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ANIMAL RESEARCH PAPER

An analysis of the implications of a change to the seasonal milk supply profile in the Irish dairy industry utilizing a seasonal processing sector model

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SUMMARY

A seasonal processing sector model was developed to simulate dairy product manufacture in Ireland. Outputs include the quantity of product manufactured, net returns and component values of milk (protein and fat) per month of year. Two milk supply profiles representative of mean calving dates of mid-February and mid-March were evaluated across three milk processing plants with differing capacities for cheese and casein. The analysis was carried out based on average Dutch National quotations over the period 2008–10. The mid-February mean calving date resulted in a lower peak supply with proportionately more milk produced in the months of January–March and October–December, which resulted in higher net returns across the three capacities analysed. Increasing the cheese and casein processing capacity resulted in higher net returns being generated.

INTRODUCTION

Economic growth has markedly slowed down during 2009/10, with many countries experiencing negative growth. In contrast to this, the dairy industry has seen a recovery in milk price, stabilization of production costs and there is modest growth in global milk supply (Breen *et al*. 2011). EU milk supply will be further bolstered by the removal of the milk quota by 2015 (European Commission 2008), whereby for the first time since 1984 milk production will no longer be constrained. It is argued that trade protection, in the form of EU supports, contributed to distorting dairy markets and has prevented sustainable growth in global dairy (A. Ferrier, unpublished results). The Common Agricultural Policy reform which is striving to remove dairy support and output restrictions will allow expansion within the dairy industry.

Although policy reforms present opportunities to producers and processors alike the threat posed through milk price volatility must be acknowledged, which is inherent in a market which is not constrained by supply. Demand for dairy produce is relatively inelastic since it is a basic food commodity in developed countries (Graugaard 2010). Milk supply is also inelastic (Pieters 2010) with only *c*. 0·06 of world milk production being traded internationally (Graugaard 2010); therefore, a small change in supply has a large impact on price. It is forecast that 0·80 of the growth in world dairy production will come from developing countries like India and China (Graugaard 2010), and therefore the impact these countries will have on the milk price will grow (J. Pieters, unpublished results), both through increased supply and demand.

The competitiveness of the Irish dairy industry lies in its low cost, grass-based production system (Prospectus 2003). The system relies heavily on grass, which has a seasonal growth profile; as a result the Irish milk supply profile is seasonal, with a peak-to-trough ratio of 5·9:1 (Central Statistics Office Ireland 2010). Processors have invested in capacity to accommodate this seasonal supply profile; however, this capacity is only fully utilized for *c*. 3 months of the year, which leads to higher processing costs. It is anticipated that by 2020, milk production in Ireland since 2010 will have increased by 50%, in a post-quota environment

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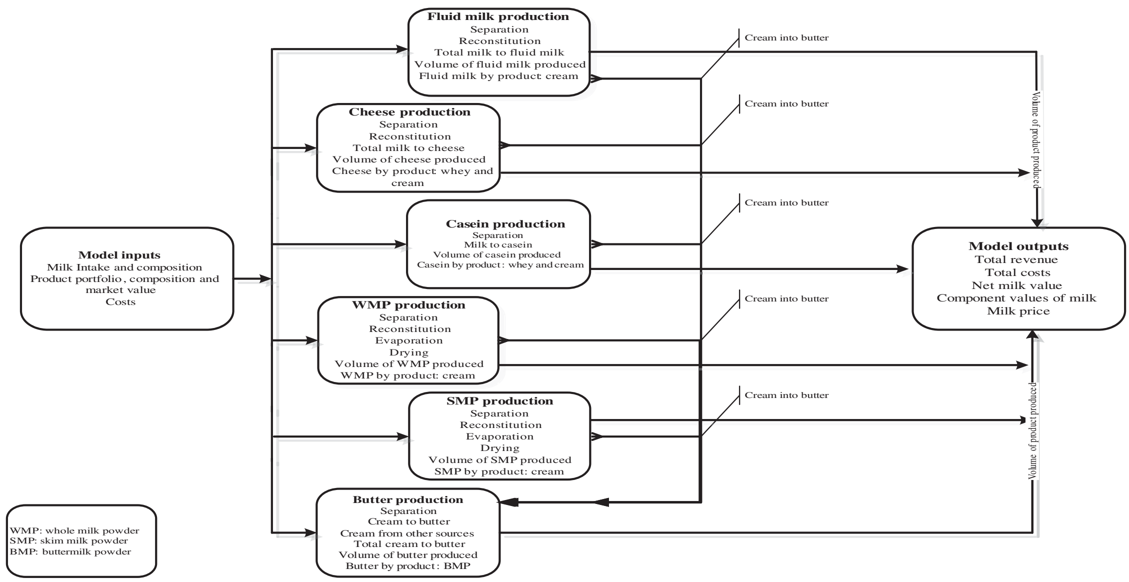

Fig. 1. Schematic of the dairy processing sector model.

(DAFF 2010). However, if the 50% increase is applied to the current seasonal supply profile, more investment will be required at the processor level to process this higher peak. While there is a significant advantage associated with the seasonal nature of milk supply at the farm level (Shalloo *et al.* 2007), there is an associated cost in the processing sector brought about by higher processing costs. In order to complete an economic appraisal of the effect of differing levels of seasonality (in terms of peak-to-trough ratio and the proportion of total milk supplied February–April) within the dairy industry, an evaluation of the effect within the processing sector must be completed.

Processing sector models have been utilized by the dairy industry worldwide to help with the decision making process: Benseman (1986) in New Zealand, Pratt *et al.* (1997), Papadatos *et al.* (2002) and Nicholson & Fiddaman (2003) in the U.S. and Geary *et al.* (2010) in Ireland.

The objective of the current study was to determine the impact of a change to the mean calving date within the current spring system operated in Ireland on processor returns, milk price and the component values of milk paid to farmers per month. Two spring calving milk supply profiles based on standard lactation curves (Olori & Galesloot 1999) were examined, one which was representative of the current national spring calving pattern with a mean calving date of mid-March and an alternative supply profile representative of the optimum at farm level with a mean calving date of mid-February (Shalloo *et al.* 2007). A number of milk processing capacity constraints were simulated across the two calving patterns.

MATERIALS AND METHODS

Model description

An annual time step milk processing sector model has been developed for the Irish dairy industry (Geary *et al.* 2010). The model presented in the current paper expands that model to function on a monthly time step, with 12 independent sets of inputs and outputs. As outlined in Geary *et al.* (2010), the approach uses a mass balance milk processing-sector model that accounts for all inputs, outputs and losses involved in dairy processing. The model is a mathematical representation of the conversion of milk into dairy products. Figure 1 provides a schematic of the model. Within the model, the production of cheese, casein, butter, whole milk powder (WMP), skim milk powder (SMP) and fluid milk is simulated with the by-products of butter milk powder (BMP), whey and cream all being further processed or sold. The volume and composition of raw milk intake, product portfolio and its composition are included as model inputs which are used in the simulations. The quantities of products and by-products that can be produced from the available milk pool to meet product specifications are calculated. Processing costs are simulated, the return from raw milk is calculated and the values per kg

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Table 1. *Composition of dairy products simulated in the model*

Components (proportion)	Cheese	Butter	WMP*	SMP*	Whey	BMP*
Fat	0·35	0·84	0·27	0·01	0·01	0·08
Protein	0·25	0·006	0·25	0·33	0·15	0·42
Lactose	0·01	0·008	0·40	0·54	0·77	0·40
Minerals	0·02	0·001	0·06	0·08	0·04	0·05
Water	0·37	0·15	0·03	0·04	0·02	0·05

* WMP, whole milk powder; SMP, skim milk powder; BMP, butter milk powder.

of fat, per kg of protein and carrier costs per litre are calculated in the model.

Dairy product production

The proportion of milk that is directed toward the production of each product is specified in the model. Some of the milk is separated into cream and skim milk based on the composition of: (a) the milk and (b) the final product to be manufactured (Table 1). The volumes of whole milk, cream and skim milk from separation are reconstituted in differing proportions to meet final product specifications. Excess cream not used in the production process can be sold or used in butter manufacture, with excess skim milk remaining from butter manufacture being used in the production of SMP. As this is a mass balance model, all components of the milk received are accounted for, whether they are utilized in product manufacture or lost in the production process. The compositions of the dairy products produced in the model are presented in Table 1 and remained constant throughout the year. The simulation for each of the dairy products produced in the model is described in detail below.

Cheese

Van Slyke & Price (1949) developed a cheese yield equation which is the industry norm today:

$$Y = ((0{\cdot}93X + 0{\cdot}78X_P - 0{\cdot}1) \times 1{\cdot}09)/(1 - W)$$

where Y is the yield of cheese, X is the percentage fat in the milk, X_P is the percentage protein in the milk and W is the water content of the cheese.

Milk protein is made up of casein and whey, with the casein proportion going toward curd formation and the whey proportion leaving the cheese process in a liquid form. Cheese protein is calculated from the ratio of milk protein in the cheese yield (X_P/Y from Van Slyke), multiplied by the casein proportion of the protein (0·8), the efficiency of casein utilization (0·99) and an adjustment for non-casein protein in the cheese (1/0·98).

$$\text{Cheese protein} = \{[((X_P/Y) \times (\text{casein}/X_P)) \times 99\%]/98\}$$

The cheese yield is calculated by dividing the volume of cheese protein by the required protein content of the final cheese product, taken to be 0·245 in the current analysis (Table 1).

The whey by-product from cheese production is manufactured into whey powder. The volume of whey produced is calculated by subtracting the volume of cheese produced from the volume of milk to cheese less any calculated losses. The whey milk is evaporated to a water content of 480 g/kg then dried to a water content of 23·8 g/kg to produce whey powder. Cream left over from separation is used in the manufacture of butter.

Casein

The milk from separation is used in casein production. The casein yield is calculated by dividing the casein in cheese by the required protein content of the final casein product, assumed to be 0·89 in the current analysis. The whey by-product from casein production is manufactured into whey powder as described above. The cream from the separation process is used in the manufacture of butter.

Butter

Cream from separation and the surplus cream from other product processes (cheese, WMP, SMP, casein and fluid milk) are used in butter manufacture. The volume of butter that can be produced from this cream is calculated by dividing the volume of fat in cream by the required fat content in the final butter product, taken to be 0·84 in the current analysis (Table 1).

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A by-product of butter manufacture is buttermilk, which is manufactured into BMP by evaporating to 500 g/kg water content then drying to 50 g/kg moisture content.

Whole milk powder

The standardized milk is evaporated to a moisture content of 480 g/kg then dried to 27 g/kg moisture content, holding fat, protein, lactose and minerals constant.

Skim milk powder

The standardized skim milk is evaporated to a moisture content of 480 g/kg and dried to a moisture content of 40 g/kg, holding fat, protein, lactose and minerals constant, to produce SMP.

Model outputs

Volume of milk used in the production of each product

The volume of milk used in the production of each product was calculated based on the defined product mix (monthly milk supply multiplied by the proportion of milk used in the production of each product per month).

Volume of products produced

The volume of product and by-product that can be produced based on the product mix, the volume of milk being processed, the composition of the milk being processed and the composition of the product being produced was calculated.

Total processing costs

Based on the product portfolio and the milk composition, the total costs (TC) per month of processing the volume of milk (using the volume-related processing costs and the volume of milk processed) and producing the product mix (using the product-related processing costs and the volume of products produced) were calculated.

Total revenue

The total revenue (TR) generated per month from the volume of products produced and the market value of the products produced was calculated.

Net milk value

The net milk value (NMV) per month, which is the difference between TR and TC, was calculated. The monthly NMV can also be calculated by multiplying the value per kg of fat by the total weight (kg) of fat plus the value per kg of protein multiplied by the total weight (kg) of protein minus the carrier cost per litre multiplied by the volume of milk processed per month.

The adjusted NMV was also calculated. When the mean calving date changed the milk solids concentrations per month also changed, which was incorporated into the overall analysis. However, to disentangle the milk solids concentration effect from the milk volume, product portfolio and processing cost effects the adjusted NMV was calculated. To calculate the adjusted NMV a standardized fat and protein proportion of 0·036 and 0·033, respectively, was assumed per month for both supply profiles. The adjusted NMV was then calculated as explained above using the calculated value per kg of fat, per kg of protein and per litre carrier cost, multiplied by the standardized weight (kg) of fat, protein and litres of milk.

Milk price

The monthly milk price per litre was calculated by dividing the NMV per month by the volume of milk being processed per month.

Component values of milk

As explained in Geary *et al*. (2010) the component pricing of milk, whereby a value per kg of fat and protein is calculated, was included in the model. The values per kg of fat and kg of protein were calculated from the NMV of products produced, the fat and protein requirements in the products produced and the weight (kg) of fat and protein available for processing. As explained in Geary *et al*. (2010), the marginal rate of technical substitution (MRTS) was used to calculate the component values of milk. The MRTS was used to determine the value per kg of fat and protein. The MRTS is the amount by which the quantity of one input, such as protein, can be reduced ($-\Delta x_2$) when one extra unit of another input, such as fat, is used (Δx_1) in order that the overall outcome, such as milk value, remains constant:

$$\mathrm{MRTS}\,(x_1,\ x_2) = \Delta x_{2}/\Delta x_1 = -\mathrm{MP}_1/\mathrm{MP}_2$$

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Table 2. *Product market values assumed per tonne of dairy product**

Products (€)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cheese	3213	3281	3152	3195	3300	3339	3391	3364	3225	3221	3203	3119
Butter	3653	2630	2610	2656	2814	2903	2980	2969	2935	3032	3065	3007
Casein	6694	6836	5905	6437	6510	5608	6330	6615	6567	6477	6803	6981
WMP†	2449	2403	2383	2464	2572	2580	2509	2431	2455	2481	2452	2468
SMP†	1962	1953	1946	2031	2112	2146	2102	2031	2016	2006	1955	1966
BMP†‡	2449	2403	2383	2464	2572	2580	2509	2431	2455	2481	2452	2468
Whey	544	496	466	514	560	548	484	516	560	565	562	603

* Assumed average market prices per month from 2008 to 2010 as per the Dutch official quotation (see Productschap Zuivel 2004–11) for butter, WMP, SMP and whey powder. Cheese market prices were representative of the UK cheddar cheese market price (Datum UK 2004–11). Casein market prices were taken from the US casein market price (CLAL 2004–11).
† WMP, whole milk powder; SMP, skim milk powder; BMP, butter milk powder.
‡ Assumed BMP market values equivalent to WMP market values.

where MP_1 and MP_2 are the marginal products of input 1 and input 2, respectively.

For each additional kg of fat or protein, the overall milk revenue will be increased depending on the product portfolio, product values and processing costs. The value of that increase is the marginal value of that component.

Model assumptions

The model assumptions are separated into two categories including raw milk and financial inputs.

Raw milk

The volume of raw milk being processed in this analysis was 5190 million litres/year, which was representative of the volume of domestic milk intake by creameries and pasteurizers in Ireland in 2010 (Central Statistics Office Ireland 2010). While in Ireland there are a number of milk processors, it was assumed in the current analysis that all of the milk flowed through one processor who could decide what products to produce. This is quite a sensitive assumption, as industry returns are highly dependent upon the type and value of products produced, which in reality is variable across processors. However, many processors now work closely together throughout the year with milk flowing between processors to maximize industry returns, minimize processing costs and increase overall profitability. Sensitivity analysis was carried out to demonstrate how sensitive the model outcomes are to product market values. Further detail on this sensitivity analysis is provided.

Financial inputs

Market values

There is some seasonal variation around product market values. The market values assumed in the current analysis were taken from the 2008–10 data of the Dutch official quotation system (Productschap Zuivel 2004–11) to capture this price variation. This is the quotation system referred to by the Irish Dairy Board in financial analyses. The market prices were representative of a 3-year average from 2008 to 2010 for each month of the year. The market values for butter, WMP, SMP and whey powder were representative of the market prices for the Netherlands. Market prices for cheese and casein were not quoted for the Netherlands; therefore, as recommended by dairy industry analysts, the market price for cheese was representative of the UK cheddar cheese market price (Datum UK 2004–11), since the market price per tonne of cheese would be similar between Ireland and the UK. The market price for casein was representative of the US casein market price (CLAL 2004–11) because it was deemed a good proxy for the market price per tonne of casein received in Ireland. As in Geary *et al*. (2010), the market price for BMP was assumed equivalent to the market price for WMP. The product market values assumed for the 12 months in the current analysis are presented in Table 2.

Processing costs

The processing costs and cost components published in Geary *et al*. (2010) were further validated via additional consultative processes with financial and managerial dairy processing personnel. Processing

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Table 3. *Volume- and product-related processing costs*

	Cheese	Butter	WMP*	SMP*	Whey powder	BMP*†	Casein
Volume costs (€)							
Collection/litre‡	0·0105	0·0105	0·0105	0·0105	0·0105	0·0105	0·0105
Standardization/litre	0·0050	0·0050	0·0050	0·0050	0·0050	0·0050	0·0050
Processing milk/litre	0·0089	0·0089	0·0089	0·0125	0·0089	0·0089	0·0089
Product costs (€)							
Processing product/t	51	57	105	113	95	105	194
Packaging/t	41	31	41	41	41	41	41
Storage/t	52	89	28	8	8	28	6
Distribution/t	58	73	83	81	83	83	58
Interest/t	102	153	132	30	42	132	30

* WMP, whole milk powder; SMP, skim milk powder; BMP, butter milk powder.
† BMP processing costs assumed equivalent to WMP.
‡ Quinlan *et al*. (2010).

costs were split into two groups following Geary *et al*. (2010): volume-related processing costs (costs/litre) and product-related processing costs (costs/tonne). The volume-related processing costs include milk collection, milk standardization and volume-related processing costs which represent a number of cost components: 0·50 fuel and power, 0·33 direct labour and added ingredients. The product-related processing costs include packaging, storage, distribution and product-related processing costs which represent a number of cost components: 0·50 fuel and power, 0·66 direct labour, other direct expenses and effluent treatment and disposal. Via the validation process, each cost component was reviewed in turn for each of the dairy products being produced. The unit processing costs included in the current analysis were assumed to stay constant per month of year and were applied either to the volume of milk being processed (volume-related processing costs) or the volume of product produced (product-related processing costs).

In the Irish dairy industry storage and finance costs are incurred as a result of the seasonal supply profile. In the peak months, when the volume of milk being processed is greatest (May in the current analysis) the volume of product being produced exceeds demand. Therefore, excess product needs to be stored. As well as incurring storage costs there is also the cost of having capital invested in product which has not been sold: this cost is captured via the financing costs. In the current analysis, the demand for each product was calculated by summing the volume of product produced throughout the year and dividing this by 12 to give the constant monthly demand for each product. This assumption of a constant demand for dairy products is in line with The World Dairy Situation (International Dairy Federation 2010), which found demand for dairy produce to be steady. When the volume of product produced per month exceeds this demand, storage and financing costs are incurred but only on the volumes that exceed demand.

The processing costs included in the current analysis are presented in Table 3.

Fixed costs

Fixed costs were included in the current analysis at a rate of €0·015 per litre, which was validated in the consultation process. This was applied to the total volume of milk being processed in the year (5190 million litres) and the cost was spread evenly over the 12 months of the year. This cost incorporates rents and rates, depreciation, quality control, management, central research and development, marketing, administration and IT.

Scenario analysis

Supply profiles

Two milk supply profiles were examined, to demonstrate the impact a change within the seasonal supply profile has on industry returns in terms of the returns to the processor and the price paid to producers. Supply profile 1 was representative of the current Irish national milk supply profile with a mean calving date of 14 March, while supply profile 2 was representative of a supply profile with a mean calving date of 14 February, which is assumed to be optimum at farm level (Shalloo *et al*. 2007). The fat, protein and lactose compositions

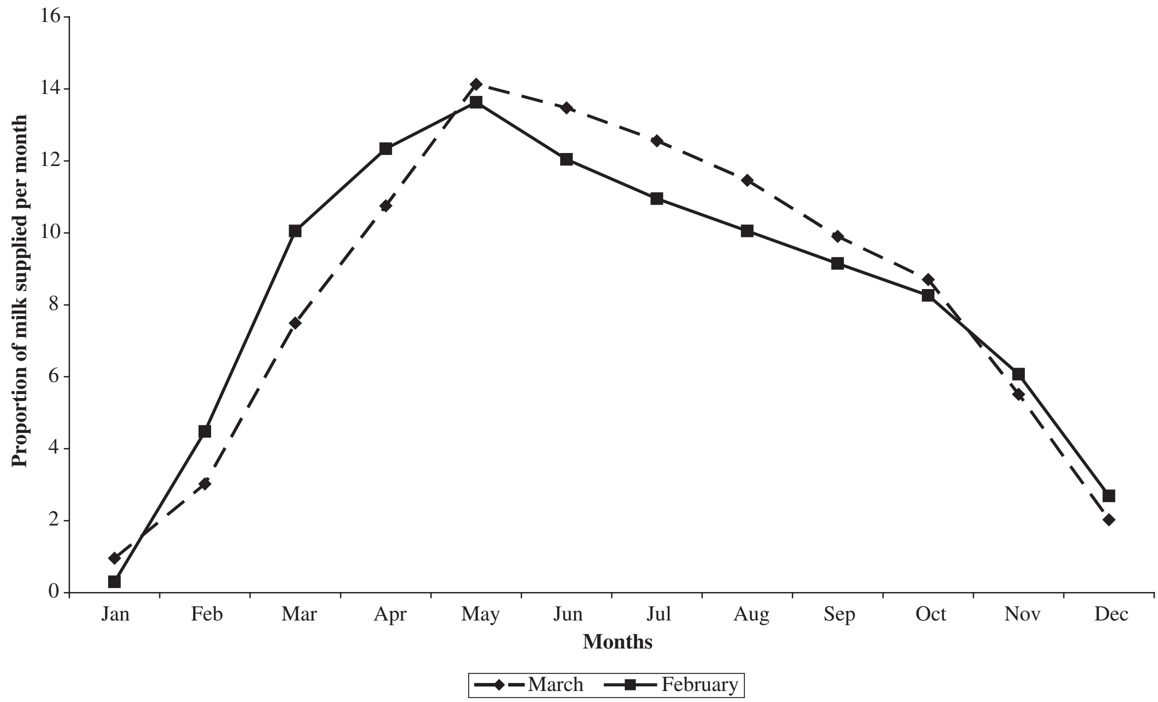

Fig. 2. March* and February* milk supply profiles. *Mean calving date 14 March, mean calving date 14 February.

for both supply profiles were generated using SLAC lactation records (Olori & Galesloot 1999).

Supply profile 1: MARCH. The national supply profile was taken from an Irish dairy processor and was assumed to be representative of the national milk supply profile with a mean calving date of 14 March. With this supply profile, peak milk production is in May, with 0·141 of the annual milk pool being produced in this month. This supply profile was representative of having 0·42 of cows calved by 1 March and 0·72 of cows calved by 1 April.

Supply profile 2: FEBRUARY. The February milk supply profile was representative of a mean calving date of 14 February, with 0·33 of cows calved by the end of January, 0·78 calved by the end of February and 0·93 calved by the end of March. The February milk supply profile has a lower peak in May of 0·136 relative to the March supply profile, with proportionately more milk supplied in the shoulders. The two supply profiles utilized in the current analysis are in Fig. 2 and result in different volumes of milk being processed each month of the year, as well as varying milk compositions.

Capacity constraints

In addition, three cheese and casein processing capacity constraints were examined, to demonstrate the impact on processor and producer returns when processing capacity for the higher returning products was altered. The first capacity constraint (Cap 1), similar to the current processing capacity in Ireland as per industry consultation, was 0·06 per month of the national milk pool (311 million litres). The second capacity constraint (Cap 2) was 0·09 per month of the national milk pool (467 million litres) and the third (Cap 3) was 0·12 per month of the national milk pool (623 million litres), partitioned into two-thirds cheese and one-third casein.

Product mix

In the current analysis, cheese and casein were not produced in the months of January and December. This is due to the poor milk quality in these months from spring calving herds, and is based on industry practice in Ireland (Guinee *et al.* 2007). The product mix in the current analysis changes per month. For each of the analyses, the casein capacity was filled first, then the cheese capacity was filled and the remainder of the milk pool was apportioned to butter, WMP and SMP at a ratio of 53:24:23, respectively. This ratio was calculated based on the Irish dairy product mix of 2008 (FAOSTAT 2009) in which 0·30 of the milk pool was used to produce butter, 0·43 to produce cheese, 0·14 to produce WMP and 0·13 to produce

SMP. Removing the 0·43 to cheese and recalculating the WMP, SMP and butter proportions to total 1·00 results in the ratios presented above. In the months of January and December, when cheese and casein were not produced, the milk pool was apportioned 0·43, 0·43 and 0·14 to butter, SMP and WMP, respectively.

In total, six scenarios representing the three capacity constraints for each of the two milk supply profiles were analysed.

Price sensitivity analysis

Sensitivity analysis was carried out to demonstrate how sensitive the model is to price changes in the market value of products. Using the March supply profile with the Cap 1 constraint, the product market values were varied. The product market values from 2004 to 2011 were utilized in the analysis. The market values from 2004 were chosen, because the lowest market value for cheese over the last 8 years (2004–11) was recorded in 2004 (cheese market prices were sourced from Datum UK 2004–11, casein market prices were sourced from US database CLAL (2004–11), all other market prices were sourced from Productschap Zuivel 2004–11). The 2011 product market values for January were utilized as the highest market values for cheese over this time period were recorded. No other model inputs were modified in the current analysis. The product market values used for cheese, butter, WMP, SMP, casein, whey and BMP for the 2004 analysis, based on an annual average, were €2375, €3005, €2558, €2044, €3990, €419 and €2558, respectively. For the 2011 analysis, the product market values used for cheese, butter, WMP, SMP, casein, whey and BMP were €3050, €3820, €3250, €2600, €6974, €900 and €3250, respectively.

RESULTS

The results for the two milk supply profiles utilizing three cheese and casein processing capacities are presented. The results are based on the national milk supply volume of 5190 million litres for 2010 (Central Statistics Office Ireland 2010) and are split into three sections, based on the three processing capacities examined. Within each of the processing capacity scenarios the results for both the March and February supply profiles are presented.

Monthly milk intake

Prior to presenting the processing model results, the monthly milk intakes for both supply profiles are presented. The proportion of total milk supplied, the volume being supplied and the fat, protein and lactose compositions per month of both milk supply profiles are presented in Table 4. Utilizing the MARCH supply profile the milk intake in January was 50 million litres, increasing to a peak milk supply in May and June of 734 and 699 million litres, respectively (Table 4). The FEBRUARY supply profile had a January milk intake of 16 million litres, increasing to a peak supply of 640 and 708 million litres in April and May. The FEBRUARY supply profile produced proportionately more milk than the MARCH supply profile in the months of February, March and April, with 0·269 of the annual milk pool produced in these 3 months for the FEBRUARY supply profile, relative to 0·213 for the MARCH supply profile. The monthly milk intake was the same across the three processing capacity scenarios examined.

Capacity 1

The model results for both the MARCH and FEBRUARY milk supply profiles utilizing the Cap 1 constraints (208 million litres/month for cheese and 104 million litres/month for casein) are discussed here. The physical outputs of the model, including the volume of milk utilized in the production of each product and the quantity of product produced are presented in Table 5. The financial outputs of the model, including NMV, milk price and the component values of milk, are presented in Table 6.

Milk utilization

With the FEBRUARY supply profile, 1% more milk (101 million litres) was used in the production of cheese relative to the MARCH supply profile (Table 5). As a result, 1% less milk (55 million litres) was used in the production of butter. In both supply profiles from March to October, the cheese processing capacity was filled.

Quantity of products produced

The casein capacity was filled for 10 months of the year (February–November) across the two supply profiles. The difference in the casein yield was due to the different fat, protein and lactose compositions of the supply profiles (Table 5). With the FEBRUARY milk

Table 4. *Volume of milk processed and the associated fat, protein and lactose content of milk for the March* and February† supply profiles, Jan–Dec*

Supply profile	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Volume of milk processed, million litres												
March	50	157	389	558	734	699	652	595	514	452	286	105
	(0·010)	(0·030)	(0·075)	(0·108)	(0·141)	(0·135)	(0·126)	(0·115)	(0·099)	(0·087)	(0·055)	(0·020)
February	16	232	522	640	708	625	568	522	475	429	315	139
	(0·003)	(0·045)	(0·101)	(0·123)	(0·136)	(0·120)	(0·110)	(0·101)	(0·092)	(0·083)	(0·061)	(0·027)
Fat (g/kg)												
March	43·5	40·3	37·0	35·5	34·5	34·4	35·2	36·4	38·3	40·2	41·5	42·8
February	41·2	38·3	36·4	34·9	34·4	34·9	35·8	37·2	39·2	41·3	42·9	44·3
Protein (g/kg)												
March	36·4	32·8	31·5	32·2	32·3	32·3	32·6	33·3	34·9	36·2	36·4	36·6
February	32·8	30·9	31·1	31·8	32·5	32·9	33·2	34·0	35·7	37·1	37·8	38·2
Lactose (g/kg)												
March	45·4	46·0	46·4	46·6	46·8	46·9	46·5	45·8	45·3	44·9	44·7	44·8
February	46·1	46·4	46·5	46·9	47·0	46·5	45·8	45·4	44·8	44·6	45·1	45·0

* Mean calving date of 14 March. Fat, protein and lactose composition sourced from Central Statistics Office Ireland (2010).
† Mean calving date of 14 February. Fat, protein and lactose composition sourced from the Moorepark Dairy Systems Model (Shalloo *et al.* 2004).

supply profile, an additional 13 840 tonnes of cheese and 2400 less tonnes of butter were produced relative to the MARCH supply profile.

Net milk value

The NMV was 1·9% higher (€29·2 million) in favour of the FEBRUARY milk supply profile (Table 6). The lowest NMV were generated in January and December when milk supply was at its lowest. In the FEBRUARY milk supply profile, a loss of €1·8 million was generated in January as the volume of milk being processed was too low to dilute the fixed costs and high-value products were excluded from the product mix. The adjusted NMV, with the compositional variation removed accounting only for the effect of seasonality, resulted in a 1·2% gain of €17·7 million from moving from a mid-March to a mid-February mean calving date.

Milk price

The average milk price across the year was €0·295 per litre for the MARCH supply profile and was 0·6 cents higher for the FEBRUARY supply profile (Table 6). In the FEBRUARY supply profile, a negative price of €0·118 per litre was generated in January which if imposed would effectively be a charge to producers supplying milk in the month of January.

Component values of milk

The average value per kg of fat and kg of protein for the MARCH supply profile was €2·26 and €6·28, respectively (Table 6). The highest values per kg of fat were generated in January and December when cheese and casein were excluded from the product mix with the highest protein values generated in February and November when the largest proportion of available milk was utilized in the production of cheese and casein. The FEBRUARY supply profile resulted in an average value per kg of fat of €2·23 and an average value per kg of protein of €6·30.

Capacity 2

The model results for both the MARCH and FEBRUARY milk supply profiles utilizing the Cap 2 constraints (311 million litres/month for cheese and 156 million litres/month for casein) are discussed here. The physical outputs of the model are presented in Table 7 and financial outputs are presented in Table 8.

Table 5 *Monthly milk volumes used and volumes of products produced for the March* and February* supply profiles utilizing capacity constraint 1†*

Volume of milk used in the production of each product (million litres)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Proportion of total
March supply profile														
Cheese	–	53	208	208	208	208	208	208	208	208	182	–	1896	0·37
Casein	–	104	104	104	104	104	104	104	104	104	104	–	1038	0·20
Butter	21	–	41	130	222	204	179	149	107	74	–	45	1173	0·23
WMP‡	7	–	19	61	104	96	84	70	50	35	–	15	538	0·10
SMP‡	21	–	18	56	96	89	78	65	46	32	–	45	546	0·10
February supply profile														
Cheese	–	129	208	208	208	208	208	208	208	208	208	–	1997	0·38
Casein	–	104	104	104	104	104	104	104	104	104	104	–	1038	0·20
Butter	7	–	111	173	209	165	135	111	82	62	–	60	1118	0·22
WMP‡	2	–	52	81	97	77	63	52	40	29	–	20	512	0·10
SMP‡	7	–	48	75	90	72	59	48	37	27	–	60	522	0·10

Volume of products produced (tonnes)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
March supply profile													
Cheese	–	5902	22 213	22 707	22 776	22 771	22 990	23 479	24 609	25 525	22 533	–	215 506
Casein	–	3586	3463	3550	3566	3566	3596	3664	3828	3958	3972	–	36 748
Butter	2278	4980	7279	12 473	17 562	16 559	15 458	14 102	11 956	10 252	5128	4738	122 764
WMP‡	1033	–	2439	7979	13 713	12 581	11 145	9465	7089	5086	–	2197	72 726
SMP‡	3465	–	4881	15 647	26 938	24 820	21 574	17 660	12 435	8506	–	7238	143 164
February supply profile													
Cheese	–	13 499	21 931	22 420	22 917	23 120	23 410	23 976	25 173	26 162	26 657	–	229 346
Casein	–	3390	3423	3507	3589	3630	3658	3737	3909	4048	4114	–	37 007
Butter	670	4732	11 724	14 915	16 696	14 403	12 940	11 873	10 823	9643	5447	6491	120 358
WMP‡	290	–	6541	10 508	12 951	10 358	8555	7169	5858	4356	137	3032	69 754
SMP‡	1098	–	13 286	21 035	25 395	19 863	15 998	12 954	9928	7050	218	9596	136 421

* Mean calving date 14 March, Mean calving date 14 February.

† Capacity constraint 1 = cheese processing capacity of 207 596 000 litres/month; casein processing capacity of 103 798 000 litres/month.

‡ WMP, whole milk powder; SMP, skim milk powder.

Table 6. *Monthly net milk value, milk price and component values of milk for the March* and February* supply profiles utilizing capacity constraint 1†*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Adjusted Total§	Average
March milk supply profile															
NMV‡ (€m)	9	59	107	155	205	197	189	176	159	149	102	26	1532	1530	
Milk price (€/litre)	0·18	0·37	0·28	0·28	0·28	0·28	0·29	0·30	0·31	0·33	0·36	0·25			0·30
Fat value/kg (€)	3·43	1·82	1·55	2·05	2·52	2·57	2·47	2·33	2·13	2·01	1·53	4·56			2·26
Protein value/kg (€)	1·42	9·55	7·43	6·83	6·45	6·47	6·67	6·78	6·95	7·26	8·44	1·88			6·28
Carrier/litre (€)	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02			−0·02
February milk supply profile															
NMV‡ (€m)	−2	79	138	172	200	180	169	161	152	146	117	49	1561	1548	
Milk price (cents/litre)	−0·12	0·34	0·26	0·27	0·28	0·29	0·30	0·31	0·32	0·34	0·37	0·35			0·30
Fat value/kg (€)	–	1·44	1·92	2·22	2·48	2·42	2·28	2·15	2·02	1·98	1·48	6·06			2·23
Protein value/kg (€)	–	9·70	6·75	6·53	6·53	6·66	6·98	7·13	7·15	7·34	8·47	2·51			6·30
Carrier/litre (€)	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02			

* Mean calving date 14 March, Mean calving date 14 February.
† Capacity constraint 1 = cheese processing capacity of 207 596 000 litres/month; casein processing capacity of 103 798 000 litres/month.
‡ NMV, net milk value (TR – TC).
§ The effect of seasonality on base price, variation in milk composition removed.

Milk utilization

With the FEBRUARY milk supply profile, 3% more milk (160 million litres) was used to produce cheese, 2% less milk was used to produce butter and 1% less milk was used to produce WMP relative to MARCH supply profile (Table 7). The volume of milk utilized in the production of casein in both supply profiles does not differ because the casein processing capacity was filled 10 months of the year in both supply profiles.

Quantity of products produced

In the FEBRUARY supply profile, 7% (20 872 tonnes) more tonnes of cheese and 4% less (4436) tonnes of butter were produced relative to the MARCH supply profile (Table 7).

Net milk value

As the casein and cheese processing capacity increased, so too did the returns. The NMV for the MARCH supply profile over the 12 months of the year was 2% lower (€33·7 million) than the FEBRUARY supply profile for the year (Table 8). In the FEBRUARY milk supply profile, a loss of €1·8 million was generated in January as the volume of milk being processed was so low (16 million litres). The adjusted NMV resulted in a gain of €17·9 million moving from a mid-March to a mid-February mean calving date.

Milk price

The average milk price was €0·006 per litre higher for the FEBRUARY relative to the MARCH supply profile (Table 8). With the FEBRUARY supply profile a negative price of €0·118 per litre was generated due to the loss being generated in that month.

Component values of milk

The average value per kg of fat and kg of protein for the MARCH supply profile was €1·88 and €7·20, respectively, and for the FEBRUARY supply profile was €1·80 and €7·22, respectively. Protein was valued higher in the Cap 2 analysis relative to the Cap 1 analysis as the capacity to produce cheese and casein was higher, more protein was required; therefore, protein carried a higher value.

Capacity 3

The model results for both the MARCH and FEBRUARY milk supply profiles utilizing the Cap 3

Table 7. *Monthly milk volumes used and volumes of products produced for the March* and February* supply profiles utilizing capacity constraint 2†*

Volume of milk used in the production of each product, million litres

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Proportion of total
March supply profile														
Cheese	–	1	233	311	311	311	311	311	311	296	130	–	2529	0·49
Casein	–	156	156	156	1558	156	156	156	156	156	156	–	1557	0·30
Butter	21	–	–	48	140	123	97	67	25	–	–	45	567	0·11
WMP‡	7	–	–	22	65	57	45	31	12	–	–	15	255	0·05
SMP‡	21	–	–	21	61	53	42	29	11	–	–	45	283	0·05
February supply profile														
Cheese	–	77	311	311	311	311	311	311	311	273	159	–	2688	0·52
Casein	–	156	156	156	156	156	156	156	156	156	156	–	1557	0·30
Butter	7	–	29	91	127	83	53	29	4	–	–	60	483	0·09
WMP‡	2	–	13	43	59	39	25	13	2	–	–	20	216	0·04
SMP‡	7	–	12	40	55	36	23	12	18	–	–	60	247	0·05

Volume of products produced, tonnes

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
March supply profile													
Cheese	–	121	24 942	34 061	34 165	34 165	34 485	35 222	36 916	36 388	16 114	–	286 577
Casein	–	5379	5195	5324	5348	5349	5393	5498	5742	5937	5957	–	55 124
Butter	2278	7469	6857	9563	14 790	13 743	12 557	11 075	8769	7450	7691	4738	106 980
WMP‡	1033	–	–	2939	8657	7528	6054	4271	1640	–	–	2197	34 320
SMP‡	3465	–	–	5772	17 009	14 859	11 715	7958	2877	–	–	7238	70 894
February supply profile													
Cheese	–	8050	32 897	33 633	34 376	34 780	35 115	35 965	37 763	34 394	20 456	–	307 449
Casein	–	5085	5135	5263	5382	5444	5485	5606	5864	6073	6171	–	55 510
Butter	670	7099	8620	12 053	13 929	11 549	9986	8781	7560	7654	7951	6491	102 344
WMP‡	290	–	1698	5537	7865	5213	3368	1861	284	–	–	3032	29 147
SMP‡	1098	–	3444	11 079	15 415	10 005	6298	3358	492	–	–	9596	60 784

* Mean calving date 14 March, Mean calving date 14 February.

† Capacity constraint = cheese processing capacity of 311 394 000 litres/month; casein processing capacity of 155 697 000 litres/month.

‡ WMP, whole milk powder; SMP, skim milk powder.

Table 8. *Monthly net milk value, milk price and component values of milk for the March* and February* supply profiles utilizing capacity constraint 2†*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Adjusted total‡	Average
March milk supply profile															
NMV§ (€m)	9	64	112	166	216	206	200	190	173	161	105	26	1628	1628	
Milk price (€/litre)	0·18	0·41	0·29	0·30	0·30	0·30	0·31	0·32	0·34	0·36	0·37	0·25			0·31
Fat value/kg (€)	3·43	2·52	1·38	1·52	2·03	2·03	1·91	1·77	1·59	1·50	2·04	4·56			1·88
Protein value/kg (€)	1·42	9·79	8·02	8·01	7·44	7·42	7·80	8·07	8·28	8·55	8·07	1·88			7·20
Carrier/litre (€)	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02			−0·02
February milk supply profile															
NMV§ (€m)	−2	85	147	183	211	190	182	175	165	157	120	49	1661	1646	
Milk price (€/litre)	−0·12	0·37	0·28	0·29	0·30	0·30	0·32	0·34	0·35	0·37	0·38	0·35			0·32
Fat value/kg (€)	–	1·91	1·36	1·71	1·98	1·87	1·69	1·56	1·22	1·55	1·92	6·06			1·80
Protein value/kg (€)	–	9·88	7·94	7·59	7·54	7·72	8·24	8·56	8·75	8·50	8·23	2·51			7·22
Carrier/litre (€)	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02			−0·02

* Mean calving date 14 March, Mean calving date 14 February.
† Capacity constraint 1 = cheese processing capacity of 311 394 000 litres/month; casein processing capacity of 155 697 000 litres/month.
‡ The effect of seasonality on base price, variation in milk composition removed.
§ NMV, net milk value (TR – TC).

constraints (415 million litres/month for cheese and 208 million litres/month for casein) are discussed here. The physical outputs of the model are presented in Table 9 and financial outputs are presented in Table 10.

Milk utilization

In the FEBRUARY supply profile, 1% more milk (62 million litres) was used in the production of cheese relative to the MARCH supply profile. In the current analysis, very little butter, WMP and SMP were being produced, as the cheese and casein capacities were not being filled in 7 out of the 10 months (Table 9).

Products produced

An additional 9243 tonnes of cheese and 2274 tonnes of casein were produced with the FEBRUARY supply profile relative to the MARCH supply profile (Table 9). These higher volumes were due in part to higher volumes of milk being used in the production of cheese and casein but were also due to milk composition.

Net milk value

The NMV was >2% higher (€35·9 million) with the FEBRUARY supply profile *v.* the MARCH supply profile. Adjusted for compositional variation, the FEBRUARY NMV was 1·3% (€21·5 million) higher than the MARCH adjusted NMV.

Milk price

The average milk price across the year was €0·007 per litre higher with the FEBRUARY supply profile relative to the MARCH supply profile.

Component values of milk

The value per kg of fat and kg of protein was €1·73, €7·71 for the MARCH supply profile, respectively, and for the FEBRUARY supply profile the value per kg of fat was €1·73 and the value per kg of protein was €7·60.

Price sensitivity analysis

When the product market values from 2004 were utilized with the MARCH supply profile, Cap 1 analysis, the NMV dropped by 20% to €1219·2, the average milk price across the year was €0·235 per litre, the value per kg of fat and kg of protein was €1·82 and €5·11, respectively. Utilizing the 2011 product market

Table 9. *Monthly milk volumes used and volumes of products produced for the March* and February* supply profiles utilizing capacity constraint 3†*

Volume of milk used in the production of each product, million litres

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Proportion of total
March supply profile														
Cheese	–	–	181	350	415	415	415	387	306	244	78	–	2793	0·54
Casein	–	157	208	208	208	208	208	208	208	208	208	–	2025	0·39
Butter	21	–	–	–	58	40	15	–	–	–	–	45	181	0·03
WMP‡	7	–	–	–	27	19	7	–	–	–	–	18	75	0·02
SMP‡	21	–	–	–	25	17	7	–	–	–	–	45	116	0·02
February supply profile														
Cheese	–	25	314	415	415	415	361	314	268	221	107	–	2855	0·55
Casein	–	208	208	208	208	208	208	208	208	208	208	–	2076	0·40
Butter	7	–	–	9	45	1	–	–	–	–	–	60	122	0·02
WMP‡	2	–	–	4	21	1	–	–	–	–	–	20	47	0·01
SMP‡	7	–	–	4	19	1	–	–	–	–	–	60	91	0·02

Volume of products produced, tonnes

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
March supply profile													
Cheese	–	–	19392	38334	45553	45550	45980	43809	36313	30007	9694	–	314632
Casein	–	5417	6927	7099	7133	7133	7191	7329	7657	7916	7944	–	71746
Butter	2278	7521	9143	8773	12012	10931	9652	8994	9464	9933	10256	4738	103694
WMP‡	1033	–	–	–	3601	2476	956	–	–	–	–	2197	10261
SMP‡	3465	–	–	–	7062	4893	1850	–	–	–	–	7238	24508
February supply profile													
Cheese	–	2603	33173	44846	45834	46399	40657	36266	32445	27858	13794	–	323875
Casein	–	6780	6846	7016	7178	7261	7315	7474	7821	8099	8229	–	74020
Butter	670	9465	8995	9194	11164	8694	8846	9193	9687	10206	10602	6491	103208
WMP‡	290	–	–	558	2769	67	–	–	–	–	–	3032	6716
SMP‡	1098	–	–	1134	5435	136	–	–	–	–	–	9596	17399

* Mean calving date 14 March, Mean calving date 14 February.
† Capacity constraint 3 = cheese processing capacity of 415 192 000 litres/month; casein processing capacity of 207 596 000 litres/month.
‡ WMP, whole milk powder; SMP, skim milk powder.

Table 10. *Monthly net milk value, milk price and component values of milk for the March* and February* supply profiles utilizing capacity constraint 3†*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Adjusted total‡	Average
March milk supply profile															
NMV§ (€m)	9	65	112	172	228	215	211	201	177	163	106	26	1683	1682	
Milk price (€/litre)	0·18	0·41	0·29	0·31	0·31	0·31	0·32	0·34	0·35	0·36	0·37	0·25			0·32
Fat value/kg (€)	3·43	2·51	1·67	1·34	1·62	1·60	1·45	1·42	1·58	1·77	2·45	4·56			1·73
Protein value/kg (€)	1·42	9·83	7·64	8·54	8·33	8·23	8·82	8·99	8·55	8·35	7·71	1·88			7·71
Carrier/litre (€)	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02			−0·02
February milk supply profile															
NMV§ (€m)	−2	90	150	194	222	200	189	180	168	159	121	49	1719	1703	
Milk price (€/litre)	−0·12	0·39	0·29	0·30	0·31	0·32	0·33	0·35	0·35	0·37	0·38	0·35			0·33
Fat value/kg (€)	–	2·30	1·34	1·30	1·57	1·41	1·45	1·55	1·66	1·84	2·29	6·06			1·73
Protein value/kg (€)	–	10·12	8·14	8·55	8·46	8·65	8·88	8·85	8·47	8·28	7·89	2·51			7·60
Carrier/litre (€)	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02	−0·02			−0·02

* Mean calving date 14 March, Mean calving date 14 February.
† Capacity constraint 1 = cheese processing capacity of 415 192 000 litres/month; casein processing capacity of 207 596 000 litres/month.
‡ The effect of seasonality on base price, variation in milk composition removed.
§ NMV, net milk value (TR – TC).

values, the NMV increased by 17% to €1785·8, with an average milk price across the year of 34·4 cents/litre. The value per kg of fat and per kg of protein was €2·57 and €7·25, respectively. The current analysis highlights how sensitive the model outcomes are to the product market values assumed in the analysis.

DISCUSSION

Moving from a national mean calving date of mid-March to a mean calving date of mid-February consistently resulted in higher NMVs, higher milk prices and resulted in greater quantities of cheese and casein being produced. In addition, as demonstrated in the current analysis, the processing capacity constraints had a considerable impact on the product portfolio and the NMVs that could be generated from the available milk pool. As the cheese and casein processing capacity became less constrained from Cap 1 to Cap 3, the value per kg of protein increased as more protein was required to produce more cheese and casein. Simultaneously, as the protein value increased, the value per kg of fat decreased as less butter and WMP were being produced as proportionally more of the available milk was going into cheese and casein production. The analysis presented here demonstrates how sensitive the model outputs were to changes in the model inputs and how the optimal industry strategy in terms of the type and volume of products produced is highly dependent on many variables like the market value of products, the volume and composition of milk received and processing capacities. Based on the current analysis and on Shalloo *et al*. (2007), moving the mean calving date from mid-March to mid-February is a profitable and feasible strategy for both farmers and processors in Ireland.

Seasonal models and milk payment systems

Simulation models are powerful tools that allow the impact of changes to a system to be examined (Rozinat *et al*. 2007), thus allowing for informed decisions. Processing sector models have been developed and utilized in the dairy industry as decision support tools for many years. Benseman (1986) developed a dual-purpose linear programming (LP) model to simulate long-term and short-term production planning in the New Zealand dairy industry. The model accounted for short-term (seasonality, market prices) and longer-term (investments) fluctuations in terms of milk availability and quality, transport costs, processing capacities and costs, product yields and product market prices. This model was utilized by the New Zealand Co-operative Dairy Company for many years to inform day-to-day production plans and long-term strategies saving them in excess of NZ$1 million per year by exploiting downstream processing. The co-operative utilized the model to highlight running costs of plants and subsequently shut plants down during low intake months. Nicholson & Fiddaman (2003) developed a dynamic dairy systems model for the US to understand the sources of price volatility and to assess the impact of dairy policies on milk price volatility. Similar to the model presented here, the US model captured farm milk supply, allocation of milk to dairy products, processing and storage of manufactured product. In addition, the model included wholesale product demand which was seasonal and adjusted to price changes. The analysis found that government minimum price regulation resulted in greater price volatility, but price support programmes and trade agreements tended to stabilize prices. Similar to the model of Papadatos *et al*. (2002), the current model allowed the potential gains and losses for producers and processors to be estimated from changing: (i) the milk supply profile, (ii) the processing capacity, (iii) the product market values, (iv) the milk composition and (v) the product mix. The current analysis demonstrated how sensitive the model is to changes in each of these variables with milk with a higher fat and protein composition producing greater product yields and a milk supply profile with a lower peak-to-trough ratio producing greater industry returns.

A tool commonly used in the dairy industry to encourage a desirable milk supply profile is seasonal milk payment systems. In New Zealand, seasonal milk payments were implemented in domestic milk markets whereby a high price was paid when milk was in short supply to encourage more milk to be supplied when demand was higher, and a low milk price was paid when supply was plentiful to discourage producers from producing more milk (Blackwell 2001). The aim of this pricing system was to reward farmers who modified their supply profile and to help processors meet capacity constraints and product demand. As demonstrated in the analysis presented here, the relative values per kg of fat and protein per month could be used as incentives to producers to modify their calving pattern and feeding regimes so as to produce milk with higher fat and protein percentages with a view to maximizing their returns.

Factors affecting seasonality

A number of factors within processing facilities are affected by the seasonal milk supply profile. The seasonal milk supply profile in Ireland has developed over the years as it is a low-cost means of producing milk. Although it is a low-cost system at farm level it is costly at processor level in terms of processing costs, inefficient capacity utilization, inefficient transport requirements and product mix limitations. The structure of the Irish processing sector has been dictated to some extent by the seasonal supply profile.

Capacity

As demonstrated in the current paper, if the capacity to produce high-value products is constrained, the returns to processors and producers are reduced. As the capacity to produce high-value products increased the quantity of product produced increased, the revenue increased, the NMV and milk price also increased.

The processing capacity in Ireland has been built around the seasonal supply profile to allow the peak supply in May and June to be processed. As a result of this, the year-round capacity utilization is low at *c*. 0·60 (Prospectus 2003) relative to 0·92 and 0·93 capacity utilization in Denmark and The Netherlands, respectively (Prospectus 2003). However, the capacity utilization in Ireland during May and June is high, at *c*. 0·92 (T. J. Flanagan, personal communication). In addition, milk transport capacity is affected by the seasonal milk supply profile with a sufficient number of milk tankers required to accommodate peak supplies, resulting in spare capacity during the periods of low milk volumes (Quinlan *et al*. 2005), which is inefficient. The Food Harvest 2020 report (DAFF 2010) suggests that milk production in Ireland will have increased by 50% by 2020; if this occurs, the Irish dairy industry is facing a considerable challenge in relation to the ability to process this additional milk at the peak. Prospectus (2003, 2009) and Food Harvest 2020 (DAFF 2010) have repeatedly highlighted the need for investment at processor level so as to maximize returns and take advantage of the current market opportunities. However, whether the industry should invest to increase peak capacity and continue with the inefficiencies of the current seasonal production system or whether the current seasonal supply profile should be altered requires a comprehensive appraisal of the industry, at both farm and processor levels.

Labour

The seasonal milk supply profile has implications for the labour requirements at the processor level. During the peak months, when plants are operating at close to full capacity, the labour requirement is high with additional part-time seasonal staff being hired. In contrast, in the months of January–March and October–December, when milk supply is at its lowest and plant capacity utilization is quite low, the labour requirement is also low. As a result, the type and specification of contracts within processing facilities are largely dictated by the seasonality of milk production. In the current analysis, labour costs were incorporated into the volume-related processing costs/litre and the product-related processing costs/tonne. As a result, the labour costs increased as the volume of milk being processed and the volume of product produced increased. Incorporating low-cost seasonal labour being employed at the peak would be a robust means of capturing the seasonality of labour costs.

Storage and financing

Storage and financing costs are incurred in the dairy industry from matching steady demand with seasonal milk supply (Keane & Killen 1980). In the current analysis, production exceeds demand for cheese from March through November and for butter, production exceeds demand from April through September. As a result, storage and financing costs are incurred in these months for the excess stock. The cost of storing and financing the excess stock has implications on the processing costs, NMV, milk price and component values of milk. Stock which is in storage has not been sold; therefore, processors have not been paid to cover the production costs nor the cost of the raw milk paid to the farmer. This is effectively working capital which is tied up in the production system and has implications for processors in terms of liquidity, insulating against price volatility and financing the everyday running of the business. Keane & Killen (1980) found in their analysis of the Irish dairy industry that production outweighed demand from April to September, with stock building from April, peaking in September and reduced to zero in March. Keane & Killen (1980) concluded that moving to a flatter supply profile would reduce the storage and financing costs. Nicholson & Fiddaman (2003) developed a dairy systems model for the US and paid particular attention to inventories of storable products, due to the seasonality of milk supply, arguing that stored products play a role in price setting. When stocks are low, market prices are high and when stocks are high, market prices tend to fall, both of which send signals in terms of demand and supply.

Product portfolio

The analysis presented in the current paper demonstrated how the changing product portfolio impacted on the NMV and milk price paid to producers. As the volume of milk used in the production of cheese and casein increased the NMV increased considerably. In January and December, when cheese and casein were removed from the product mix, due to the seasonal variation in milk composition, the NMV is greatly reduced and at times losses were generated when the milk volumes were too low to cover fixed costs. In addition, the composition of milk from both supply profiles varied which also impacted on the quantity of product produced from the available milk. Geary *et al*. (2010) found that milk with higher fat and protein compositions generated higher NMVs. In the LP model developed by Benseman (1986), the product yield was updated per month to account for the seasonal variation in milk composition. In the current analysis, the fat and protein composition of milk with a mean calving data of mid-February had higher fat and protein content than the mid-March milk. As a result, the February supply profile consistently generated higher NMVs. In addition, the product market values impact on the returns as demonstrated in the sensitivity analysis outlined in the current paper. Therefore, it should be noted that the optimal product mix could change between years as the product market values change.

To determine the optimal product mix for the industry, the processing sector model presented here should be linked with a farm systems model. By doing this, the impact on farm profit of changing the calving pattern and the impact at processor level in terms of product mix and NMV could be calculated and from this the optimal strategy for both producer and processor could be determined.

Practicalities of shifting the mean calving date

Since, the implementation of milk quota in 1984, the mean calving date in Ireland has slipped from mid-February to mid-March; however, in a no-quota situation the optimal mean calving date may be earlier (Shalloo *et al*. 2007). Shalloo *et al*. (2007) examined the influence of variation in mean calving date on the profitability of Irish pasture-based production systems in a no-quota scenario and found the optimal to be mid-February (lowest feed costs, highest farm profit) relative to 31 January, 1 March and 15 March. Research carried out in the north eastern part of Ireland (Ballyhaise in Cavan) would suggest that the optimum mean calving date may only be slightly later, for example, up to 10 days. The biggest components of the optimum mean calving date centre on technical grassland management rather than on region. To achieve this shift in the mean calving date, greater farm management is required in terms of grassland management, feed budgeting and the use of high Economic Breeding Index animals (Shalloo *et al*. 2007). At the processing level, the Irish dairy industry operates close to peak capacity (0·92) in the months of May and June; therefore, a shift from a mean calving date of mid-March to mid-February, which effectively lowers the peak, would be of benefit and could defer the requirement for capacity investment in the near future.

CONCLUSION

The analysis presented in the current paper illustrated that by moving the Irish national mean calving date from mid-March to mid-February the NMV generated would be greater and so the milk price paid to producers would also be greater. In addition, increasing the capacity to process high-value products has a considerable positive impact on dairy industry returns. The analysis also highlighted how sensitive the model outcomes were to the product market values with returns decreasing considerably as the market values of cheese and casein decreased. As the Irish dairy industry responds to the market opportunities being presented, it will need to determine what the optimal industry strategies are that will allow the industry to prosper. The model presented here in conjunction with the Moorepark Dairy Systems Model (Shalloo *et al*. 2004) could support the decision-making process. The impact of industry changes like a change in the mean calving date or a change in the product mix could be examined at farm and processor level using both models together to determine the net impact on returns at farm and processor level thus providing an indication of the optimum strategy for producer and processor alike.

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