For comparison purposes, mid-season lowland lamb enterprises are ranked on the basis of gross margin per hectare, and assigned to one three equally sized groups which we have termed least, average and most profitable. The average levels of gross margin per hectare and indicators of technical performance across the top and bottom performing groups can then be compared with best practice from the outputs achieved from research flocks(Creighton, 2014). As is clear from Table 1, the large differences between the values of output per hectare between the least and most profitable groups of farms are due in large part to differences in weaning and stocking rates. Higher levels of technical performance is reflected in the average carcass output per hectare of 231 kilos on most profitable mid-season lamb enterprises versus 121 kilos on the least profitable enterprises. The performance achieved on the research flocks highlights the potential production output achievable in favourable agronomic conditions under management best practice and is significantly ahead of that been achieved by the top performing group of commercial farms. These results would appear to support the findings of the current production research and indicate that significant scope exists to exploit productivity gains through the implementation of tried and test best practice on commercial farms (S. Hanrahan, 2010).

Table 1. Financial and Technical Performance of Sheep Flocks

	Research Flocks (Creighton, 2014)	**Least Profitable** Teagasc NFS	**Most Profitable** Teagasc NFS
Stocking (ewe/ha)	14	8.75	5.57
Weaning (lams/ewe)	1.74	1.32	1.09
Lamb carcass (kg/ha)	486	231	121
Gross Margin (€/ha)	1037	896	217

The aim of this paper is to bridge the information gap about what is actually being achieved on farms and what is achievable given the underlying agronomic conditions and management technology. To do the potential impacts on farm output and gross margins of improved levels of animal/flock technical performance must be investigated. Utilising NFS data we identify and analyse key herd performance indicators including reproduction, and mortality, rates for the full distribution of Irish sheep farms. To simulate the impact of improved flock performance through these key "Livestock Demographic Parameters" it is necessary to understand the factors affecting their achievement both in terms of farm environmental factors and management technologies. Individual models for the key demographic parameters are specified as is a model of farm level gross margin. These model specifications are then used to simulate the impact of improved technical performance on farm gross margin. It is proposed that gaining an understanding of the actual factors, management, environmental and biological that drive technical and financial performance on the ground for the distribution of sheep farms will inform the production literature, and extension advice. A sheep systems flowchart diagram for a representative sheep flock is presented in Figure 2 of the appendices which highlights the key demographic parameters including those analysed in this study.

Materials and Method

In this paper, key demographic indicators identified as driving output and consequently gross margins on sheep farms include both reproduction, and mortality rates. These parameters synergise both the biological attributes of the flock and farm management practice. To estimate their impact on farm returns (gross margin) this study uses panel data methods to model farm gross margins utilising 3 years of the NFS panel dataset for an average of 196 sheep farms annually. An important feature of this paper is that it combines new information on both biophysical animal performance and farmers' actual management choices in terms of lambing rates and mortality rates and their timing. While NFS data is available dating back to 1975, the detailed monthly animal demographic breakdowns used in this paper are only available from 2008. In order to identify suitable variables within the NFS to accurately capture animal demographic data a lengthy process of data cleaning was undertaken. This involved extracting NFS raw data files (Check tables used to build up aggregate reported NFS variables) to provide a detailed monthly breakdown of animal stocks and activities by age class, including births, deaths, transfers, sales, purchases. Using a subsample of the NFS means that the dataset employed is a nationally representative short panel with relatively few time periods and many individual farms (N = 588, T = 3). 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).

Exploiting the panel nature of the National Farm Survey, this paper estimates a number of panel data random effects models (Howley et al., 2012). While performing a Hausman test suggests using a fixed effects estimator, doing so causes observations to drop out of the sample due to this lack of variability across years (S. Hynes et al., 2009). Given the nature of the NFS dataset, where there is very little variability in relevant variables for individual observations (farms) over time the fixed effects estimator which uses within group variation in estimation is less appropriate in this context. 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 (Greene, 2001). Given the structure of the NFS, where there are a lot more individuals than years, a random effects model is most appropriate for this study. 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.

The key demographic indicators, lambing rates, lamb death rates and ewe death rates are included as explanatory variables in a model of gross margin along with relevant farm specific environmental descriptors and management variables consistent with the literature. The following random effects model of farm gross margin is specified:

$$Y_{it} = \beta_o + \beta X_{it} + (U_{it} + \varepsilon_{it}), \qquad \text{(eq1)}$$

Where Y_{it} is the dependent variable, the log of gross margin per hectare (GM/ha) per farm i in year t (t = 08, 09, 10). X_{it} is a vector of explanatory variables which is composed of exogenous farm environmental factors, endogenous farm management factors and animal demographic variables. ($U_{it} + \varepsilon_{it}$) 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), εit is the within-entity error term. Thus from (eq1) farm gross margin can be expressed as a function of

$$G = f(E, M, D)$$

Where farm gross margin (C) is a function of farm environmental factors (E), endogenous farm management factors (M), and animal demographic variables (D).The results of this model of gross margin are presented in table 2 and discussed in the following section.

Leading on from the presentation of results for the model of gross margin this paper subsequently simulates the impact of improved flock performance on farm returns by simulating change in a given demographic parameter. Estimating the impact of these improved performance scenarios first requires the specification of individual models for the key demographic parameters investigated; ewe birth rate, lamb deaths rate, ewe death rate. These individual models provide a farm level estimate of the given demographic rate based on the underlying agronomic conditions and management for the full sample of farms. Simulating an improved "animal performance" scenario is achieved by estimating the impact of bringing the full sample of sheep farms into the top third of performance for lambing rate conditional on each farms agronomic conditions and management technologies. To achieve this all sample farms are moved into the top third of technical performance based on their residual estimate from the individual agronomic random effects model (e.g. Lambing Rate Model). This effectively applies a level of performance to those "under-performing" farms that is actually been achieved on agronomically similar farms based on a model of lambing rate. Simulating an improved lambing rate performance through the residual estimate changes the farm specific technical conditions under which gross margin is estimated for these farms. Subsequently comparing actual gross margin figures to simulated estimates for improved technical performance scenarios thus indicates the potential impacts on farmer's returns of improved animal performance achievable through specific technology adoptions as specified in the individual demographic model.

Results and Discussion

Model of Farm Gross Margin

Regression results of a random effects model of gross margin are presented in Table 2. As outlined in the methods section the model of gross margin presented in this study of sheep farms groups explanatory variables into three categories; exogenous farm environmental factors, endogenous farm management factors and animal demographic variables.

Table 2. Model of Farm Gross Margin on Irish Sheep Farms
Regression results for farm management, environmental and animal demographic variables associated with gross margin returns

(Dependent Variable - Log of Gross Margin per Hectare)		
Constant	3.626***	(0.307)
(Conditional Lambing Rate)	1.527***	(0.109)
(Conditional Lamb Death Rate)	-2.144***	(0.531)
(Conditional Ewe Death Rate)	-2.597***	(0.440)
Month of First lambing	*-0.203****	*(0.040)*
Concentrates fed per ewe	*-0.050****	*(0.006)*
Enterprise specialisation	*-0.448****	*(0.138)*
Stocking rate	*0.142****	*(0.015)*
*Stocking rate * Teagasc client*	*-0.038***	*(0.017)*
Fertiliser application rate	*-0.003***	*(0.001)*
*Fertiliser application rate * Teagasc client*	*-0.001*	*(0.001)*
Log of labour hours worked	*-0.038*	*(0.124)*
*Log of labour hours worked * Teagasc client*	*0.407****	*(0.148)*
Teagasc client	*0.116*	*(0.151)*
Concentration of Lambing period (months)	*-0.062****	*(0.018)*
2009 Year	0.146***	(0.050)

2010 Year	0.508***	(0.054)
Region 3	0.324**	(0.127)
Region 4	0.288**	(0.145)
Region 7	-0.340**	(0.148)
Soilcode 6	-0.945***	(0.364)
Hill or Lowland Farm	0.270**	(0.131)

N = 589

Standard errors in parentheses

Significance levels * p<0.10 ** p<0.05 *** p<0.01

Region
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

Animal Demographic Indicators

Results for Animal Demographic Indicators are presented in parentheses. These variables represent key technical performance indicators for sheep flocks and synergise information on both the biological performance of animals in the flock and farm management practice. Past 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, 2012, B, 2012, C) 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, B). In this context the number of lambs reared per ewe is a product of both reproduction and morality rates. Within the NFS data recorders collect data of individual farmers at specified points in the year. Data is collected on the range of farm activities and unlike a production experiment there is no specific recording system for animal inventories and activities, to which the farmer must adhere. Data is collected on farmers own records of farm activities and management. Data is not collected on abortion or stillbirths and only information on lambs born alive is recorded. Accordingly lamb births and conversely lamb deaths within the initially period post lambing (perinatal deaths) are most probably under reported. Despite these data limitations, monthly stock tables give an estimate of lamb death rates and birth rates such that the product of the two variables is an accurate measure of weaned lambs available for marketing.

In this model of gross margin the *Conditional Lambing Rate* variable captures the reproductive rate of the ewe flock. It is defined here as the number of lambs (born alive) divided by the number of ewes let to the ram. Model results are in line with the findings of previous studies which highlight stocking rates and lambing rates as drivers of both technical and finance performance on sheep farms (Teagasc, 2012, C) The sign of the coefficient on lambing rate can be seen to be positive and highly statistically significant.

Conditional Lamb Death Rate variable captures the number of lamb deaths (before weaning) as a proportion of the number the lambs born alive. On Irish sheep farms the primary output from the production system is sheepmeat carcass and higher lamb deaths will necessarily reduce output and ultimately returns. In line with *a priori* expectations the sign of the coefficient is negative and statistically significant.

Conditional Ewe Death Rate is a measure of ewe deaths as a proportion of the opening stock of breeding ewes. As expected model results report ewe death rates as significant and negative indicating that higher ewe death rates decrease the productive capacity of the ewe flock and reduce the potential number of cull ewes, thus negatively affecting gross margins. In the following section the effect of specific management technologies and animal biophysical descriptors on these three important animal performance parameters are explicitly modelled based on the current agronomic and production literature.

Management Variables

Management explanatory variables are presented in italics in table 2. Explanatory variables are deemed to be management variables if they come under the direct influence and management control of the farm holder.

A farmer is deemed to be a *Teagasc client* if they have a subscription payment to the Teagasc advisory service. As a client of a farm research and extension provider, have access to up-to-date best practice (S. Hanrahan, 2010). However for this sample of sheep farms a correlation matrix shows that the *Teagasc client* variable is highly correlated with (*Fertiliser application rate), (Stocking rate) and (Log of labour hours worked).* To address this issue Teagasc client membership is interacted with the three continuous variables. The coefficient on the individual term for *Teagasc client* can be seen to have a statistically insignificant effect on GM/ha.

Concentrates fed per Lu captures the quantity of supplementary concentrates fed to sheep livestock per year. The explanatory variable thus captures the intensity of supplementary feeding on a per livestock basis. As highlighted more technically efficient and profitable farms have in the past been shown to place a greater emphasis on pasture expenditure rather than supplementary feed (Teagasc, 2012, C). 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. The *Fertiliser application rate* variable in this model corresponds to the level of inorganic Nitrogen fertiliser (kgs) per unit area (ha) of application. Both variables are statistically significant with negative signs on the coefficient. While the coefficient on the individual term for fertiliser application is negative previous studies have highlighted that many sheep farms operate extensively at very low levels of inorganic fertiliser application. The coefficient on the square of fertiliser application is positive but insignificant but may indicate that relatively higher rates of fertiliser application are positively related with farm gross margins. The interaction term *Fertiliser application rate * Teagasc client* is statistically insignificant.

While the individual term *Log of labour hours worked* is statistically insignificant the interaction term *Log of labour hours worked * Teagasc client* is highly significant and positive which indicates that the higher farm labour inputs are associated with increased GM/ha for Teagasc clients.

Stocking rate is defined as the number of breeding ewes per hectare of forage area where forage area is an enterprise level variable. In line with a priori expectations the sign on the coefficient is positive and statistically significant indicating that stocking rates as positively associated with farm GM/ha. The interaction term *Stocking rate * Teagasc client* is significant at the 95% level and the sign on the coefficient is negative.

Month of First Lambing captures the influence of seasonality of production on gross margin returns for Irish sheep farms. Previous studies have highlighted the various levels of financial and technical performance associated farms operating early, mid-season, and later lambing systems of production (Connolly, 1997b, 1997c; Flanagan, 1999; NFS, 2012). The coefficient in Table 2 is significant and negative indicating that farms which commence lambing early exhibit higher GM/ha. This would be in line with previous study which show farms that operate early lamb production systems typically exhibit higher levels of technical performance and higher levels of output per hectare. Returns from these systems however has been shown to be more reliant on market conditions and the need to achieve a price premium for out of season lamb given the higher input costs of production (Connolly, 2000).

Typical of Irish sheep farms the majority of sheep farms in the sample also operate alternative farming enterprises. The *Enterprise Specialisation* variable captures the fraction of the farm forage area dedicated to the sheep enterprise. The variable has a significant negative relationship with GM/ha. This appears counter intuitive but is most probably explained by the fact that many of the dedicated sheep farms in the sample operate hill production systems which are typically more extensive in their nature with lower GM/ha.

Concentration of Lambing period is a variable which describes the relative concentration / spread in the lambing period measured in months. Birth data is aggregated on a monthly basis and thus while the measure of lambing period is not precise it does give an indicator of lambing spread. While the importance of compact calving to financial returns has been well documented (Eblex, 2008) less research has been focused on this area in for the sheep enterprise. Benefits of compact lambing include labour and costs savings associated with batching ewes and lambs for feeding, routine veterinary treatments, and batching of lambs to avail of favourable market conditions. In-line with this rational the sign on the coefficient is significant and negative, i.e. less compact lambing period negatively associated with GM/ha.

Exogenous Variables

Exogenous explanatory variables outside farm management control are presented in italics. These variables represent farm environmental conditions and are used to control for the influence of weather, farm structural factors (farm size), geography, associated soil conditions and production system (whether upland or lowland).

Regions 3 and 4 in Table 2 report positive and significant coefficient results indicating that sheep farms in the East and Midlands have higher gross margins per hectare than farms in the Border (Region 1, reference dropped region). The opposite is true for the Southern Region (Region 7). This can reasonably be explained by farm type associated with each region. The East and Midlands would typically be associated with better agronomic conditions and lowland production relative to the reference Border region while sheep production in the Southern would be predominantly at higher altitude and extensive in nature.

A *Year* dummy is used to control for exogenous shocks outside the control of the farm gate, in particular weather and price shocks. The significant and positive coefficients recorded for 2009 and 2010 relative to the reference dropped year (2008) can be explained by the relatively positive market environment witnessed for sheepmeat product in 2009/2010, in which tightening supplies on international markets had positive effects on output prices and consequently gross margins (Teagasc, 2009, 2010)

Modelling "Lambing Rates" on Irish Sheep Farms

Estimation of the impact of improved animal performance scenarios on gross margins requires the specification of individual models for the key demographic parameters investigated. The impact of ewe birth rates on GM/ha is presented in the results of the gross margin model (Table 2) entering the model through the "Conditional Lambing" rate variable. In the following section the results of an individual model of "Lambing Rate" is presented in Table 3 based on the current agronomic and sheep production literature. As previously highlighted, data is collected on farmers own records of farm activities and management. Data is not collected on abortion or stillbirths with only lambs born alive recorded. Accordingly lamb births as recorded by NFS data will combine some measure of early perinatal deaths post lambing. The model presented below takes this into account in model specification.

Table 2. Model of Lambing Rates on Irish Sheep Farms

(Dependent Variable - Lambs born per ewe mated)

Constant	1.321***	(0.037)
Concentration of lambing period (months)	*0.023****	*(0.006)*
Concentrates fed per ewe	*0.006****	*(0.002)*
Fulltime (FTE)	*-0.064***	*(0.025)*
Fertiliser application rate	*0.001****	*(0.000)*
Veterinary expenditure per Lu	*0.001**	*(0.000)*
Proxy for efficiency	*0.199****	*(0.021)*
Cheviot	*-0.147****	*(0.038)*
Scottish Blackface	*-0.285****	*(0.047)*
Year 2009	-0.046**	(0.020)
Year 2010	-0.095***	(0.022)

N = 589

Standard errors in parentheses
* p<0.10 ** p<0.05 *** p<0.01

Ewe Breed	
Sufflok/Suffolk Cross	1
Greyface/half-breed	2
Cheviot	3
Belclare Cross	4
Continental Crosses	5
Scottish Blackface	6
Other Hill Cross	7
Other	8

As previously outlined the dependent variable in this study of lambing rate is defined as the number of lambs born alive divided by the number of ewes mated with the ram. This variable also takes into account the net of inlamb purchases minus sales if applicable.

Management Variables

Management explanatory variables are presented in italics in Table 3. Explanatory variables are deemed to be management variables if they come under the direct influence and management control of the farm holder.

Concentration of Lambing period is a variable which describes the relative concentration / spread in the lambing period measured in months. The coefficient is positive and significant indicating that longer lambing spreads are associated with higher lambing rates.

Meeting the nutritional requirement of the ewe is a key factor in achieving the maximum productive potential of the ewe flock. While the NFS does not have specific breakdowns of flock diets, information is collected on range of variables that may be used as proxies for positive dietary provision and ewe management. In the results presented in Table 3 *Concentrates fed per ewe* and *Fertiliser application rate* are used as proxy nutritional variables. 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. Nitrogen fertiliser application per unit area is thus included as a proxy for forage provision in the model. The Nitrogen *Fertiliser application rate* is a farm level variable which is assumed to be representative for the sheep enterprise of mixed farms in the sample. Concentrate feed is a substitute for grass and grass silage and so the *Concentrates fed per ewe* is included as an explanatory variable. Previous studies have shown that flock productivity as measured through litter size increases for higher ewe live weights at mating (S. Hanrahan, O'Malley, L, 1999). Other studies have shown that a high birth and milk yield associated with ewe body condition score is desirable for lamb survival and can be supported by higher rates of supplementation (at a time when forage supply is limited) (Grennan, 2002). On the other hand other studies have shown that overfeeding of ewes at the various stages of pre and post mating has the potential to negatively affect fertility, development of a viable foetus and increase lambing difficulties (Afbini, 2012). However the model as presented here hypothesises that evidence of suboptimal production is primarily due to under nutrition of the ewe and insufficient body condition. Thus while the NFS doesn't provide a measure of the feed value of forage and ration fed to sheep, evidence of management practices which increase nutritional supply are expected to be positively associated with increased lambing rates. From Table 3 both *Fertiliser application rate* and *Concentrates fed per ewe* are significant and positive in-line with the rational presented.

Veterinary expenditure per Lu is calculated as the spend on veterinary supplies attributed to the sheep enterprise per sheep livestock unit. The relative spend on veterinary medications per livestock unit is taken a proxy for animal husbandry and relative flock health status. Whilst disease outbreak and poor health status will necessitate treatment and incur veterinary cost it is hypothesised that the majority of costs associated with veterinary expense are for preventative measures such as routine worm drenching and vaccination for clostridial diseases and abortion. This is particularly relevant given that our definition of lambs born alive incorporates information on stillbirths and abortions. In-line with expectations the sign on is positive and significant indicating that *Veterinary expenditure per Lu* is associated with achieving higher production per ewe.

Previous studies such as T. W. J. Keady (2014) have highlighted that ewe genotype is inherently linked to ewe prolificacy or lambing rate and that Belclare-cross ewes have proven to attain higher lambing rates than a wide range of other crossbred types (T. W. J. Keady, Hanrahan, J.P, Flanagan, S, 2009). To capture between breed differences across flocks a breed variable is included in the model. The breed dummy variable captures the predominant ewe breed of each flock (one of eight categorical breed variables). Results highlight a significant negative relationship for the *Cheviot* and *Blackface Mountain* Breeds relative to the reference dropped breed *Sufflok/Suffolk Cross*. This is in-line with a priori expectations that hill breeds would exhibit lower lambing rates than the predominant *sufflok/suffolk cross* used on the majority of lowland farms (Lynch, 2010). While the sign on *Belclare cross* breed is positive it proves statistically insignificant.

Fulltime (FTE) or fulltime equivalent is calculated based on the number of labour hours attributed to the farm. In the NFS full time farms are defined as farms which require at least 0.75 standard labour units to operate or a minimum of 1,350 labour hours. *Fulltime (FTE)* is significant at the 95% level and negative.

Exogenous Variables

As per the model of gross margin presented in Table 1 exogenous explanatory variables outside farm management control are presented in italics. A *Year* dummy represents the influence of exogenous farm environmental variables including weather, and prices. The significant and negative coefficients recorded for 2009 and 2010 relative to the reference dropped year 2008 can be explained by particularly adverse weather conditions experienced in the Spring of both years and throughout the key lambing periods which negatively affected output of lambs from ewe flocks.

A similar modelling approach based on the production research was adopted to examine the factors affecting both “Ewe Death Rates” and “Lamb Death Rates” the results of which are presented in the Table 4 and Table 5 of the appendices. The analysis now turns its focus to combining the results of both the demographic models and the model of gross margin in order to simulate the economic returns to improved flock technical performance.

Improved Technical Performance Simulation

Results and Discussion

The individual models presented in the previous section provide a farm level estimate of the various demographic rates of interest based on the underlying agronomic conditions and management for the full sample of farms. Simulating an improved "animal performance" scenario, for example, improved lambing rates, is achieved by estimating the impact of bringing the full sample of sheep farms into the top third of performance for lambing rate conditional on their agronomic conditions and management. To achieve this all sample farms are moved into the top third of lamb rate performance based on their residual estimate from the individual agronomic random effects model (Lambing Rate Model). This effectively applies a level of performance to those "under-performing" farms that is actually been achieved on agronomically similar farms based on the model of lambing rate. Simulation results for bringing all farms into the top distribution of performance for lambing rate is shown to increase the average lambing rate from 1.2 to 1.48 lambs/ewe which consequently increases GM/ha from €437/ha to €478/ha. This is equivalent to a GM/ha increase of 25% for the sample of NFS sheep farms. Performing a similar exercise this time for lamb death rate decreases lamb death rate from 8% to 5% with an estimated increase in GM/ha in the order to 6%. Ewe death rate is estimated to decrease from 6% to 3% and is associated with a 9% increase in GM/ha

Simulating an improved lambing rate performance in this way through the residual estimate changes the farm specific technical conditions under which gross margin is estimated for these farms. Comparing actual gross margin figures to simulated estimates for improved technical performance scenarios thus qualifies and quantifies the significant potential positive returns to farmers of improved animal performance achievable through specific technology adoptions as specified in the individual demographic model. A similar simulation exercise for "Conditional lamb death rate" and "Conditional ewe death rate" shows that bringing farms into the top distribution of technical performance has as expected the potential to increase farm gross margins significantly though not to the same extent as "Conditional Lambing rate".

Conclusions and future work

Analysing data from the Irish panel dataset, the Teagasc National Farm Survey (NFS) shows Irish sheep farms operate at relatively low levels of profitability and technical performance and that on farm technical advances have been stagnate over the past 20 years (Connolly, 2000; NFS, 2013). Using a nationally representative panel dataset, the National Farm Survey this paper identifies and analyses key flock performance indicators including reproduction and mortality rates for the sample of sheep farms. NFS data files not previously manipulated for research purposes are used to capture monthly animal data flows and describe key demographic parameters of interest; lambing rate, lamb death rate and ewe death rate for the full sample of NFS sheep farms for the 3 year period 2008 – 2010. These "Livestock Demographic" variables are important indicators for estimating and modelling flock dynamics and production, combining two drivers of flock performance; the biological characteristics of the stock on the farm and the farmers' flock management practices given the underlying environmental conditions. Results indicate the potential impacts on farm output and gross margins of improved animal performance which is achievable through specific technology adoptions. This study thus bridges the information gap about what is actually being achieved on farms and what is achievable given the underlying agronomic conditions and management technology.

Other areas for further investigation in the area of flock performance include flock replacement strategies employed by sheep farms and the impacts of participation in discussion groups on technology adoptions. The Sheep Technology Adoption Programme (STAP) is a programme designed to encourage the adoption of best management practice on sheep farms and thereby increase profitability through the discussion group forum. The programme was launched 2013 and NFS data on farmer participation is now becoming available. The production literature emphasises the potential benefits of retaining homebred ewe lambs to replaced cull ewes, including animal health benefits, and targeted breeding/ performance recording. However there has been little research on the actual practices adopted by the distribution of sheep farms. New NFS data will allow an investigation of the factors influencing whether a farm operates a closed flock or what percentage of breeding replacements are source from off farm purchases. In particular structural constraints associated with operating at a low level of scale in the context of homebreeding replacement stock can be investigated.

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Appendices

Table 4. Model of Ewe Death Rates on Irish Sheep Farms

(Dependent Variable - Ewe Deaths per Opening Stock of Breeding Ewes)

Constant	0.068***	(0.025)
Lambing rate	-0.025**	(0.010)
Lamb Death rate	0.193***	(0.048)
Enterprise specialisation	-0.030***	(0.011)
Month of First lambing	-0.005	(0.003)
Proxy for efficiency	-0.019***	(0.006)
Winter forage Expenditure per Lu	0.000***	(0.000)
Pasture Expenditure per ha	-0.000	(0.000)
Hill or Lowland System	0.016*	(0.009)
Year 2009	0.012**	(0.005)
Year 2010	0.002	(0.005)

N = 588
Standard errors in parentheses
* p<0.10 ** p<0.05 *** p<0.01

Table 5. Model of Lamb Death Rates on Irish Sheep Farms

(Dependent Variable - Annual Lamb Deaths per Lamb crop)

Constant	0.110***	(0.010)
Ewe death rate	0.124***	(0.033)
Winter forage expenditure per Lu	-0.001**	(0.000)
Veterinary expenditure per Lu	-0.000**	(0.000)
Pasture expenditure per ha	-0.000***	(0.000)
Enterprise specialisation	-0.019**	(0.010)
Fulltime (FTE)	-0.014***	(0.005)
Proxy for efficiency	-0.019***	(0.005)
Concentration of lambing period (months)	-0.003**	(0.001)
Land value	0.014**	(0.005)
Soilcode 5	0.045***	(0.012)
Soilcode 6	0.068**	(0.028)
2009 Year	-0.010***	(0.004)

N = 588
Standard errors in parentheses
* p<0.10 ** p<0.05 *** p<0.01

Figure 2. Sheep Systems Flowchart