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Abstract

Previous research has highlighted the economic advantages of spring calving in countries such as Ireland that have a long spring/summer grazing season. However, the widespread adoption of such a production system leads to a highly seasonal milk supply and a range of problems that are associated with seasonality. The objective of this paper is to use historical data to quantify the economic benefits of a spring calving system. Data from over 400 dairy farms in Ireland over a period of 15 years is examined. Fixed, random and between effects panel models are estimated to test the significance of calving season on production costs. The results show the effect of calving season is significant at lowering production costs. These models returned results suggesting that high compact early Spring herds have significantly lower costs than over seasons. However the fixed effect model demonstrates little difference between production costs in different seasons suggesting individual effects such as the ability of the farmer may play a role in reduction of costs. Herds that are calved over a shorter period tend to have lower production costs.

Key Words: Seasonality, Fixed effect and Calving date

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Introduction

Production systems research has shown that for countries with a mild climate, such as New Zealand, parts of the United States and Ireland, dairy farmers can maximise profit by matching their peak production to peak pasture. This facilitates a lower input system, provides some insulation from fluctuations in grain prices and allows farmers to compress calving and milking into a shorter season. While such a system may be profitable from a farmer's perspective, it can create a range of problems and costs for the sector as whole, as will be outlined below.

The objective of this paper is to conduct a micro-economic analysis of the relationship between total production costs on dairy farms and the seasonality of production. While there have been many studies of optimal calving date, most of these have been from a production systems perspective and have simulated the optimal calving date for a hypothetical farm. The approach adopted here differs in that a panel data set of over 6,500 observations is used to estimate a total cost function. The advantage of this approach is that it facilitates the examination of production costs on farms while allowing for farm specific factors, such as scale and efficiency, time specific factors such as price and weather shocks, and unobservable time invariant individual effects, such as the farmer's inherent managerial ability. The overall objective of the analysis is to determine whether costs of production are lower for spring calving systems when all of the above factors are considered.

This paper begins with a background section exploring previous research conducted on the seasonality of milk production. Citing previous studies, this section of the section discusses the costs and benefits of a highly seasonal milk supply. Following this, the methodology section outlines the empirical approach adopted and describes

the dataset. The final two sections of the paper present the key results of the analysis and discuss the implications for the future of dairy farming in Ireland.

Background

Milk production in Ireland is primarily a grass-based low-cost system resulting in highly seasonal milk supply (Keane, 1986). Crosse et al (2000) calculate that 85% of milk in Ireland is produced from a spring calving summer grazing system between March and October. Ireland is favoured by a climate that has complimentary grass growth between April and October and hence the availability of a grass based diet (Hennessy and Roosen, 2003). This emphasis on a spring calving system is to take advantage of grass growth and leads to high seasonality in the supply of milk in Ireland.

Seasonality is defined as a regular pattern of peaks and troughs within each successive year in the supply or demand for a product (Keane, 1980). Seasonality is measured using a ratio of a peak to trough month in milk deliveries each year. Ireland's seasonality has remained high over the last two decades, with a 7 to 1 ratio of peak monthly production (May) to trough monthly production (January) (Hennessy and Roosen, 2003). Due to this seasonality of supply, dairy processors pay a price premium to some dairy farms to produce all year round. Hence, the Irish dairy sector is unique in that it is characterised by two separate sectors, namely manufacturing and liquid milk producers. The commercial milk sector (liquid milk production) deals with a perishable product and has largely a constant market requirement, hence the encouragement of regular milk production (Keane, 1980). A premium is paid to liquid

milk producers as an incentive to provide a regular milk supply. Manufacturing milk producers supply milk that is used as an input in products such as casein, butter, cheese and milk powder. These products are less perishable and are possible to store for long periods, and so do not encourage a steady supply of milk. Hence dairy farmers produce their peak milk production in the most cost efficient months, namely April through September.

In an Irish context, a number of studies have tried to identify the optimum calving date. Shalloo and Horan (2008) used the Moorepark Dairy Systems Model to identify the most profitable calving date from a selection of four possible dates in a no quota situation; 31st January, 14th February, 1st March and 15th March. The Moorepark Dairy Systems model is a stochastic budgetary simulation model of a hypothetical farm (Shalloo et al 2004). The results of the analysis showed that an average calving date of the 15th March returns the lowest total costs of all four scenarios. However, this study only investigated dates associated with spring calving systems. Furthermore, this analysis was carried out by varying the calving date on the same hypothetical farm. It did not explore the effect of other factors that may affect production costs such as the farmers' management abilities and so forth.

Valencia and Anderson (2000) investigated optimal milk production systems in Northern Ireland and compared spring and autumn based systems. They show that when production is constrained by a milk quota, which is the case at present, a spring calving herd of medium genetic potential cows and a long grazing season are favoured. Their research also found that in a no quota situation, autumn calving, cows

of high genetic quality and higher quality silage along with a long grazing season was the optimal production system.

Dillon et al (2002) highlighted that there are opportunities to reduce costs on dairy farms through increased reliance on grass. Costs such as slurry storage and spreading, as well as the labour involved with indoor feeding, would be reduced on grass based systems. The analysis suggested that spring calving herds should be turned out to grass as early as possible to benefit from the lower feed costs of grass and the higher yield that can be achieved. Shalloo et al (2004) also concluded that lower costs of production are associated with a greater number of grazing days which maximize grass input. Sayers and Mayne (1998) determined that early turnout in dairy herds reduce silage usage and increase yield and constituents in the milk. This reduction in the reliance on indoor feeding implies a reduction of costs while also increasing income through the greater constituents achieved in the milk produced.

These studies demonstrate that grass based systems provide the lowest cost of production in Ireland and that maximising the grass intake on dairy farms is important in the lowering of production costs. However, it is noted in most of the above studies that milk yields increase when herds are introduced to grass during Spring. Farmers maximise milk production and hence produce milk when it is cheapest to do so; consequently the majority of dairy farms in Ireland are spring grazing to take advantage of grass growth. This leads to a high quantity of milk being produced in the same period of the year and causes a seasonality effect on the supply of milk in Ireland.

At the farm level, seasonality results in less efficient use of capital and other resources as their use is stretched at peak supply months yet under utilised in low supply months. Groover (2000) showed that spring producers compress large workloads into short periods, while year round producers can spread the use of inputs and facilities over the whole year. Another added cost to spring calving operations is the strategy to have all cows calving in a specific period of spring and the culling of those cows that calve outside this period. Year round producers have less critical constraints on their calving patterns and incur fewer costs from premature culling. Such a high demand on labour and capital on spring calving farms could lead to increased costs of production.

Seasonality also presents problems at the food processing level. Seasonal supply makes it necessary for processors to have higher plant processing and transport capacity than if the peak to trough ratio was lower. This inevitably adds costs to processing and so results in a lower milk price (Oltenacu et al (1989). Furthermore, there are also implications for product quality and product mix. Seasonality in milk production creates late lactation milk, which is of lower quality due to high somatic cell count, bacteria and free fatty acids (Hennessy and Roosen, 2003). With such a large volume of milk produced during summer, the product mix that can be produced is less perishable. This leads to increased storage costs and ultimately lower prices for milk. Could and should farmers switch to a less seasonal supply in order to maximise profits?

It can be argued that many of the problems associated with seasonality can be resolved through an appropriate pricing mechanism, i.e. processors can devise a price system that will encourage year round production. This is the case in many countries;

Ireland operates a price premium scheme for year round supply as does Canada for example. However, Hennessy and Roosen (2003) argued that the consequences of distortionary milk pricing schemes that adjust the seasonality of milk production are not as simplistic as they may seem at first. They concluded that any pricing scheme designed to promote quality and alter seasonal production must recognise that the underlying biological processes impose interactions between season and quality.

Outlined above is the reality that any production system is not without its own disadvantages or costs. The objective of this analysis is to use historical data to quantify the economic benefits of a spring calving system with a view to determining whether the savings at farm level justify the costs for the processing sector.

Data

Irish National Farm Survey data (NFS) from 1994 to 2008 is used in the course of this study to compile and analyse production costs on dairy farms. The NFS is collected as part of the Farm Accountancy Data Network (FADN) for the provision of Irish data to the EU commission and surveys approximately 1200 farms annually. These farms are assigned a weighting factor that enables an aggregation process to represent the full farming population of approximately 115,000 farms. The data is unbalanced allowing farms to enter and exit the sample over the fifteen-year period. For the purposes of this study only the data collected on dairy farms is used. This results in an annual sample of approximately 400 farms, giving rise to 6559 observations in total.

The sample includes specialist[2] and mixed dairy enterprises. Only production costs relating to the dairy enterprise are considered. The NFS data collection process allocates direct costs of production to specific farm enterprises; see Connolly et al

[2] A specialist dairy farm produces 66% or more of their gross output from dairying

(2008). However, overhead costs are not assigned to individual enterprises. This means that some manipulation of the data is necessary to estimate total production costs. Overhead costs are estimated on a proportional enterprise gross output basis. The costs of hired casual labour are included in direct costs while permanent hired labour is included in overhead costs. Unpaid family labour and the cost of other owned resources are not included in the calculation of total costs. Production costs are standardised to a Euro cost per litre of milk produced.

Table 1. **Total cost of Production on all Irish Dairy farms**

Year	**1994**	**1998**	**2002**	**2004**	**2006**	**2007**	**2008**
Total costs	18.66	19.19	20.24	20.27	20.73	22.67	25.88
Concentrates Cost	3.50	3.24	3.90	3.53	3.91	4.27	5.23
Pasture & Forage Cost	2.94	2.98	3.31	3.20	3.60	3.54	4.38
Other direct costs	3.42	3.54	3.20	3.26	3.19	3.51	3.75
Overhead Cost	8.80	9.42	9.81	10.29	10.03	11.35	12.53
Net margin	11.79	10.35	8.77	9.76	6.19	11.52	8.21

Source: National Farm Survey. All figures in cent per litre

Table 1 outlines the total cost of production for selected years of the sample from 1994 - 2008. The results are representative of all Irish dairy farms and show total costs increasing marginally up until 2006. Costs rose substantially in 2007 and again in 2008 and show cost inflation as serious problem in the dairy industry at present.

Data on actual calving date is not available from the NFS but the number of calves born each month is recorded. Using this data, a seasonal dummy variable with different categories was created; February, March, April, Summer and Autumn/Winter. Farms were classified according to the birth month of the median

calf. February includes January and February; Summer includes May, June, July and August while Autumn/Winter include September, October, November and December.

Table 2 shows a selection of summary statistics for the five dummy variable categories using all years in the sample. It illustrates that scale is larger on those farms with an Autumn/Winter calving season while also returning the highest yields per cow. In contrast, herds with March and April calving seasons are on average smaller and have lower yields.

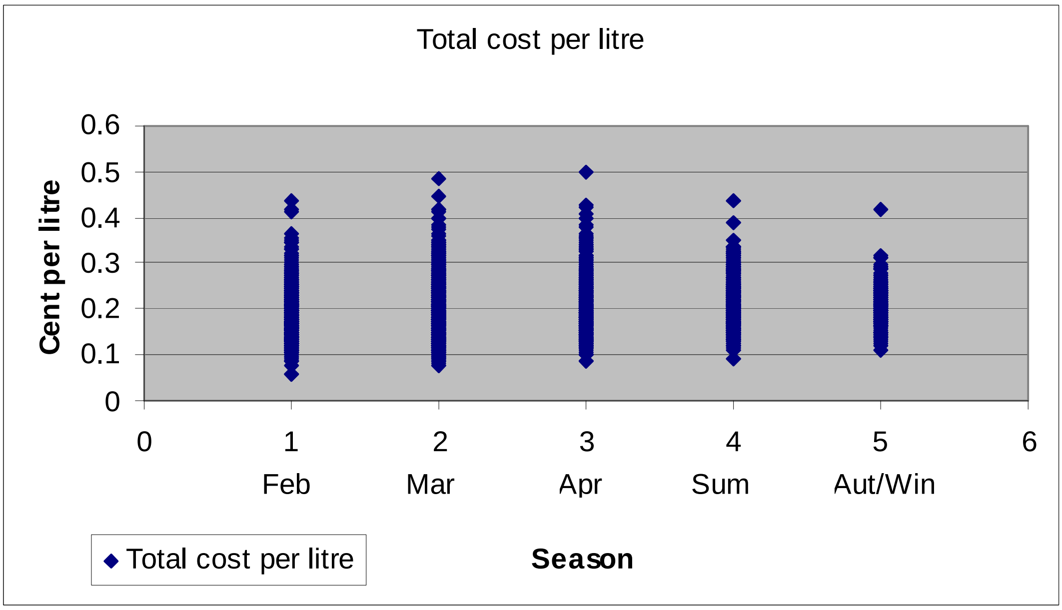
Table 2. Summary Statistics for all Dairy Farms by calving season 1994-2008

Year	**February**	**March**	**April**	**Summer**	**Autumn/Winter**	**All**
N	*1488*	*3455*	*1032*	*417*	*174*	*6566*
Herd Size (Cows)	44	37	36	54	64	40
Farm Size (Hectares)	46.26	42.56	44.47	55.86	64.28	44.89
Yield (Litres)	4832	4539	4419	4852	5527	4622

Source. National Farm Survey.

Figure 1 presents a graphical depiction of the relationship between the total cost of production and the five calving season dummy variables.

Figure 1: Seasonal dummies versus total cost of production per litre



The relationship between production costs and calving season is further depicted in Table 3. Expectedly, the Autumn/Winter and Summer category demonstrates higher costs compared to their spring counterparts due the availability of more grass pasture in spring calving herds. February is shown to be the lowest cost month in every year of the analysis.

Table 3 Production Costs according to Calving Season

	February	March	April	Summer	Autumn/Winter	All
1994	18.11	18.24	19.55	20.67	21.18	18.66
1998	18.88	19.05	19.60	20.22	21.62	19.19
2002	19.28	19.83	21.64	23.08	20.35	20.24
2004	19.59	19.88	21.95	22.28	21.28	20.27
2006	19.16	20.40	23.15	22.36	23.60	20.73
2008	24.74	25.44	28.27	29.05	27.66	25.88

Source: National Farm Survey Data, all figures in cent per litre

Total costs of production for 2006 are disaggregated in Table 4 between the different median calving dates. This year was chosen as it remains the last "normal cost year"

(Donnellan and Smyth, 2009). Subsequent years have shown high cost inflation. As expected, concentrate costs per litre are higher in the Autumn/Winter category as they are in peak production at a time when less grass is available. Pasture and forage costs are lower on these herds also, with the exception of April. Differences in pasture & forage costs between Autumn and Spring herds are not as large as expected, this may be due to the relatively lower quantities of fertilizer being purchased on autumn herds compared to the spring system that needs to maintain pasture in the very early and very late parts of the growing season. Labour expenses are higher in the Summer and Autumn winter due to the prevalence of year round milking.

Table 4. Production costs disaggregated according to calving season in 2006

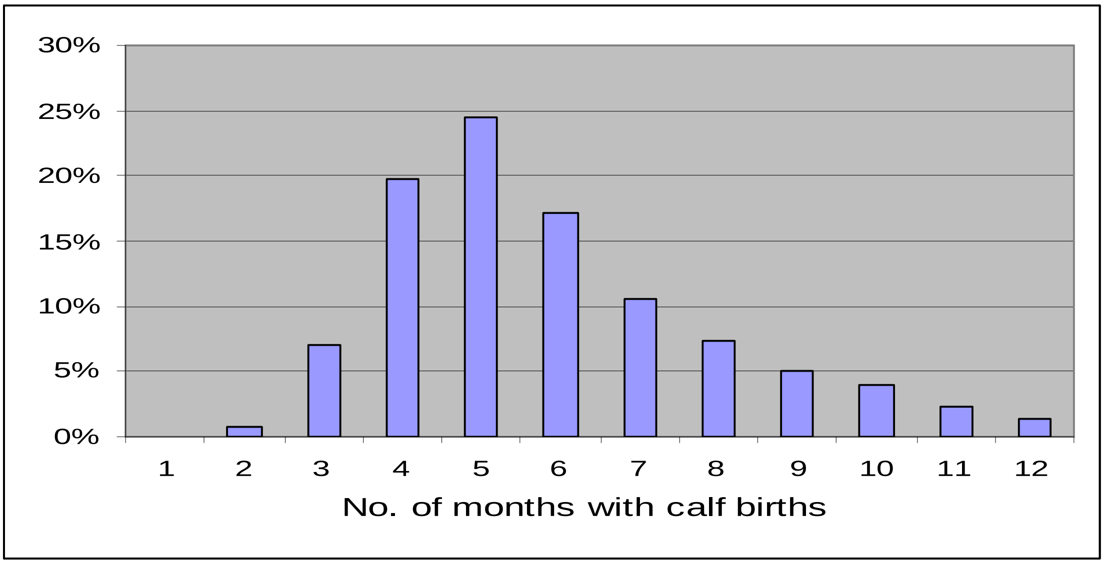
	February	March	April	Summer	Autumn/Winter	All
Concentrates	3.50	3.65	5.15	4.70	4.88	3.91
Pasture and Forage	3.26	3.61	4.18	3.25	3.76	3.60
Other direct costs	3.07	3.15	3.32	3.53	3.35	3.19
Energy and Fuel	1.75	2.19	2.46	1.96	2.04	2.13
Labour	0.44	0.30	0.61	1.18	1.61	0.45
Overhead Costs	7.14	7.49	7.44	7.74	7.98	7.45

Source. National Farm Survey.

The seasonal calving dummies are formulated on the basis of the birth month of the median calf. However, it is important to note that this data does not allow for the spread in calving season. For example, the median calf may be born in March but births may be recorded over 8 or 9 months of the year. The level of calving compaction is likely to be as important as the calving season. Research has shown that herds that operate a compact calving season tend to be more efficient and have lower costs of production (Veerkamp, 2001) Analysis was carried out to determine how

compact the calving season was on each farm. Figure 2 shows the distribution of the number of months with births recorded on all farms in the sample.

Figure 2. Calving Compaction on Irish dairy farms.



As can be seen compaction is relatively low, with only about 10% of the farms having a calving season of three months or less. Over 60% of the sample has a calving season of between four and six months. This wide spread shows a flaw in the use of the median calving month as a proxy for the seasonality of the individual dairy farms. A seasonal calving herd requires that a minimum of 90% of the cows calve during four consecutive months (Dillion et al, 1995)). The data was subsequently investigated in more details to determine groups according to their seasonality of calving.

Adding the total number of calves born in four consecutive months creates twelve new variables. For example, if a farm has 90 cows calved from January through April out of a total of 100 cows; this farm fits the definition of a seasonal herd. This is replicated in all remaining months, February through May, March through June etc. Following a similar methodology to earlier in this chapter, five different calving categories are chosen. These seasonal variables are named as follows; Early Spring

herds, Mid Spring herds, Late Spring herds, Summer herds and Autumn and Winter herds. Table 5 shows a breakdown of the variables.

Table 5. Breakdown of Seasonal Herds

Season	**Months included**
Early Spring	January - April
Mid-Spring	February - May
Late Spring	March - June
Summer	April- July, May-August & June - September
Autumn & Winter	July – October, August – November & September - December

Due to the low compaction of calving witnessed in figure 2, many farms do not fit the strict definition of a seasonal herd above. Hence, the categories in table 6 are further broken down according to the percentage of total calves born in that period. Full seasonality refers to those farms that have all of their total calves born in that season. High seasonality is defined as having greater than 90% of total calves born in that season. Due to the large numbers of farms that don't conform to the previous two categories, two extra categories are developed. Medium seasonality refers to those herds with 70% - 90% of total births in that season. Finally, the low seasonality category is defined as less than 70% of total births in a season. Table 7 shows the breakdown of these seasonal herds.

Table 6. Number of Farms in each Seasonal Herd.

Season	No. of farms in this Season	%
Full Compact Early Spring	578	8.81
High Compact Early Spring	1072	16.35
Medium Compact Early Spring	824	12.57
Low Early Compact Spring	471	7.19
Full Compact Mid - Spring	872	13.26
High Compact Mid - Spring	874	13.28
Medium Compact Mid - Spring	693	10.56
Low Compact Mid – Spring	288	4.39
Full Compact Late Spring	134	2.04
High Compact Late Spring	90	1.39
Medium Compact Late Spring	171	2.31
Low Compact Late Spring	102	1.55
Full Compact Summer	6	0.09
High Compact Summer	5	0.08
Medium Compact Summer	10	0.15
Low Compact Summer	36	0.55
Full Compact Autumn/Winter	2	0.03
High Compact Autumn/Winter	1	0.02
Medium Compact Autumn/Winter	15	0.23
Low Compact Autumn/Winter	315	4.81
Total	6559	100%

Table 6 above indicates the large number of farms that are Spring calving herds. Over 90% of the sample is categorized as a seasonal spring calving herd with the majority of this figure in early or mid-Spring. However, 5% of the sample is detailed as Autumn or Winter season herds which gives space for some analysis between seasons. Due to the fact that many of the late Spring, Summer and Autumn categories have small numbers of observations, they are combined together for the regression analysis. High and full Spring categories are also placed together in the regression to fit the definition of a seasonal calving herd as defined by Teagasc. Hence, Table 7

displays the final categories, as they are defined in the regression formulation. Some summary statistics are also shown as a means of a comparison between the categories.

Table 7. Summary Statistics for Final Seasonal Regression Variables

	Total Number 1994-2008	Weight 1994-2008	Total Cost 2006 cpl	Total Cost 2008 cpl	Farm size 2006 Ha	Farm size 2008 Ha	Yield 2006 litres	Yield 2008 litres
Full Compact Early Spring	1,650	108,224	19.75	24.71	50	48	5173	5074
Med Compact Early Spring	824	56,775	19.73	26.37	46	49	5197	4930
Low Compact Early Spring	471	26,967	22.28	27.92	63	69	5814	5476
Full Compact Mid-Spring	1,746	120,926	20.06	25.10	48	47	4909	4565
Med Compact Mid-Spring	693	47,232	21.02	26.20	58	53	4541	4423
Low Compact Mid-Spring	288	16,460	21.75	26.88	69	70	5559	5456
All Late Spring & Summer	554	44,926	24.01	29.85	36	33	4507	3551
All Autumn and Winter	333	17,790	23.13	28.24	65	75	6103	5965

Methodology

The following section details the methods applied to the data to determine differences in production costs according to calving season.

Model Estimators

A panel data set contains repeated observations over the same units (firms, individuals, households), collected over a number of periods (Verbeek, 2000). Basic estimators of panel data sets are the Pooled Ordinary Least Squares (OLS), the Fixed Effects Model (FE), the Between Effects model (BE) and the Random Effects model (RE). The pooled OLS estimators ignore the panel structure of the data and treat the

observations as being serially uncorrelated for a given individual, with homoskedastic errors across individuals and time periods (Johnston and DiNardo, 1997). In other words, the estimator does not recognise that the same individuals are sampled over time and therefore does not exploit the main advantage of panel data, that being the ability to explore the individual specific effect.

If we can assume that the errors have a mean of zero and are independent for different *i's*, (individuals in the sample), then we can use the pooled OLS method to fit this model. However, for repeated measures of the response on the same individual as in panel data, it is unlikely that the error is independent of unobserved effects *(u)*. Hence the use of OLS techniques to estimate panel data is subject to unobservable heterogeneity bias. This bias arises when the error term is correlated with any one (or more) of the independent variables across time. Furthermore, even if the error term is not correlated with any of the independent variables, its presence will in general yield inefficient estimates and invalid standard errors.

The fixed effects estimators however, control for all stable characteristics of an individual or farm, including those characteristics that are not observed or measured.(Stock and Watson, 2003) Examples of such unobserved effects are land quality and managerial ability. These estimators remove all those time invariant observations and express them as part of the error term.

The between effect regression may be used if you want to control for omitted variables that may change over time, but are constant between farms (Stock and Watson 2003). Examples of omitted variables are weather and price shocks, as they

affect all farms equally and may change in different times. Using the between effects results in a loss of information as is takes the mean of each variable across the panel set and runs the regression on the data set of means.

The random effects model may be employed if there is any reason to believe that there are some omitted variables that may be constant over time but vary between case and other variables that may be fixed between cases and vary over time. The random effects model is weighted average of the fixed and between effects models, (Stock and Watson, 2003).

In this analysis a pooled OLS model is run first and then FE, BE and RE models were specified. All four models are used as a way of comparison to ensure results are dependable. Due to the each model having different characteristics such as the FE model picking up all the individual effects and placing it in the error term and the BE model explaining time effects, it is imperative to document all results that are recorded.

Model Specification

Following the work of Colman and Zhuang (2003), a cost function is specified. Factors that are hypothesised to affect total production costs, such as herd size, efficiency per cow and stocking rate are included as explanatory variables in the model. Of interest for this analysis, a calving compaction variable which is included in the calving season dummies is also shown in the regression. It is normal in this type of analysis to include variables measuring all inputs.

The model in full is shown in equation 1:

Total cost of production per litre= f(Cows, Cows², Yield per cow, Yield per cow², Stocking rate, Stocking rate², Concentrate, Concentrate², Fully early-Spring, Medium early-Spring, low early-Spring, Fully mid-Spring, Medium mid-Spring, low mid-Spring, Late-Spring and Summer, Autumn and Winter. **1.**

Where,
Total Cost = Total costs/ total milk quantity
Cow= Herd size
Cows² = Herd size squared
Yield per cow = Yield per cow in litres
Yield per cow² = Yield per cow in litres squared
Stocking rate = Cows per dairy forage hectare
Stocking rate² = Cows per dairy forage hectare squared
Concentrate = Value of concentrates purchased per cow
Concentrate² = Value of concentrates purchased per cow
Fully early spring = Dummy variable for a fully compact early spring herds
Medium early spring = Dummy variable for a medium compact early spring herds
Low early spring = Dummy variable for a low compact early spring herds
Fully mid spring = Dummy variable for a fully compact mid spring herds
Medium mid spring = Dummy variable for a medium compact spring herds
Low mid spring = Dummy variable for a low compact mid spring herds
Late spring and summer = Dummy variable for all late spring and summer herds
Autumn & Winter = Dummy variable for all autumn and winter herds

The basic regression function solved with the pooled OLS estimator is as follows:

$$Y_i = \beta_0 + \beta_i X_i + u_i \ . \qquad \textbf{2.}$$

Following the estimation of the OLS model, the fixed effects panel data model is estimated in the following form:

$$Y_{it} = \beta_0 + \beta_i X_{it} + u_{it} \qquad \textbf{3.}$$

Where $u_{it} = (\mu_i + u_{it})$

i= 1, 2….N

t= 1, 2 …T

μ = individual effect

where Y_{it} is the independent variable and X_{it} is a vector of explanatory variables. This means that the effect of a change in X is the same for all units for all periods, but the average level for one farm may be different to another farm. Using a fixed effect model the results can capture the individual unobservable effect. Holding unobservable characteristics such as managerial ability and soil constant is desirable in this research as it allows the inclusion of variables that vary over time to determine if they affect the dependant variable.

The random effects panel data model is estimated in the following form:

$$Y_{it} = \beta_0 + \beta_i X_{it} + u_{it} \qquad \textbf{4.}$$

Where $u_{it} = (\mu_i + \lambda_t + u_{it})$

μ = individual effect

λ = Time effect

The random effects model is used if there are some omitted variables that may be constant over time but vary between case and other variables that may be fixed between cases and vary over time.

The between effects panel data model is estimated in the following form:

$$Y_{it} = \beta_0 + (\frac{1}{N} \beta_i X_{it}) + u_{it} \qquad \textbf{5.}$$

Where $u_{it} = (\lambda_t + u_{it})$

λ = Time effect

The between effects regression is used if you want to control for omitted variables that may change over time but are constant between farms.

A Hausman test (Hausman, 1978) was carried out to check whether the individual effects (u_i) are correlated with the regressors (X_{it}) so as to determine if the fixed effect model is reliable. It tests the consistency and efficiency of both the RE and FE models and establishes which has the superior statistical properties. Generally, the fixed effect model is determined to be more consistent and efficient when the Hausman test is performed. As the FE and RE models can measure different effects over time, the RE model sometimes may not be as statistically consistent, it provides a weighted regression of the BE and FE models. This is important as to illustrate which effects are important. Hence, all models are documented in the results section.

Results

The results of the full model combining all the variables in the pooled OLS regression are presented in table 8. Yield returns the expected result; negative and significant, but at a declining rate. This suggests that increasing the intensity of production reduces total costs but only up to a certain point. However, the expected economies of scale are not present due to the insignificance of herd size, suggesting that increasing herd size has no significant effect on the reduction total cost of production. Stocking rate and concentrates are shown to increase production costs but at a declining rate. Some of these results are different to previous studies using similar data that have cited the presence of economies of scale, Colman and Zhuang (2003) and Smyth et al (2009).

The pooled OLS regression results show that when herd size, yield, stocking rate and concentrate use are controlled for, the season of calving does have a significant effect

on total production costs. Using the high compact early Spring season as the reference group, the pooled OLS regression shows all seasons except medium compact mid Spring and high compact mid Spring are significantly more expensive than the reference group. The latter seasons show no significant difference to the reference group, however, medium mid-Spring is extremely close to significance at ninety percent.

Table 8. Pooled OLS Regression

Total cost per litre	Coefficient.	Std. Err.	t	P>|t|
Cows	.0000239	.0000489	0.49	0.625
$Cows^2$	1.15e-06	2.77e-07	4.15	0.000
Yield per cow	-.0000465	3.27e-06	-14.20	0.000
Yield per cow^2	3.03e-09	3.32e-10	9.11	0.000
Cow per for hec.	0310299	.0056377	5.50	0.000
Cow per for $hec.^2$	-.0055711	.0026089	-2.14	0.033
Con per cow.	0000542	1.70e-06	31.81	0.000
Con per cow^2	-3.88e-09	2.69e-10	-14.42	0.000
Med early spring	.0063978	.001627	3.93	0.000
Low early spring	.0159349	.0020636	7.72	0.000
High mid spring.	0004016	.0013212	0.30	0.761
Med mid spring	.0026366	.0017454	1.51	0.131
Low mid spring	.0112117	.0024657	4.55	0.000
Late spring/summer	.00636	.0019388	3.28	0.001
All autumn/winter	.0157555	0024047	6.55	0.000
Time 1	-.0661448	.002858	-23.14	0.000
Time 2	-.0539534	.002859	-18.87	0.000
Time 3	-.0517631	.0028538	-18.14	0.000
Time 4	-.0602639	.0027902	-21.60	0.000
Time 5	-.056795	.002771	-20.50	0.000
Time 6	-.0611901	.0027542	-22.22	0.000
Time 7	-.0510218	.0027216	-18.75	0.000
Time 8	-.0508534	.0026599	-19.12	0.000
Time 9	-.0520214	.0027426	-18.97	0.000
Time 10	-.0546765	.0027109	-20.17	0.000
Time 11	-.0447952	.0027393	-16.35	0.000
Time 12	-.0502625	.0027735	-18.12	0.000
Time 13	-.0481747	.0028054	-17.17	0.000
Time 14	-.0278202	.0028693	-9.70	0.000
Constant	.3363427	.0087894	38.27	0.000

As the use of OLS techniques to estimate panel data models is subject to unobservable heterogeneity bias, this bias may be yielding inefficient estimates and invalid standard errors. Hence the FE, BE and RE models are explored to determine if the results obtained above are consistent.

The results of the Hausman test are presented in Table 9. As the Chi² statistic is significant, it can be concluded that the FE model is the appropriate statistical model to use. However the RE and BE models are included as the fixed effect model can collect up all the unobserved characteristics and place them in the error term. Hence the results of the between and random effects models are noted.

Table 9. Hausman test

	(b) Fixed	(B) Random	(b-B) Difference
Cows	-.0016846	-.0004256	-.001259
Cow2	6.21e-06	2.75e-06	3.47e-06
Yield per cow	-.0000563	-.0000518	-4.52e-06
Yield per cow2	2.93e-09	3.11e-09	-1.79e-10
Cow per for hec	.0585599	.0501697	.0083903
Cow per for hec 2	-.0106823	-.0103989	-.0002834
Con per cow	.0000528	.0000543	-1.49e-06
Con per cow^2	-3.46e-09	-3.57e-09	1.02e-10
Med early spring	.0013554	.0028392	-.0014838
Low early spring	.003577	.0085956	-.0050185
High mid spring.	-.0005993	-.0005099	-.0000894
Med mid spring	-.0020063	-.0011783	-.000828
Low mid spring	.00218	.0056824	-.0035024
Late spring/summer	.0026422	.0039398	-.0012976
All autumn/winter	-.0018114	.0053451	-.0071565
	chi² = 8086.57		
	Prob>chi² = 0.0000		

The results of the model solved using FE are presented in Table 10. The FE model shows that all expected economies of scale are present, as when herd size increases the cost of production per unit decreases, but at a declining rate. Similarly, increased efficiency (yield per cow) reduces per unit costs but at a declining rate and increasing stocking rate initially increases costs but also at a declining rate.

The FE model suggests that low compact early spring and all late Spring/Summer demonstrate significantly higher costs than the reference group of high compact early spring herds. All other seasons illustrate no significant difference in total cost per litre to high compact early spring season. However, medium compact mid Spring herds are extremely close to having significantly lower costs than the reference season. These results suggest that some seasons which are traditionally thought to be more expensive to produce milk in are not significantly different to compact early Spring herds. However the FE model accounts for individual effects such as managerial ability and could prove that these individual effects are causing no significant difference between the seasons.

Table 10. Fixed Effect Regression

Total cost per litre	Coefficient.	Std. Err.	t	P>|t|
Cows	-.0016846	.0000984	17.13	0.000
$Cows^2$	6.21e-06	5.11e-07	12.15	0.000
Yield per cow	-.0000563	3.83e-06	-14.68	0.000
Yield per cow^2	2.93e-09	3.86e-10	7.58	0.000
Cow per for hec.	0585599	.0071252	8.22	0.000
Cow per for $hec.^2$	-.0106823	.0028859	-3.70	0.000
Con per cow.	.0000528	1.87e-06	28.14	0.000
Con per cow^2	-3.46e-09	2.05e-10	-16.90	0.000
Med early spring	.0013554	.0012462	1.09	0.277
Low early spring	.003577	.0019397	1.84	0.065

High mid spring.	-.0005993	0010499	-0.57	0.568
Med mid spring	-.0020063	.0013825	-1.45	0.147
Low mid spring	.00218	.0021722	1.00	0.316
Late spring/summer	.0026422	.00161	1.64	0.10
All autumn/winter	-.0018114	.0024781	-0.73	0.465
Time 1	-.083563	.0022961	-36.39	0.000
Time 2	-.071953	.0022153	-32.48	0.000
Time 3	-.0675598	.0021723	-31.10	0.000
Time 4	-.0747557	.0021106	-35.42	0.000
Time 5	-.0700596	.0020428	-34.30	0.000
Time 6	-.0718538	.0019872	-36.16	0.000
Time 7	-.0617936	.0019322	-31.98	0.000
Time 8	-.0576584	.0018778	-30.71	0.000
Time 9	-.0583934	.0018842	-30.99	0.000
Time 10	-.060218	.001856	-32.45	0.000
Time 11	-.0501975	.001854	-27.08	0.000
Time 12	-.0540704	.0018426	-29.34	0.000
Time 13	-.0507343	0018341	-27.66	0.000
Time 14	-.0287191	.0018522	-15.51	0.000
Constant	.4517301	.0110542	40.86	0.000

The results of the model solved using BE are presented in Table 11. The BE model shows that increased efficiency (yield per cow) reduces per unit costs but at a declining rate. However increasing stocking rate initially increases costs but again non-linearly. The expected economies of scale are not present due to the insignificance of herd size. This can be explained by the BE model averaging the independent variables in the regression. Concentrates are shown to increase production costs but at a declining rate. It suggests that there is no significant difference in total cost per litre on medium compact early Spring, high compact mid Spring, medium compact mid Spring and all late Spring/Summer herds compared to high compact early Spring season. The insignificance of late Spring and Summer in this result is very surprising as dairy farmers in this category are not matching peak production with the peak grazing season. Low compact early Spring, low compact mid Spring and all Autumn and Winter demonstrates that costs are significantly

higher than the reference group. These results are more in line with what is expected and show the value of higher calving compaction in the reduction of costs. Once again some of the coefficients return results that are close to significance, which must be noted.

Table 11. Between Effects Regression

Total cost per litre	Coefficient.	Std. Err.	t	P>|t|
Cows	.0001316	.0001096	1.20	0.230
$Cows^2$	.5.04e-07	6.50e-07	0.78	0.438
Yield per cow	-.0000587	6.88e-06	-8.53	0.000
Yield per cow^2	4.13e-09	7.24e-10	5.71	0.000
Cow per for hec..	.0292867	.0116278	2.52	0.012
Cow per for $hec.^2$	-.0072213	.0046572	-1.55	0.121
Con per cow.	.0000688	6.24e-06	11.03	0.000
Con per cow^2	-9.64e-09	2.24e-09	-4.30	0.000
Med early spring	.0068244	.0048949	1.39	0.164
Low early spring	.0149029	.0056896	2.62	0.009
High mid spring.	.0023584	.0039363	0.60	0.549
Med mid spring	.0048997	.0049752	0.98	0.325
Low mid spring	.0148792	.0068007	2.19	0.029
Late spring/summer	.0040362	.0053018	0.76	0.447
All autumn/winter	.016109	0063229	2.55	0.011
Time 1	-.0456265	.0127184	-3.59	0.000
Time 2	-.0163763	.0135686	-1.21	0.228
Time 3	-.0269335	.0132942	-2.03	0.043
Time 4	-.0301625	.0131748	-2.29	0.022
Time 5	-.0366465	.0134393	-2.73	0.006
Time 6	-.046851	.0137613	-3.40	0.001
Time 7	-.012247	.0140215	-0.87	0.383
Time 8	-.028584	.0131183	-2.18	0.030
Time 9	-.0469659	.0154918	-3.03	0.002
Time 10	-.0256105	.0140742	-1.82	0.069
Time 11	-.003464	.0177939	-0.19	0.846
Time 12	-.0386293	.017758	-2.18	0.030
Time 14	-.0104097	.0251823	-0.41	0.679
Time 15	.0173479	.0151278	1.15	0.252
Constant	.3321738	.0199615	16.64	0.000

The results of the model solved using RE are presented in Table 12. The RE model shows that all expected economies of scale are present, when herd size increases, the cost of production per unit decreases, but at a declining rate. Similarly, increased efficiency (yield per cow) reduces per unit costs but at a declining rate. Stocking rate and concentrates are shown to increase production costs but at a declining rate. Once again, using the high compact early Spring season as the reference group, it shows that all seasons except Medium compact mid Spring and high compact mid Spring are significantly more expensive than an early compact Spring herd. The results from the RE model mirror those of the OLS and most of the BE model.

Table 12 Random Effects Regression

Total cost per litre	Coefficient.	Std. Err.	t	P>|t|
Cows	-.0004256	.0000696	-6.12	0.000
$Cows^2$	2.75e-06	4.01e-07	6.85	0.000
Yield per cow	-.0000518	3.42e-06	-15.16	0.000
Yield per cow^2	3.11e-09	3.48e-10	8.94	0.000
Cow per for hec..	.0501697	.0062514	8.03	0.000
Cow per for $hec.^2$	-.0103989	.0025369	-4.10	0.000
Con per cow.	.0000543	1.74e-06	31.22	0.000
Con per cow^2	-3.57e-09	2.03e-10	-17.54	0.000
Med early spring	.0028392	.0012444	2.28	0.023
Low early spring	.0085956	.0018443	4.66	0.000
High mid spring.	-.0005099	.0010481	-0.49	0.627
Med mid spring	-.0011783	.0013707	-0.86	0.390
Low mid spring	.0056824	.0020933	2.71	0.007
Late spring/summer	.0039398	.0015794	2.49	0.013
All autumn/winter	.0053451	.0023323	2.29	0.022
Time 1	-.0440488	.0021179	-20.80	0.000
Time 2	-.0326866	.0020706	-15.79	0.000
Time 3	-.0299633	.002037	-14.71	0.000
Time 4	-.0374288	.0019685	-19.01	0.000
Time 5	-.0329207	.0019206	-17.14	0.000
Time 6	-.0358541	.0018775	-19.10	0.000
Time 7	-.0258261	.0018247	-14.15	0.000
Time 8	-.0234631	.0017723	-13.24	0.000
Time 9	-.0241185	.0018049	-13.36	0.000
Time 10	-.0271927	.0017746	-15.32	0.000

Time 11	-.017804	.0017802	-10.00	0.000
Time 12	-.022661	.0017858	-12.69	0.000
Time 13	-.0207576	.0017966	-11.55	0.000
Time 14	.028061	.0019049	14.73	0.000
Constant	.3420065	.0093201	36.70	0.000

Summary and Conclusion

Many studies have highlighted the economic advantages of spring calving in countries such as Ireland that have a long Spring/Summer grazing season. However, the widespread adoption of such a production system leads to a highly seasonal milk supply that causes processing capacity problems and resource utilization problems on farms. The objective of this analysis was to use historical data to quantify the economic benefits of a spring calving system. The results of this analysis conclude that certain calving seasons are more expensive to produce milk in, proving that shifting the seasonality of Irish milk supply won't be that easy.

Table 13. Summary of seasonal regression p- value results

	OLS	FE	BE	RE
Medium early spring	0.000***	0.277	0.164	0.023**
Low early spring	0.000***	0.065*	0.009***	0.000***
High mid spring	0.761	0.568	0.549	0.627
Medium mid spring	0.131	0.147	0.325	0.390
Low mid spring	0.000***	0.316	0.029**	0.007***
Late spring/summer	0.000***	0.10*	0.447	0.013**
All autumn/winter	0.000***	0.465	0.011**	0.022**

*** Significant at 99% ** Significant at 95% * Significant at 90%

Table 13 illustrates all results returned for each regression model. It clearly shows that there are different results returned depending on the model used. However, strong conclusions can be made from this analysis. Medium compact early Spring herds show significantly higher costs in two of the models and low p-values in the other

two, suggesting that this is a higher production season than a high compact early Spring herd. The results are fully conclusive on low compact early Spring herds that show significantly higher costs than the reference group in all four models.

High compact mid-Spring herd return no significant difference in costs across any of the models. This result proves that compact calving herds in early and mid Spring are quite similar. Medium compact mid Spring herd also show no significant difference to high compact early spring, but have low p-values in the OLS and FE models stating opposing conclusions.

Low compact mid Spring and late Spring and Summer herds demonstrate significantly higher costs than the reference group in three of the models and a positive coefficient sign in the other. This would suggest that these seasons are more expensive than high compact early Spring herds. Autumn and Winter herds imply a similar relationship but the FE model returned a negative coefficient, albeit a small insignificant one.

The late Spring, Summer, Autumn and Winter herds are mainly comprised of low compact calving herds and they demonstrate mainly higher production costs than high compact calving season. Couple this with both low compact Spring herds returning higher costs, it proves that that a high compaction calving season is vital in the reduction of production costs.

The results showed the effect of calving season on production costs is significant, using the FE, RE, BE and OLS. These models returned results suggesting that high compact early Spring herds have significantly lower costs than over seasons. However the FE model demonstrates little difference between production costs in different

seasons, individual effects such as the ability of the farmer may be a reason for result. Generally herds with high calving compaction in early Spring have lower production costs than those in other seasons. Allied with this information a change in the seasonal supply of milk may not be easy to achieve due to generally higher costs in other seasons apart from Spring calving herds.

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