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Costs of production of all year-round vs block calving herds in the UK

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ABSTRACT

The UK's climate and topography enables multiple different calving patterns to operate within the same market, facilitated by industry infrastructure that allows for a variety of milk purchasing arrangements. All year round (AYR) calving is most common, and with current labor challenges spring block (SB), autumn block (AB) and twin block (TB) calving systems could potentially become more popular, but research comparing the efficiency of AYR with block calving systems operating within the same market conditions is limited. This study compared the costs of production of AYR against 3 block calving systems on a pence per energy corrected milk liter (PPL), to assist benchmarking activities, costs and management decisions. Farm accounts data (from 2017 to 2020), from 604 farms broadly representing the national split of calving patterns in the UK, were included in a linear mixed effects (LME) model used for inference with maximum likelihood estimation. Random effects included year and farm, with fixed effects including herd size (cows), farm size (hectares) and average annual milk yield per cow that were each standardized to enable all calving patterns to be compared at the same scale (i.e., same herd size, farm size and milk yield). Calving pattern was self-determined by the farmer under guidance from a trained data collector. Cost of production variables investigated included milk price, stock sales (calves, cull cows, breeding animals), total income (all dairy farm revenues), total purchased feed, purchased forage, variable costs, gross margin, labor, overhead costs and net profit. Autumn block herds had lower total income, lower forage purchases, higher labor and lower net profit compared with AYR. Spring block herds had higher total income, higher forage purchases, lower labor and lower overhead costs compared with AYR. There were no differences between TB and AYR herds. Using the LME model, the impact of changing the fixed effects on costs of production were estimated, based on a 1 Standard Deviation (SD) change. Increasing herd size (1 SD, 345 cows) was associated with a reduction in net profit of AB herds by 3.34 PPL but an increase in net profit for SB herds by 5.57 PPL compared with AYR. Increasing farm size (1 SD, 164 ha), all 3 block calving herds had different associations compared with AYR; net profits would be increased for AB and TB herds (by 1.33 and 2.12 PPL, respectively) while SB herds would have reduced net profit by 4.26 PPL. Increasing energy corrected milk yield (1 SD, 4,038 L) would only benefit the net profit of SB herds over AYR by 6.04 PPL as SB herds had the lowest milk yield per cow. The results demonstrated that increasing land, cows or milk yield per cow was associated with different responses in cost of production depending on calving pattern. Findings from this study could be used by extension services, farm advisers and farmers for benchmarking purposes and when considering farm-scale decisions or switching from an AYR to block calving pattern.
Key words: All year round calving, Seasonal calving, Costs of production, Linear Mixed Effects

INTRODUCTION

The UK dairy industry is unique in its ability to support seasonal and all-year-round calving patterns due to its climate, topography and infrastructure. According to the UK's Agriculture and Horticulture Development Board (**AHDB**), 72% of UK herds operate all year-round calving, 8% spring calving, 9% autumn calving and 11% operate both spring and autumn block calving (AHDB, 2021). Recent figures suggest an increase in herds operating a block calving pattern, with larger herds continuing to operate all year round (**AYR**) calving (AHDB, 2025). Larger herds may not have the resources to manage effectively during peaks of production that are inevitable in a seasonal or block calving pattern, raising uncertainty over whether AYR and block calving herds can function at the same operating and economic efficiency scale.

The objective of dairy herds that only calve cows in a short timescale is to capitalize on matching peak

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feed requirements with peak grass growth in the spring months (Garcia and Holmes, 1999; Ramsbottom et al., 2015; Deming et al., 2019) to reduce the need for supplementary feed, unlike herds that calve AYR that use supplementary feed to meet production shortfalls not met by forage alone (March et al., 2014). A significant difference between the lactation curves of autumn block (**AB**) and spring block (**SB**) calving cows has been reported; autumn calving cows have lower peaks but more persistency, along with a second peak milk yield the following spring due to greater availability and quality of pasture (Garcia and Holmes, 1999). However, pasture quality varies significantly due to variable weather conditions, which could lead to vast swings in milk yield and use of purchased feed from year to year in pasture-reliant systems such as SB.

Calving pattern is intrinsically linked with components of pasture-based systems such as stocking rate, fertility and feed supplementation strategies, therefore its effects cannot be isolated (Garcia and Holmes, 1999). Consequently, many studies have looked at the differences between confined (housed year-round) and grazing herds (Knaus, 2016; Shortall, 2019; Gargiulo et al., 2020). Studies comparing the financial performance of different calving patterns within the same marketplace are limited and seasonal calving patterns are often confounded by pasture use or supplementary feeding investigations. For example, Ramsbottom et al., (2015) investigated factors affecting profitability in spring calving herds in Ireland, Hanrahan et al., (2018) also compared pasture use and profitability among spring calving herds in Ireland, and Ma et al., (2018) looked at profitability of low, medium and high intensity dairy systems in New Zealand.

In contrast, many AYR calving herds will graze, but their objective is not to manipulate their lactation curve to match grass growth, therefore, less seasonal production results in greater reliance on non-forage feeds and higher input costs (Geary et al., 2014). A survey of British dairy farmers in 2012 found that grazing all cows during the summer was no longer the predominant system and that the number of herds not grazing at any point during the year had increased (March et al., 2014), suggesting AYR calving herds were becoming more intensive. High genetic merit cows can demand energy over 5 times their maintenance requirement, which cannot be met by grazing alone (March et al., 2014). By moving away from a pasture-reliant production system, herds can produce greater milk yields, leading to greater profit potential notwithstanding management decisions to control input costs.

The differing inputs and outputs of each calving pattern and the associated production system requirements define a separate set of key performance indicators (**KPI**) to benchmark the performance of dairy production systems operating in the same market. Thus, assessing the effect of management decisions on a herd's performance is difficult when comparing figures at face-value. Comparing businesses of different scales in benchmarking is also an issue, leading to incorrect and misinformed decisions made by farmers and farm managers.

This study compared costs of production for AYR against the 3 block calving systems using liters of ECM i.e., income and expenditure categories were divided by ECM liters to achieve the desired KPI for investigation. Pence per liter ECM is a common calculation to report a farm's cost of production profiles in the UK with nationally available benchmarks published by the UK Government and AHDB. The objective was to provide empirical evidence on the economic profiles of different calving patterns operating within the same marketplace in the UK. The aim was to enhance and improve benchmarking methods between and across herds with different calving patterns by removing the effects of business scale. We hypothesized that block calving herds would have lower feed expenditure and higher profitability than AYR, and that larger herd/farm size would lower expenditure, although increased yields would raise expenditure. Olagunju et al., (2022) found that herd size, stocking density, milk yield and share of hired labor all had a positive impact on dairy farm total productivity.

MATERIALS AND METHODS

Data Collection

Commercial farm data totaling 1062 financial records from 604 farms across the UK was collected by independent data collectors using audited financial accounts and farm information (Kite Consulting, Dunston, UK). Financial information data sets spanned 4 years (2017–2020), with financial year ends ranging from 30th September to 31st July for each production year. The panel data set was unbalanced, since not all farms were present every year. In mixed farming enterprises where any costs could not be directly attributed to the dairy farm business then costs were allocated as per the proportion of the farm's gross revenue attributed to the dairy enterprise, using the same methodology that Ramsbottom et al., (2015) used to attribute overhead costs. For example, if 80% of total revenue was attributed to the dairy business, then 80% of costs for paid labor was attributed to the dairy enterprise.

Farmers were allowed to self-assess their calving pattern into one of 4 options: AYR, SB, AB or twin block (**TB**). Farmers calving a proportion of their herd in distinct blocks in both autumn and springtime are referred to as 'twin block' calving herds in the UK. Calving pattern classification was agreed under the guidance of independent data collectors, who verified the categoriza-

Table 1. Descriptions of dependent variables used for the comparison of all year round calving to seasonal calving patterns in the Linear Mixed Effects models

Dependent variable[1]	Description
Milk price	*Revenue generated from milk sales. Inclusive of bonuses, penalties and seasonality.*
Stock sales	*Revenue generated from sales of cull cows, breeding stock and calf sales. Will include any transfers of animals into a beef enterprise at market value.*
Total income	*Includes all revenue from milk sales, stock sales, agri-environmental schemes, government subsidies and a herd valuation change adjustment. Herd valuation change was calculated using standardized values for all livestock types.*
Feed	*All purchased feed for the adult dairy herd, not including any purchased or homegrown forages.*
Forage purchases	*Any forage purchased. Includes any straw used for feed only.*
Total variable costs	*Includes purchased feed, health and fertility and forage and crop costs along with any youngstock rearing costs, purchased livestock, purchased forage and bedding, recording and registration of livestock.*
Gross margin	*Total income minus total variable costs.*
Labor costs	*Labor costs included all regular and contract labor, including seasonal labor, and any non-family director's remuneration but did not include any drawings for family labor.*
Total overhead costs	*Paid labor including any contracting hire and costs, machinery repairs and depreciation, property repairs and depreciation, dairy repairs, fuel, electricity, water, council tax, insurance, professional fees, finance costs (not including capital repayments), land rent (actual rental expenditure not imputed values) and office costs.*
Net profit	*Total income minus total variable costs and total overhead costs.*

[1]Not all dependent variables analyzed in the linear mixed effects models are presented but can be found in the supplementary materials (Hicks, 2025).

tion using the monthly milk deliveries to check peaks and troughs in milk sold as a proxy for calving pattern. To minimize the possibility of bias due to farmer self-classification of calving pattern, the data collectors also asked questions about the farm's fertility practices to establish the service and calving windows, including 6 week calving rate KPI to establish the compact nature of a block calving system. The liters sold and average milk quality data were taken from their milk purchaser statements for the 12-mo period. This was converted to ECM at 4% fat and 3.3% protein (Hagemann et al., 2011). All cost of production categories were run as dependent variables separately and the results can be found in the supplementary material (Hicks, 2025). A selected set of dependent variables from the 26 cost of production categories will be discussed in this paper, chosen for their relevance to farm benchmarking. Dependent variables include: milk price, stock sales, total income, feed costs, forage costs, total variable costs, gross margin, labor costs, total overhead costs and net profit. A description of each can be found in Table 1.

Data analysis

A linear mixed effects (**LME**) model was built using lme4 package (version 1.1–26; Bates et al.., 2015) in R for inference with maximum likelihood estimation to uncover any differences between calving pattern and the relationship of fixed effects and their interactions on the dependent variables. With multiple data points per farm and multiple years of data, the LME model was considered as the best approach to account for non-independence of the data.

Fixed effects included average dairy herd size (cows), annual cow yield (ECM liters) and farm size (hectares). Relationships between fixed effects and the dependent variable were assessed by scatter plots as it is understood that while a LME model was chosen for this study, nonlinear relationships can exist when the transformation of inputs into outputs occurs via a biological process such as milk synthesis. Average dairy herd size was calculated using the average between the farm's opening and closing stock numbers or from their milk recording organization figure where the figure did not closely resemble the average herd size for the 12-mo period (in situations where herd expansion or shrinkage occurred for example). Dairy farm size included all land, owned or rented, that was attributed to the dairy herd for grazing and growing forage crops. It did not include arable land used to grow grain crops that were subsequently fed to the dairy herd; this was accounted for as feed transferred at a standard cost for all businesses and reflected market values at the time. Multicollinearity between fixed effects was assessed using the Variance Inflation Factor (**VIF**) and no issues were detected (VIF < 2).

To avoid specification errors and influence on parameter estimates, we tested for outliers. Dependent variables with values more than 3 times the interquartile range below the first quartile or above the third quartile were considered extreme outliers using the *is.extreme* function from *rstatix* package in *R* (version 0.7.0; Kassambara, 2021) and removed from the data set. Records removed from each LME model ranged from 1 to 29 records.

A random, farm and year, effect was included to account for the non-independence of measurements and unbalanced data set. It would have been possible to use year as both a fixed and random variable, however, as specific years were not of interest, it was only included as a random variable. The LME model compared AYR to

Table 2. Numbers of farm observations included for the comparison of all year round calving with different seasonal block calving patterns by year and calving pattern

Year	2017	2018	2019	2020	Total	%
All year round	94	249	300	210	853	80.3
Autumn Block	4	47	54	10	115	10.8
Spring Block	0	14	22	2	38	3.6
Twin Block	3	18	22	13	56	5.3
Total	101	328	398	235	1062	100

SB, AB and TB systems; differences between the 3 block calving patterns were not investigated.

All fixed effects were standardized (mean-centered and scaled by standard deviation) to account for differences in measurement units and improve model convergence (i.e., milk yield at 10,000 vs herd size of 250). Standardization of variables removes correlations between main effects and their interactions (Harrison et al., 2018). Normality of continuous variables were visually assessed using Q-Q plots. Linearity and homoscedasticity were visually assessed by plotting residuals against fitted values.

RESULTS

The number of observations by year and calving pattern are shown in Table 2 and the descriptive statistics for the fixed effects in Table 3. Descriptive statistics for the dependent variables used in the LME analysis are shown in Table 4 by calving pattern.

The starting point to compute any differences was the intercept value from the LME models (Tables 5 and 6), which in this case was the mean price expressed in ppl for AYR herds at the mean herd size, farm size and yield levels, as shown in Table 3. To calculate the predicted difference between AYR and a block calving herd, the estimate (parameter) needed to be added or subtracted from the intercept. For example, the mean milk price for AYR was 27.91 PPL (intercept) and the AB result was – 0.64 PPL (estimate), therefore the AB mean milk price was 27.27 PPL (Table 5).

The impact of one of the fixed effects (herd size, farm size, yield) were calculated similarly. Due to standardization of fixed effects, the estimates for herd size, farm size and yield in the LME models represented a 1 unit change in standard deviation (**SD**) from the mean (intercept). Thus, a 1 SD increase in herd size was associated with milk price for AYR herds as follows: 27.91 (intercept) + 0.42 PPL (estimate) = 28.33 PPL, whereas a 1 SD decrease would be 27.49 PPL.

Interaction effects between calving pattern and fixed effects were also calculated using AYR (intercept) as the starting value. To simplify the calculation, fixed effects on AYR herds should be calculated first, before combining estimates for a different block calving system (2 stage process). For example, to calculate how increasing herd size for AB herds was associated with milk price

Table 3. Descriptive statistics for all year round calving herds and block calving patterns for each fixed effect used in the Linear Mixed Effects models

	Mean	Median	SD	SEM
All year round:				
Herd size (cows)	353	232	374	2.51
Dairy farm size (ha)	198	152	168	1.13
Yield (liters ECM per cow/year)	9155	9223	1617	10.88
Autumn block:				
Herd size (cows)	239	214	119	2.18
Dairy farm size (ha)	193	142	167	3.07
Yield (liters ECM per cow/year)	7947	7931	1392	25.55
Spring block:				
Herd size (cows)	245	233	95	3.04
Dairy farm size (ha)	149	138	68	2.18
Yield (liters ECM per cow/year)	5820	5908	885	28.32
Twin block:				
Herd size (cows)	336	264	259	6.80
Dairy farm size (ha)	192	156	138	3.63
Yield (liters ECM per cow/year)	7378	7244	1617	42.50
All calving patterns:				
Herd size (cows)	336	232	345	2.08
Dairy farm size (ha)	195	149	164	0.99
Yield (liters ECM per cow/year)	8992	8890	4038	24.32

Table 4. Descriptive statistics for each calving pattern for the dependent variables used in the Linear Mixed Effects models

Dependent Variable (PPL)[2]	AYR[1] Mean	AYR[1] SD	AB[1] Mean	AB[1] SD	SB[1] Mean	SB[1] SD	TB[1] Mean	TB[1] SD
Milk Price	28.84	2.51	29.57	2.23	28.96	1.69	28.34	2.87
Stock Sales	3.04	1.19	3.49	1.13	3.38	1.51	3.19	1.15
Total Income	34.36	3.30	35.78	3.22	35.50	2.74	34.48	3.28
Feed	9.09	1.97	7.41	2.08	4.50	1.43	6.55	2.40
Forage Purchases	0.35	0.57	0.55	0.72	0.89	0.81	0.56	0.72
Total Variable Costs	16.76	2.90	14.98	3.24	12.79	3.38	13.71	2.89
Gross Margin	17.56	3.57	20.79	4.08	22.72	4.36	20.77	3.97
Labor Costs	2.73	1.60	2.93	1.71	2.76	1.93	3.01	1.54
Total Overheads	13.29	2.80	14.22	3.12	14.10	3.05	14.66	2.71
Net Profit	4.22	3.90	6.56	4.39	8.62	5.62	5.87	4.22

[1]AYR = All Year Round, AB = Autumn Block, SB = Spring Block, TB = Twin Block.

[2]PPL = Pence Per Energy Corrected Milk Liter.

compared with AYR, the first step was to calculate the impact of increasing herd size for AYR herds (27.91 + 0.42 PPL = 28.33 PPL; Stage 1). The second step in the calculation included the AB estimate plus the interaction term; 28.33 (Stage 1) – 0.64 (estimate for AB) - 0.86 PPL (interaction estimate) = 26.83 PPL (Stage 2). This example can be seen in Table 7.

The average milk price for AYR herds was 27.91 PPL and there were no differences ($P > 0.05$) compared with block calving systems, (Table 5). None of the fixed effects were associated with milk price ($P > 0.05$). Stock sales averaged 3.13 PPL for AYR and no differences were seen compared with block calving systems, nor for any of the fixed effects ($P > 0.05$). However, there were interaction effects for stock sales, with an increase in farm size associated with a decrease in milk price for TB farms (−0.74 PPL; $P = 0.007$) but an increase for SB farms (1.26 PPL; $P = 0.015$).

Differences were seen between block calving herds and the AYR mean of 32.78 PPL for total income; AB herds were lower ($P = 0.001$) but SB herds were higher ($P = 0.025$; Table 5). The fixed effect of herd size was not significant for AYR total income, but there was an interaction for total income in block calving herds; increasing herd size was associated with a decrease ($P = 0.001$) in milk price for AB herds, but an increase ($P = 0.013$) for SB herds. Changing farm size and yield was associated with total income PPL estimate of 1.06 ($P = 0.014$) and −1.80 ($P = 0.004$) respectively for AYR herds. An interaction effect meant that increased farm size for AB herds was associated with higher ($P = 0.022$) total income, whereas for SB herds it was associated with lower ($P = 0.011$) total income (Table 5).

AYR herds averaged 7.47 PPL on feed purchases (Table 5). Increasing yield was associated with higher ($P < 0.001$) feed costs for all but TB herds, where increasing yield was associated with lower ($P = 0.027$) costs. Compared with AYR, AB and SB herds had different associations with purchased forage costs, with AB having lower ($P = 0.003$) and SB having higher ($P = 0.015$) costs. Increasing farm size was associated with reduced ($P = 0.004$) purchased forage costs for AYR, but this differed for SB and TB herds. For SB herds, increasing farm size was associated with an increase ($P = 0.007$) in forage purchases, whereas for TB herds forage purchases would decrease ($P = 0.025$). Increasing yield followed a similar pattern to that of increasing farm size, in that it was also associated with lower ($P < 0.001$) forage purchases. Again, there were differences in how increasing yield affected forage purchases for AB and SB; in AB herds increasing yield was associated with lower forage purchases, whereas in SB herds this was higher ($P = 0.001$ for both; Table 5).

Average variable costs were 14.33 PPL for AYR herds (Table 6). Fixed effects had no impact ($P > 0.05$) on variable costs, but there was an interaction effect ($P = 0.022$), where increasing farm size was associated with a decrease in variable costs for TB herds. Farm size positively influenced gross margin ($P = 0.004$) while yield had a negative association ($P < 0.001$). Herd size showed no direct association with gross margin ($P > 0.05$) but a negative interaction for AB ($P = 0.009$) and positive interaction for SB ($P = 0.032$) was witnessed. All block calving herds had interactions for farm size, with AB ($P = 0.018$) and TB ($P = 0.002$) showing positive associations but SB negative ($P = 0.001$) with gross margin.

AYR herds spent an average of 3.75 PPL on paid labor, with AB herds higher ($P = 0.037$) and SB lower ($P = 0.005$). Both herd size and yield increased paid labor costs. Total overhead costs were 14.84 PPL for AYR and SB herds were lower ($P = 0.023$). Yield impacted overhead costs differently for block calving herds; AB had a positive association ($P = 0.002$) and SB were negatively associated ($P = 0.012$).

Mean net profit for AYR herds was 3.68 PPL and AB farms were lower ($P = 0.006$). Yield was associated with

Table 5. Results from the Linear Mixed Effects model for milk price, stock sales, total income, feed and forage purchases (all in PPL) comparing all year round calving with different seasonal block calving patterns

Item	Milk Price		Stock Sales		Total Income		Feed		Forage Purchases	
	Estimate	*P* Value	Estimate	*P* Value	Estimate	*P* Value	Estimate	*P* Value	Estimate	*P* Value
(Intercept) [1]	27.91	<0.001	3.13	<0.001	32.78	<0.001	7.47	<0.001	0.15	0.184
Block calving effects:										
AB[2]	−0.64	0.057	−0.46	0.081	−1.85	0.001	−0.07	0.865	−0.38	0.003
SB[2]	0.25	0.751	0.14	0.822	2.86	0.025	1.52	0.117	0.76	0.015
TB[2]	0.36	0.307	0.25	0.357	−0.26	0.652	−0.05	0.910	−0.21	0.122
Fixed effects:										
Herd Size	0.42	0.284	0.27	0.372	−1.09	0.089	−0.24	0.605	0.26	0.078
Farm Size	0.02	0.937	−0.29	0.135	1.06	0.014	0.13	0.635	−0.27	0.004
Yield	0.42	0.268	−0.26	0.391	−1.80	0.004	1.96	<0.001	−0.55	<0.001
Block calving x fixed effect interactions:										
AB × Herd Size	−0.86	0.117	−0.31	0.457	−2.90	0.001	0.38	0.557	0.30	0.141
SB × Herd Size	0.79	0.452	−0.67	0.412	4.24	0.013	0.50	0.698	−0.31	0.427
TB × Herd Size	−0.03	0.948	0.46	0.242	−0.67	0.447	−0.02	0.973	−0.09	0.623
AB × Farm Size	0.14	0.632	−0.16	0.450	1.08	0.022	0.14	0.630	−0.13	0.197
SB × Farm Size	−0.66	0.339	1.26	0.015	−2.90	0.011	−0.27	0.720	0.70	0.007
TB × Farm Size	0.55	0.164	−0.74	0.007	1.22	0.075	−0.18	0.625	−0.31	0.025
AB × Yield	0.49	0.331	0.06	0.875	−0.26	0.756	0.09	0.879	−0.64	0.001
SB × Yield	0.07	0.942	−0.04	0.964	3.19	0.051	−0.53	0.664	1.34	0.001
TB × Yield	−0.87	0.112	0.23	0.586	−1.25	0.163	−1.41	0.027	−0.13	0.519

[1]The intercept value represents All Year Round (AYR) calving herds.

[2]AB = Autumn Block, SB = Spring Block, TB = Twin Block.

Table 6. Results from the Linear Mixed Effects model for variables costs, gross margin, paid labor, overhead costs and net profit (all in PPL) comparing all year round calving with different seasonal block calving patterns

	Variable Costs		Gross Margin		Paid Labor		Overhead Costs		Net Profit	
Item	Estimate	*P* Value	Estimate	*P* Value	Estimate	*P* Value	Estimate	*P* Value	Estimate	*P* Value
(Intercept) [1]	14.33	<0.001	18.43	<0.001	3.75	<0.001	14.84	<0.001	3.68	<0.001
Block calving effect:										
AB[2]	−0.89	0.144	−1.10	0.122	0.64	0.037	1.13	0.064	−2.38	0.006
SB[2]	2.80	0.051	−0.10	0.953	−2.11	0.005	−3.29	0.023	3.18	0.122
TB[2]	0.18	0.777	−0.14	0.851	0.39	0.208	0.62	0.327	−0.74	0.415
Fixed effects:										
Herd Size	0.43	0.545	−1.30	0.114	1.26	<0.001	0.24	0.737	−1.23	0.224
Farm Size	−0.60	0.163	1.48	0.004	−0.14	0.424	0.31	0.440	0.80	0.188
Yield	1.14	0.098	−2.99	<0.001	0.83	0.019	0.39	0.570	−3.02	0.002
Block calving x fixed effect interactions:										
AB × Herd Size	0.39	0.695	−3.01	0.009	0.11	0.808	−0.07	0.943	−3.34	0.017
SB × Herd Size	−1.09	0.566	4.77	0.032	−0.92	0.320	−0.93	0.624	5.57	0.042
TB × Herd Size	1.08	0.228	−1.72	0.105	0.02	0.968	0.08	0.925	−1.46	0.252
AB × Farm Size	−0.24	0.600	1.31	0.018	−0.20	0.273	−0.32	0.462	1.33	0.041
SB × Farm Size	2.03	0.084	−4.47	0.001	0.20	0.680	0.33	0.767	−4.26	0.010
TB × Farm Size	−1.38	0.022	2.30	0.002	0.22	0.315	0.23	0.671	2.12	0.011
AB × Yield	−1.26	0.163	0.56	0.597	0.93	0.033	2.87	0.002	−1.59	0.219
SB × Yield	1.62	0.373	1.39	0.513	−2.61	0.006	−4.63	0.012	6.04	0.021
TB × Yield	−1.41	0.144	0.88	0.436	0.88	0.057	1.30	0.189	−1.47	0.284

[1]The intercept value represents All Year Round (AYR) calving herds operating a conventional system.

[2]AB = Autumn Block, SB = Spring Block, TB = Twin Block.

Table 7. Calculation of the relationship between individual coefficient estimates from a Linear Mixed Effects model; an example for milk price

		Fixed Effects		
Calving pattern	Mean[1]	Herd size[2]	Farm size[2]	Yield[2]
AYR[3]	27.91	27.91 + 0.42	27.91 + 0.02	27.91 + 0.42
AB[3]	27.91 - 0.64	27.91 + 0.42 – 0.64 – 0.86[4]	27.91 + 0.02 – 0.64 + 0.14[4]	27.91 + 0.42 −0.64 + 0.49[4]
SB[3]	27.91 + 0.25	27.91 + 0.42 + 0.25 + 0.79[4]	27.91 + 0.02 + 0.25 – 0.66[4]	27.91 + 0.42 + 0.25 + 0.07[4]
TB[3]	27.91 + 0.36	27.91 + 0.42 + 0.36 – 0.03[4]	27.91 + 0.02 + 0.36 + 0.55[4]	27.91 + 0.42 + 0.36 – 0.87[4]

[1]The pence per liter estimates at mean values for herd size, farm size and yield.

[2]The pence per liter estimates for a 1 unit change in standard deviation

[3]AYR = All Year Round, AB = Autumn Block, SB = Spring Block, TB = Twin Block

[4]The last value represents the interaction term

NB. No interpretation of *P* values has occurred to demonstrate this example.

lower net profit (P = 0.002) for AYR. Herd size was associated with lower (P = 0.017) net profit for AB herds and higher net profit for SB herds (P = 0.042). Farm size influenced net profit across all block calving patterns; AB herds were higher (P = 0.041), SB herds lower (P = 0.010) and TB herds higher (P = 0.011) compared with AYR. Yield was positively associated with net profit for SB herds (P = 0.021) only.

DISCUSSION

The focus of this study was to understand if differences exist between the costs of production on a PPL basis for AYR and 3 block calving patterns: AB, SB and TB. A secondary objective was to understand how changing herd size, farm size and yield were associated with each of the dependent variables and if this differed between AYR and block calving patterns. The representation of observations per calving pattern were similar to those reported by AHDB (2021); AYR herds were over-represented by 8%, SB herds under-represented by 4% and TB herds underrepresented by 6% (Table 2). Although the data set was considered representative of the UK dairy industry in terms of calving pattern representation, the statistical power of the results is questioned due to the large number of AYR herds. The choice of calving pattern a dairy herd operates will not only impact their costs of production; non-economic factors such as having a structure, time for family and support from advisors have also been reported by spring calving herds in Ireland (Mulkerrins et al., 2022).

The mean milk price PPL was higher than that reported by Wilson (2011) demonstrating the change in the UK milk market, which will have included changes in milk purchasing since the abolishment of milk quotas in 2015 and trading consequences from BREXIT. Ramsbottom et al., (2021) also reported increased costs and farm output over the period 2010 to 2018 in Irish seasonal calving herds . The current data set included farms with and without seasonally adjusted milk prices; a practice typically employed by milk purchasers to encourage a more balanced milk supply throughout the year (Keane, 1981; Sun et al., 1995). Therefore, it's unsurprising that no differences were found between AYR and block calving systems, suggesting that block calving herds can generate similar annual milk prices to AYR systems despite fluctuations in monthly milk volume sold, and there is no advantage for one calving pattern over the other within the UK. Farmers do have a small amount of control in the milk price they receive because their management decisions affect milk quality (Wilson, 2011), but UK milk prices are largely dictated by milk purchasers.

In contrast with Wilson (2011), who reported a clear trend between larger herds achieving higher milk prices and higher yields, this study found no association between herd size or yield with milk price. Previous research has also found that smaller farms have a price advantage over larger farms, but it is the lower costs of production achieved by larger farms that drives increased herd size (Macdonald et al., 2007).

Other than revenue from milk and stock sales, total income also includes any agri-environment scheme payments, government subsidies and a herd valuation change. Herd valuation change allows for any annual differences in carry-over stock to be accounted for where the costs (or sales) are included but the sales (or purchases costs) are not. For example, a herd might have a large carry-over of forage stocks and therefore the costs will be included in the accounting year, but they have yet to be used. To this end, the differences in total income witnessed are most likely from agri-environmental scheme and subsidy income. This is further supported by the fact that increasing farm size would also increase total income. Since decoupling farm subsidy payments from production in the early 2000s toward payments per farm (Tranter et al., 2007), this relationship is not surprising. However, SB herds differed with a reduction in total income when increasing farm size, unlike AB and TB herds which were deemed no different to AYR. As SB herds rely upon synchronizing forage supply with demand to minimize use of costly supplementary feeds (Kelly et al., 2020), it is possible that environmental schemes encouraging taking land out of production are unsuitable for SB herds and hence a reduction in farm income. Evidence shows significant variations in subsidy effects. For UK dairy farms, Harkness et al., (2021) found that agri-environment payments can reduce income variability by 4–8%, while direct subsidies may actually decrease income stability by 6–35%. In Ireland, Maria Martinez Cillero and Reaños (2022) identified a positive relationship between technical efficiency and environmental payments for dairy farms, particularly with newer schemes like the Green, Low-Carbon, Agri-Environment Scheme. However, Latruffe et al., (2017) cautioned that subsidy effects can be positive, neutral, or negative depending on the specific country context. The impact is not uniform, suggesting careful, localized assessment is crucial for understanding subsidy influences on dairy farm income.

No difference in feed costs between calving patterns was an unexpected observation. It is generally accepted that block calving herds attempt to minimize use of supplementary feeds by matching their lactation curve with seasonal grass growth (Dillon et al., 1995), although Garcia and Holmes (1999) found autumn calving herds required more concentrate feed compared with spring calving systems. Differences in quantities of concentrates fed across calving patterns would have different total costs but the additional yield generated from supplementary feeding may diminish any differences on a PPL basis, as used in this study. Indeed, lower concentrate and higher forage ratios in diets leads to lower milk production from lower energy dense diets (Yang et al., 2001). This can also explain how increasing yields increased purchased feed costs in this analysis.

The current study included purchased forage costs separately from feed costs, as reliance on forage is a key differentiator between block calving systems. Lack of differences in feed costs may be explained by differences witnessed in purchased forage costs, as certain block systems could choose to purchase forage instead of concentrates to fulfil any feed shortages. Despite milk potential from 1kg of concentrates being greater than 1kg of forage, the cost per ton is vastly different, and therefore purchased feed poses a higher cash cost to a business. Prices for 1 ton of 18% crude protein compound were £195 for delivery in May to October 2018 (prices agreed July 2017, Redman, 2017) in comparison to ensiled forage using a formula of between £1 and £1.20 depending on input costs (fluctuations in fuel cost being the main driver) per 1% of Dry Matter (DM) i.e., £40 for 1 ton of 35% DM silage (valuation formula commonly used in the field). The higher cash outlay for purchasing concentrate feed may not be viable for some businesses, particularly if they have high financial borrowings or poor credit facilities already pressuring monthly cash flow. It is logical that increasing farm size would reduce purchased forage costs, as the extra land could be used to grow additional forage that would otherwise be purchased. However, this was not true for SB herds, as increasing farm size was also associated with increased purchased forage costs. SB herds also showed an association with increases in purchased forage costs with increasing yield. From these 2 observations, it is possible that SB herds are purchasing higher quality forage than they can produce in-house.

The current study supports Deming et al. (2018) in finding that differences in labor requirements were expected between AYR and block calving herds because of uneven labor requirements across seasonal calving patterns. Potentially, the uneven labor demand in seasonal calving herds as per Deming et al., (2018) may be at odds with peak labor requirements to the disadvantage of AB herds. This study did not include the quantity of labor inputs, only costs. However, judging labor purely on cost could be considered a blunt indicator; labor costs reveal nothing about the working conditions, worker happiness or value to the business that employed labor brings. Kolstrup (2012) reported that prospective and current dairy farmworkers were primarily driven by internal motivators (i.e., work that is interesting and fun) and not external motivators (work that leads to certain rewards; Kolstrup, 2012). Due to variation in labor requirements associated with block calving systems, these systems may attract different personnel than herds operating AYR and therefore a different set of employment drivers.

It was expected that increasing yield would also increase labor costs for AYR herds. However, SB herds would benefit from lower paid labor with an increase in yield, demonstrating a dilution effect. This agrees with Krpalkova, et al. (2016) who found that herds with the lowest yields (under 7,499 L) had the highest labor and total costs per liter, and the lowest profitability.

Increasing herd size was associated with increased paid labor costs. This is expected, although some labor efficiency from increased herd size should be anticipated (Wilson, 2011). Previous research by Yi and Ifft (2019) demonstrated a positive relationship between financial success and labor use efficiency for New York dairy farms (a combination of labor productivity and cost efficiency). Douphrate et al. (2013) stated that on large US dairy farms, milking parlor capacity typically set herd size and thus labor use requirements with 1 worker per 80 – 100 cows the norm. The capacity of the milking parlor may not be a constraining factor to herd size with different calving patterns as Douphrate et al. (2013) also commented that the desire to maximize return on investment leads to maximizing parlor throughput, which is contrary to a seasonal calving system as parlor throughput will vary during the year. The lack of interaction effects for herd size and paid labor PPL for block calving herds could suggest a disaggregation between parlor throughput, herd size and labor PPL.

Despite AB herds showing lower net profit PPL compared with AYR, SB herds showed a positive effect from increasing yield. A consistent positive relationship between milk yield and profitability is debated within the literature. Wilson (2011) reported that yield was responsible for 66% of the variation in net margin performance on conventional dairy farms in the UK but this did not distinguish between calving pattern. On the other hand, Schorr and Lips (2018) found that the effect of milk yield increased with income i.e., it was nonlinear; the best performing herds benefitted most from increasing yields whereas the bottom decile of herds had a negative effect of producing more milk. In this study, SB herds also demonstrated a higher total income compared with AYR herds; higher income and a positive association with increasing yield on net profit could suggest that SB herds are better performers than AYR (Figure 1).

Changing farm size also had several impacts on block calving herds over AYR. The reduction in profit for SB herds with increasing farm size follows similar findings from Hanrahan et al. (2018) that net profit per hectare reduced as dairy farm size increased on pasture-based dairy farms. Although not specific to a certain dairy system, Coyne et al., (2021) found that engagement with agricultural environment schemes was driven by existing farm and land management, season and flexibility for a scheme to adapt to farm-specific features. The same report also found that financial incentives were a key motivator for engagement, as they provided income and stability (Coyne et al., 2021). Thus, SB herd's participation in environmental schemes could be possible, so long as the financial reward could match any shortfall in income or increase in costs arising from switching land use away from the dairy herd. Of course, policymakers should ensure that options for agricultural environmental schemes are complimentary to existing land management practices as per Coyne et al., (2021) and would not impact forage production potential for dairy farms.

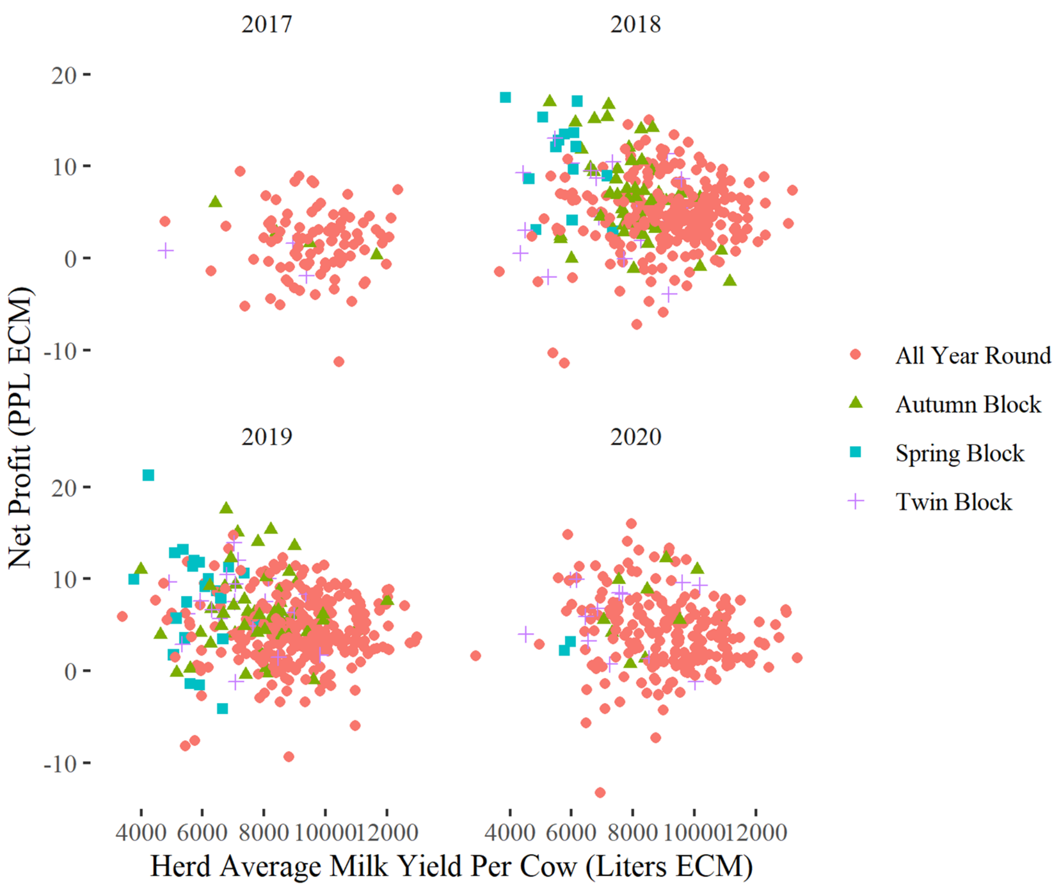

Figure 1. Relationship between Net Profit PPL[1] ECM[2] and herd average ECM[2] milk yield per cow per year by calving pattern for 2017–2020. [1] GBP Pence Per Liter (PPL) [2] Energy Corrected Milk (ECM)

One factor that could have influenced the net profit results across all calving patterns is the lack of consistency in farm representation across all 4 years. Wolf et al. (2020) reported that a single year of data was insufficient to correctly rank dairy farms on profitability. Due to the uneven data set and differing scales of fixed effects used for the LME models, the data had to be standardized to aid model convergence. However, comparing simple averages for the different calving patterns (Table 3) and dependent variables (Table 4) against the estimates produced from the LME models (Tables 5 and 6) demonstrates considerable differences. Placing all calving patterns on an equal herd size, farm size and yield (due to standardization) may not be a true representation of the scale block calving herds can achieve compared with AYR.

CONCLUSION

This study explored the differences between AYR and block calving herds for typical income and expenditure categories associated with milk production. When standardized for herd size, farm size and milk yield, AYR and TB herds have similar cost of production profiles, which will be helpful for benchmarking activities across and between these 2 systems. However, AB vs AYR and SB vs AYR had several differences in opposing directions; total income and forage purchases were lower for AB but higher for SB, with the opposite pattern observed for paid labor and total overheads, which all contributed to AB herds having lower and SB herds having higher net profit compared with AYR. While this study did not compare AB and SB herds directly, the analyses suggest different cost of production profiles when presented on a PPL basis between these 2 calving patterns compared with AYR. The impact of changing herd size, farm size and yield also differed for AYR vs block calving herds and again AB and SB herds often had opposing impacts. These findings demonstrate the differences in the business scale and limitations of each calving pattern to achieve parallel scale with businesses operating different calving pattern, and a potential disaggregation of herd size and farm size for block calving herds as they are unable to maximize resource use over a 365-d period, unlike AYR.

NOTES

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