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The costs of seasonality and expansion in Ireland's milk production and processing

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Abstract

Ireland's milk production sector relies on grass-based spring-calving systems, which facilitates cost advantages in milk production but entails a high degree of supply seasonality. Among other implications, this supply seasonality involves extra costs in the processing sector including elevated plant capacities and varying levels of resource utilisation throughout the year. If both the national raw milk production increased substantially (e.g. post-milk quota) and a high degree of seasonality persisted, extra processing capacities would be required to cope with peak supplies. Alternatively, existing capacities could be used more efficiently by distributing the milk volume more evenly during the year. In this analysis, an optimisation model was applied to analyse the costs and economies arising to an average Irish milk-processing business due to changes to the monthly distribution of milk deliveries and/or the total annual milk pool. Of the situations examined, changing from a seasonal supply prior to expansion to a smoother pattern combined with an increased milk pool emerged as the most beneficial option to the processor because both the processor's gross surplus and the marginal producer milk price increased. In practice, it may however be the case that the extra costs arising to the producer from smoothing the milk intake distribution exceed the processor's benefit. The interlinkages between the stages of the dairy supply chain mean that nationally, the seasonality trade-offs are complex and equivocal. Moreover, the prospective financial implications of such strategies will be dependent on the evolving and uncertain nature of international dairy markets in the post-quota environment.

Keywords

Ireland • linear optimisation • milk processing • expansion • seasonality costs

Introduction

Seasonal cost advantages may amplify seasonal production where output is storable (Hennessy and Roosen, 2003). In the Irish dairy market, this means that milk is produced mostly in grass-based spring-calving systems to reduce production costs. This seasonal mode of operations entails a series of implications throughout the entire dairy products supply chain, which reduces the cost advantages of grass-based milk production. The processing sector is confronted with highly seasonal deliveries of the perishable resource raw milk, which necessitates the provision of an infrastructure capable of coping with the resulting supply peaks. Further implications include poor plant capacity utilisation in the shoulder periods, a seasonal labour requirement and higher fixed costs (e.g. due to elevated stock holding costs). To overcome these challenges, the processing business could aspire to a more evenly distributed pattern of raw milk deliveries, which would allow for a higher degree of capacity utilisation and a targeting of the higher-margin, less price-sensitive markets (Downey and Doyle, 2007). However, smoothing the milk supply curve, either through milk imports or through adjusting calving dates (Keane and Killen, 1980), raises the costs of raw milk (Killen and Keane, 1978; Harte and O'Connell, 2007; Geary *et al.*, 2013).

The economic sustainability of seasonality in the dairy market is reconsidered in the context of a quota-free market. The Food Harvest 2020 Committee set a target of 50% growth in Irish milk production by 2020 (DAFF, 2010). In contrast, estimates regarding Ireland's potential to expand milk production by 2020 ranged from 20% to 30% (compared to 2008; e.g. ICOS, 2009; Keane, 2010: 3; Läpple and Hennessy, 2012). A substantial expansion requires the creation of additional processing capacities in case the seasonal milk supply pattern with its pronounced supply peak is maintained. Alternatively, in switching to a smooth milk supply curve, existing capacities could be utilised more efficiently. Given these prerequisites, the question arises how the economic performance of Irish milk-processing businesses could be affected by continued supply seasonality as compared to a smoother supply distribution in a quota-free setting.

This paper seeks to systematically evaluate the costs and economies arising to Irish milk-processing businesses as a

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result of certain strategy changes, viz. changes to the monthly distribution of milk supplies alone, to the annual milk volume alone or to both the milk supply distribution and volume combined. The analysis presented builds upon previous work; therefore, only essential information is provided here on the model, input data and scenarios. The reader is referred to Heinschink *et al*. (2012, 2013) and Heinschink (2014) for further details. In this paper, a concise description of the model and the data applied, as well as the scenarios analysed, is followed by a discussion of the implications due to the above-stated strategies. Emphasis is put on the costs and economies incurred by altering the degree of supply seasonality and/or the total milk quantity available. The article finishes with a discussion of the key findings and a conclusion.

Materials and methods

Model

Model purpose

The analysis was carried out using the Milk Processor Optimisation Model (MPOM) (Heinschink *et al*., 2012, 2013; Heinschink, 2014), a model designed for studying technical and financial implications of alternative milk supply profiles and quantities (Figure 1). The model file was prepared in Microsoft Excel and solved using GAMS/CPLEX. The results were processed in Microsoft Excel.

Optimisation mechanism

The MPOM was parameterised for a year, with a monthly time step as a multi-product problem of a model milk-processing enterprise. In the objective function, the total annual processor gross surplus was maximised, whereby total variable and fixed costs were deducted from the total sales revenue to identify the annual gross surplus. The objective function was subject to both required and optional constraints. The required constraints include maximum raw milk intake and processing capacities, while the optional constraints included minimum output quantities for individual dairy commodity product lines. The maximum gross surplus and the optimum product mix were established as follows: (a) the primary constraints were met in any case; (b) the milk solids were allocated to the individual product lines or combination of product lines with the highest margins up to their capacity maxima and subject to the availability of raw milk; and (c) the remaining milk solids were processed into lower-margin products with spare capacities up to the point at which the raw milk pool was exhausted. The optimum solution included the gross surplus-maximising product mix, the maximum gross surplus and the marginal values of the modelled milk solids.

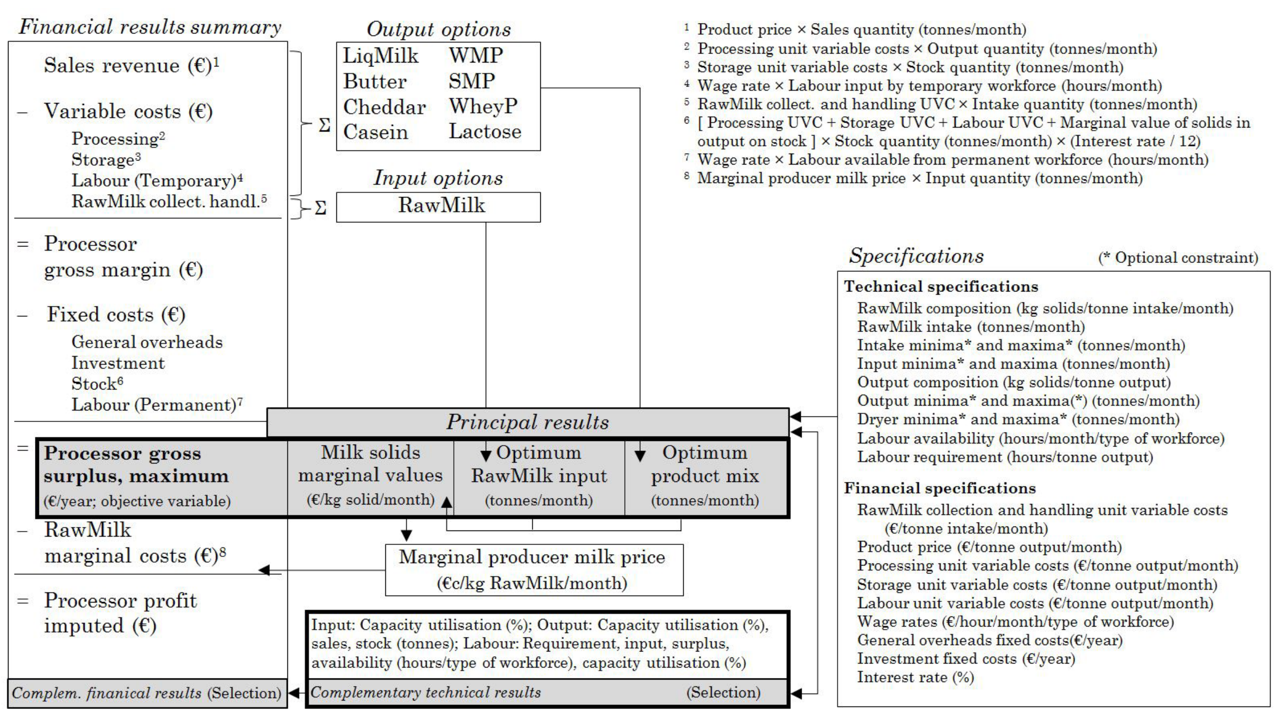

Figure 1. The Milk Processor Optimisation Model (MPOM). RawMilk = raw milk, manufacturing milk; LiqMilk = liquid milk; WMP = whole milk powder; SMP = skim milk powder; WheyP = whey powder; UVC = unit variable costs.

Post-optimisation calculations

Accounting rows were applied post-optimisation to calculate further results from the optimum solution, such as the marginal producer milk price (MPMP) and the financial results summary. The MPMP, or shadow price for raw milk, was calculated from (a) the value of milk constituents depending on the final product and (b) a constant volume deduction accounting for the raw milk collection and handling costs plus the total fixed costs expressed per kilogram of raw milk. The MPMP indicates the amount that a processor can pay for an extra kilogram of raw milk without reducing the maximum processor gross surplus. This implies that more-profitable products entail a higher MPMP than less-profitable ones as it is economical to only pay as much as the raw milk is worth to the processor. Therefore, each time the capacity maximum of a higher-margin product line (or combination of product lines) was fully exploited, the MPMP decreased to reflect the raw milk value if the next most profitable product (or combination of products) was manufactured.

Model output

A report of technical results was generated for each scenario, which included output-related quantities (production, sales and stock), degrees of capacity utilisation (milk intake, processing, marketing and labour pool), as well as labour requirement and contribution (by permanent and temporary workforce). In addition, a summary of financial results was compiled for each scenario, comprising sales revenue, variable and fixed costs, processor gross surplus and the marginal costs of raw milk (Table 1).

Calculation of strategy-related costs

The summaries of the financial results of two scenarios were juxtaposed (i.e. initial versus target scenario) in order to identify the strategy-related costs (i.e. seasonality and/or expansion). This comparison of strategies is presented as “initial scenario → target scenario”, and the results indicated are those identified for the target scenario. To facilitate comparisons among scenarios with different milk volumes, costs are given in euro cents (referred to as “cents” hereafter) per kilogram of raw milk processed. This implies that the unit margin of an indicator (e.g. processor gross surplus per kilogram of raw milk) could fall when moving from a scenario with a smaller annual raw milk pool to one with a larger one, whereas the total surplus could increase if the loss in unit margin was offset by the volume gain. The difference between the gross surpluses of the target and initial scenarios equalled the total strategy-incurred costs (TC) or, in case of negative costs, total strategy-incurred savings (TS). The TC (or TS) were broken down into activity costs (AC) and opportunity costs (OC) (Table 2). The AC comprised activities carried out by the processor (e.g. producing a certain output), whereas the OC were calculated as the difference between the AC and TC (or TS). A portion of the OC was due to labour hours available from the permanent workforce but not used for producing output (e.g. in the trough months due to reduced workload). The residual amount is explained by a less-profitable product mix and is referred to as product mix OC. The product mix OC are identical to the difference in the sales revenue between the compared cases.

Scenarios and data

Scenario description

Pairwise comparisons of four scenarios were made to examine the processor’s costs incurred by raw milk supply seasonality and/or expansion. The degree of seasonality, either average (Avg) or low (Low), was expressed through the monthly distribution of raw milk supplies. The situations pre-expansion (PreE) or post-expansion (Expan) differed by the annual raw milk pool available for processing (Figures 2 and 3). The Avg cases were characterised by a bell-shaped supply pattern typical for Ireland (derived from CSO: AKM01, data set 2009), which was similar in a perennial observation (CSO: AKM01, data sets 2008–2013). The hypothetical Low scenarios were based on a perfectly even calving pattern, which resulted in a low degree of supply seasonality; this pattern was closer to the raw milk distribution observed in the majority of continental European Union (EU) Member States. Both supply patterns were combined with (a) the baseline annual throughput to depict a situation before expansion (PreE; 273,746 t/yr) and (b) an increased annual throughput to model post-expansion scenarios (Expan; +50%). The raw milk pool in PreE represented the national average, quota-constrained milk processor supply, which was computed as total raw milk quantity delivered to milk-processing enterprises (CSO: AKM01, data set 2009) divided by the number of processors (derived from DAFM, personal communication; Agri-Food Market Analysis, 2007). The assumed increase in the Expan cases was based on the targeted national milk pool expansion of 50% by 2020 (DAFF, 2010: 41; Keane, 2010: 3).

Scenario specifications

To ensure that the differences between the scenarios’ results were related only to supply seasonality and/or expansion, key specifications were common in all four scenarios. This included product composition; product prices (36-mo averages of actual price data from 2008 to 2010; derived from various sources as identified in Heinschink *et al*., 2013, and Heinschink, 2014: 127ff.); unit variable costs of processing, storage and labour; hourly wage rates, the interest rate, the type of raw milk purchased (RawMilk = cows’ milk) and the eight product options (LiqMilk = liquid milk, Butter, Cheddar = cheddar cheese, Casein = rennet casein, WMP = whole milk powder, SMP = skim milk powder, and the by-products WheyP = whey powder, Lactose = lactose powder) (Heinschink *et al*., 2012). This set of commodities represents the products that are particularly important in Ireland's national product mix (IDB, 2009, 2010a, 2012; NMA, 2012). LiqMilk is perishable and domestic demand is not expected to increase post quota removal (CSO: AKA02; Heinschink, 2014: 120). Thus, LiqMilk output was pre-specified and identical in all scenarios and is not discussed further. Varying scenario specifications are listed in Table 3 (Heinschink *et al*., 2012, 2013; Heinschink, 2014). Some specifications were common in the PreE scenarios only. In all PreE scenarios, the monthly maximum output capacities for Butter, Cheddar, Casein and WMP were derived as the national output (IDB, 2010a) divided by the number of processors manufacturing that product line (DAFM, personal communication, Milk and dairy establishments approved under the hygiene regulations, quarterly verification for the status of premises, 15 July 2010) and divided by 12. Both the monthly maximum RawMilk intake and the dryer capacities were derived from the peak capacity requirement in a seasonal situation based on the assumption that the plant will operate close to its upper limit of the RawMilk intake and dryer equipment in the peak month (Heinschink, 2014: 123). SMP, WMP, WheyP and Lactose outputs were limited by the availability of milk solids. In addition, SMP, WMP and WheyP were constrained by maximum dryer capacity. The number of contract workers was calculated from the total annual labour hours required in PreE-Low divided by the annual work hours available from a full-time worker; the latter was computed as 40 h/wk × 48 work wk/yr = 1,920 h/worker per year (Oireachtas, 1997). This approach was based on the rationale that a processing business would (a) only employ the number of contract workers required for processing regularly available RawMilk quantities and (b) additional workforce would be hired temporarily for coping with the peak supplies. The specifications in the Expan scenarios deviated from the PreE ones as follows. To accommodate the peak milk supply around May, selected capacity maxima (RawMilk, Butter and Dryer) were expanded in Expan-Avg, which also incurred fixed costs on investment. In contrast, no plant capacity expansion was required in Expan-Low. In addition, the modelled plant's marketing capacity for WMP was raised

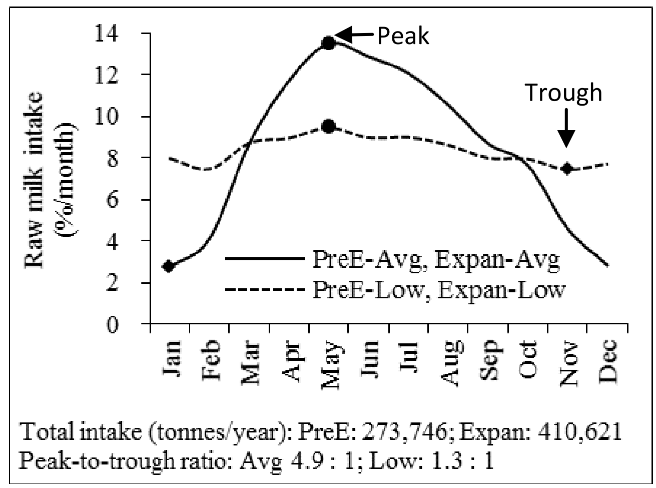

Figure 3. RawMilk intake, by month (%). PreE = pre-expansion; Expan = post-expansion; Avg = average degree of supply seasonality; Low = low degree of supply seasonality.

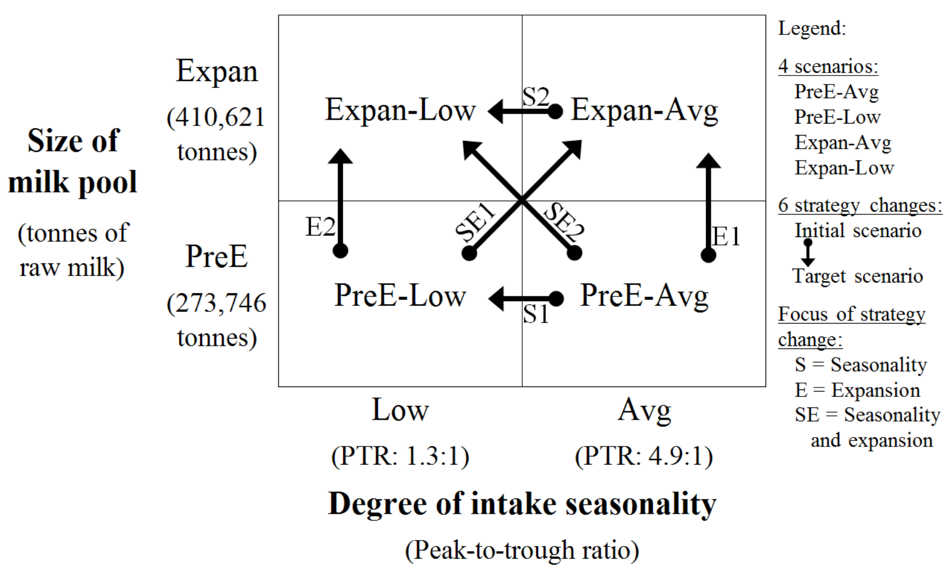

Figure 2. Overview of scenarios and strategy changes. PreE = pre-expansion; Expan = post-expansion; Avg = average degree of supply seasonality; Low = low degree of supply seasonality.

in both cases based on the assumption that the Irish dairy industry would successfully implement market development and penetration strategies to enhance the sales volumes and share of the growing global market for milk powders (IDB, 2010b). The enlarged milk pool entailed a higher workload; hence, the labour pool was raised in both Expan situations using the same approach as applied in PreE, but based on the workload identified for Expan-Low. Finally, some specifications varied in all four scenarios. The total quantity of milk solids available for the products depended on the supply profile and volume, which differed in all four scenarios. Differing unit variable costs of RawMilk collection and handling were assumed in all situations (Avg, Low; Pre-E, Expan) as milk assembly is more costly in the trough months due to longer collection distances and underutilisation of tanker capacities (adapted from Quinlan *et al*., 2011).

Validation

Model structure and assumptions were scrutinised in two independent expert reviews by dairy technologists at Teagasc Moorepark, Ireland's national dairy research centre. The validation focussed on ensuring that the model provided an accurate representation of processing decisions in Irish dairy manufacturing enterprises. Furthermore, processing cost data were validated in a two-stage process. First, preliminary unit variable processing costs for each product were prepared in consultation with Moorepark dairy technologists based on data from a survey conducted by Breen (2001). Next, dairy co-operative production managers and management accountants were consulted in order to calibrate the cost data for each product line. Through an iterative process, the experts revised the cost estimates until a consensus was reached on a representative set of costs per unit of output for each product line.

Results

Scenario results are described under a series of headings outlined below. Common to most optimisation models, outputs are sensitive to assumptions and data specifications. Accordingly, the presentation focusses on key interlinkages and the development and/or stability of individual model indicators.

Product mix and capacity utilisation

It is apparent from the dissimilarities between Avg and Low that the monthly optimum product mix was strongly affected by the seasonality of RawMilk supplies. Unlike the Low scenarios, the capacities of the most profitable manufactured product Casein could *not* be exploited fully in the Avg cases due to RawMilk shortages in the winter months. The utilisation of the annual Casein capacity increased, however, when a larger milk pool was available (Expan-Avg). Moreover, the Avg scenarios annually involved a higher proportion of the less-profitable milk powders than the Low cases. This was due to the supply peaks in the summer months, in which the capacities of the higher-margin product lines were reached and a large proportion of RawMilk was processed into lower-margin products (Figures 4 and 5).

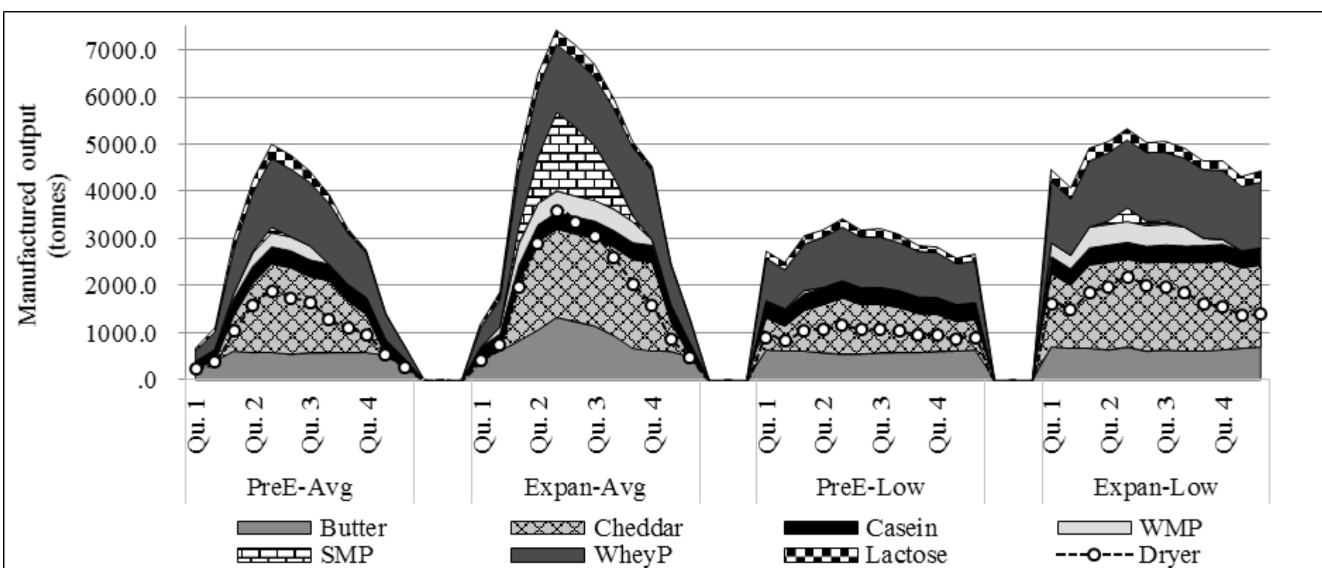

Figure 4. Manufactured output, by month (tonnes). PreE = pre-expansion; Expan = post-expansion; Avg = average degree of supply seasonality; Low = low degree of supply seasonality; WMP = whole milk powder; SMP = skim milk powder; WheyP = whey powder.

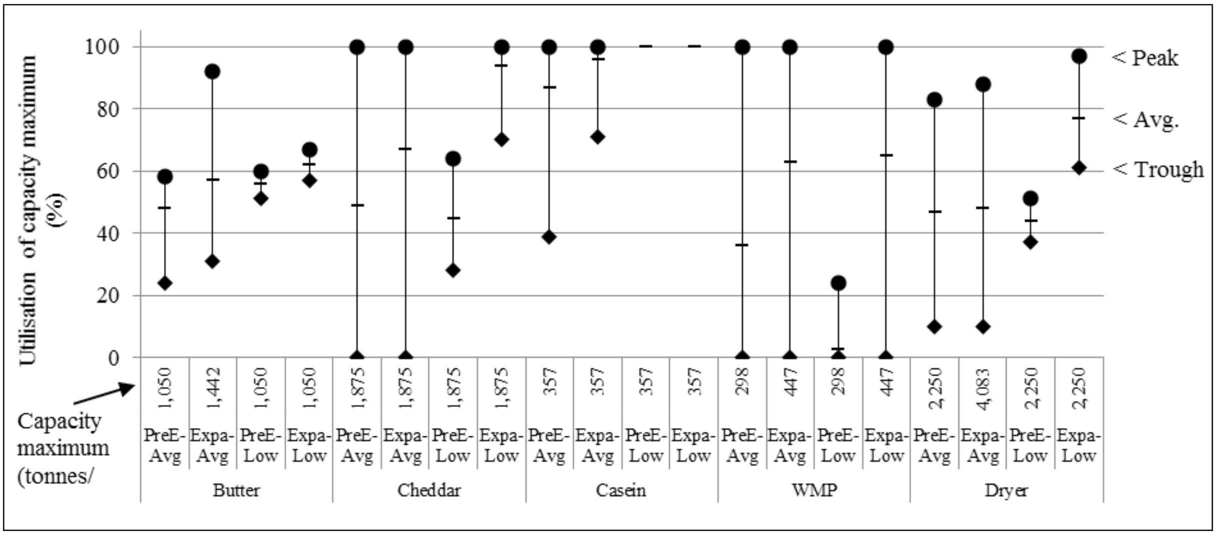

Figure 5. Utilisation of capacity maximum – trough month, peak month and annual average (%). PreE = pre-expansion; Expan = post-expansion; Avg = average degree of supply seasonality; Low = low degree of supply seasonality; WMP = whole milk powder.

Product storage

In the MPOM, stock holding costs consisted of (a) variable costs depending on storage duration and (b) stock fixed costs representing interest on the resources tied up in stock (i.e. variable costs of processing, storage and labour, as well as marginal value of milk solids). The scenario results illustrate how a higher degree of seasonality affects the stock holding costs.

Following the RawMilk supply peak, large stocks of output had built up in the PreE-Avg and Expan-Avg scenarios, which in turn resulted in stock holding costs approximately five times as high as in PreE-Low and Expan-Low, respectively. Stock fixed costs amounted to approximately two-thirds of total stock holding costs in all scenarios, which highlights the importance of OCs arising from resources tied up in stocks (Figure 6).

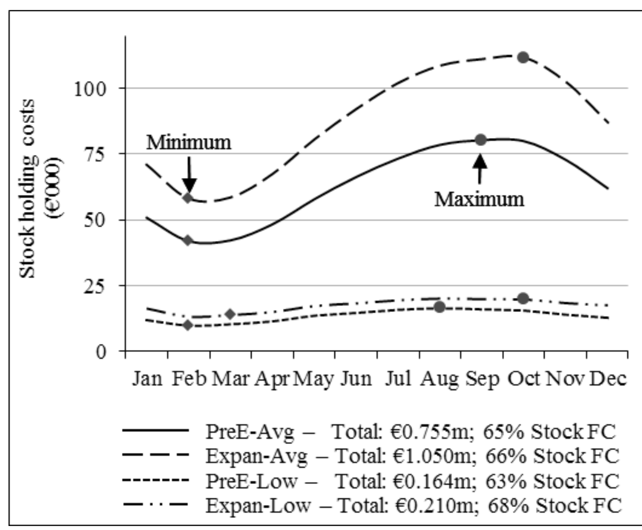

Figure 6. Stock holding costs, by month (cents/kg RawMilk). Stock holding costs = storage variable costs + stock fixed costs; FC = fixed costs; PreE = pre-expansion; Expan = post-expansion; Avg = average degree of supply seasonality; Low = low degree of supply seasonality.

Strategy-incurred costs

Because the PreE and Expan cases operated different milk pools, financial indicators are expressed as euro cents (referred to as cent) per kilogram of RawMilk to facilitate cross-comparisons (Table 1). Four types of strategy changes were investigated, whereby the initial situation prior to the strategy change and the targeted situation post-strategy change were compared (denoted as initial scenario → target scenario) (Table 2). First, total throughput was retained, while the RawMilk supply curve was flattened (PreE-Avg → PreE-Low, Expan-Avg → Expan-Low) to examine the impact of supply seasonality alone. Second, total throughput was increased, while the supply distribution in place was retained (PreE-Avg → Expan-Avg, PreE-Low → Expan-Low) to examine the impact of expansion alone. Third, both total throughput and the degree of supply seasonality were increased (PreE-Low → Expan-Avg) and fourth, total throughput was increased, while the degree of supply seasonality was reduced (PreE-Avg → Expan-Low) to study the impact of these combined strategies.

Strategy changes taking a seasonal supply distribution as the starting point are of special interest when discussing the future Irish dairy market (PreE-Avg → Expan-Avg, PreE-Avg → Expan-Low). The strategy changes starting from a lower

Table 1. Financial results summary, in terms of annual average (cents/kg RawMilk)

Financial results summary[1]	PreE-Avg	Expan-Avg	PreE-Low	Expan-Low
Sales revenue	37.32	35.34	37.76	36.11
Variable costs	-7.02	-6.20	-6.72	-6.17
RawMilk collection and handling	(0.97)	(0.92)	(0.90)	(0.84)
Processing	(5.80)	(5.05)	(5.77)	(5.28)
Storage	(0.10)	(0.09)	(0.02)	(0.02)
Labour (temporary)	(0.15)	(0.14)	(0.02)	(0.03)
Gross margin	30.30	29.14	31.03	29.94
Fixed costs	-2.70	-3.39	-2.55	-1.98
Overheads	(1.46)	(0.97)	(1.46)	(0.97)
Investment	(0.00)	(1.28)	(0.00)	(0.00)
Stocks	(0.18)	(0.17)	(0.04)	(0.03)
Labour (permanent)	(1.06)	(0.97)	(1.06)	(0.97)
Gross surplus	27.61	25.75	28.48	27.96
Marginal producer milk price[2]	24.09	22.12	24.69	24.68

[1]PreE = pre-expansion; Expan = post-expansion; Avg = average degree of supply seasonality; Low = low degree of supply seasonality. Minor differences may occur due to rounding to nearest significant figure.
[2]Annual weighted average.

Table 2. Strategy-incurred costs and change in the MPMP, in terms of annual average (cents/kg RawMilk)

Costs incurred[1]	Seasonality (S)		Expansion (E)		Seasonality + expansion (SE)	
Strategy change	Retain total throughput, flatten distribution of milk intake		Increase total throughput, retain distribution of milk intake		Increase both total throughput and intake seasonality	Increase total throughput, reduce intake seasonality
	S1	S2	E1	E2	SE1	SE2
Initial scenario[2]	PreE-Avg	Expan-Avg	PreE-Avg	PreE-Low	PreE-Low	PreE-Avg
↓	↓	↓	↓	↓	↓	↓
Target scenario[2]	PreE-Low	Expan-Low	Expan-Avg	Expan-Low	Expan-Avg	Expan-Low
Activity costs, total (AC)	-0.30	-1.31	-0.12	-1.13	0.19	-1.43
RawMilk coll. hand.	(-0.07)	(-0.07)	(-0.06)	(-0.06)	(0.02)	(-0.13)
Processing	(-0.02)	(0.23)	(-0.75)	(-0.49)	(-0.72)	(-0.52)
Stock holding[3]	(-0.22)	(-0.20)	(-0.02)	(-0.01)	(0.20)	(-0.23)
Labour used[4]	(0.01)	(0.02)	(-0.09)	(-0.08)	(-0.10)	(-0.08)
General overheads	(-0.00)	(-0.00)	(-0.49)	(-0.49)	(-0.49)	(-0.49)
Investment	(-0.00)	(-1.28)	(1.28)	(0.00)	(1.28)	(0.00)
Opportunity costs, total (OC)	-0.57	-0.90	1.97	1.64	2.54	1.08
Product mix[5]	(-0.44)	(-0.77)	(1.98)	(1.64)	(2.42)	(1.21)
Labour surplus[6]	(-0.13)	(-0.13)	(-0.01)	(-0.00)	(0.12)	(-0.13)
Strategy-inc. costs, total (TC/TS)[7]	-0.87	-2.21	1.86	0.51	2.73	-0.36
MPMP change[8]	0.60	2.56	-1.97	-0.01	-2.57	0.59

[1]Reported values are the differences between the target and initial scenarios. Positive values represent costs, negative values designate economies of the target scenarios relative to the initial scenarios. Minor differences may occur due to rounding to nearest significant figure.
[2]PreE = pre-expansion; Expan = post-expansion; Avg = average degree of supply seasonality; Low = low degree of supply seasonality.
[3]Stock-holding costs = storage variable costs + stock fixed costs.
[4]Labour costs incurred by production, attributable to product mix.
[5]Product mix OC = TC or TS - AC - labour surplus OC. Product mix OC are the gross surplus forgone in the target scenario due to a less-profitable product mix compared to the initial scenario, or surplus generated in the target scenario due to a more profitable product mix compared to the initial scenario; identical to difference in sales revenue of target scenario relative to initial scenario.
[6]Labour costs incurred by labour available from permanent workforce but not attributable to product mix due to RawMilk shortage (in winter months).
[7]TC = total strategy-incurred costs. Where TC assume a negative value, they are referred to as TS = total strategy-incurred savings.
[8]MPMP = marginal producer milk price, annual weighted average. Positive values denote increases, negative values stand for decreases in the MPMP compared to the initial scenario.

degree of supply seasonality (PreE-Low → Expan-Low, PreE-Low → Expan-Avg) are hypothetical in the context of Ireland's current milk supply profile. However, they are included here to aid the understanding of how competitors with a less-seasonal mode of operations, closer to the practice in the majority of continental European businesses, maintain a financial advantage compared to the situation of seasonal milk deliveries. It is acknowledged that Ireland-specific data imposed on the Low scenarios may not fully mirror the conditions met by continental processing businesses.

Seasonality-incurred costs

The seasonality-incurred costs provide information on the financial disadvantage of a seasonally operated milk-processing business compared to one with a more smoothly distributed milk intake. PreE-Low registered TS of 0.87 cents/kg of RawMilk compared to PreE-Avg, a quarter of which was due to lower stock holding costs and two-thirds resulted from lower total OC. The higher-margin product mix was responsible for half of the TS. At 2.21 cents, the TS were notably elevated in Expan-Low compared to those in Expan-Avg. The majority of the TS was attributable to the absence of plant investment (1.28 cents) as well as the presence of the higher-value product mix (0.77 cents). A smoother supply distribution does, however, not necessarily lower all costs. The increased processing costs (0.23 cents) absorbed a portion of the TS, but this did not offset the higher profitability of the Expan-Low product mix compared to the one in Expan-Avg (Table 2).

Expansion-incurred costs

These expansion-incurred costs indicate the financial differences induced by a larger annual RawMilk volume compared to a lower-volume initial scenario, for instance,

Table 3. Selected technical and financial scenario specifications[1]

Data set	Unit	PreE-Avg	Expan-Avg	PreE-Low	Expan-Low
Technical specifications					
RawMilk intake	t/yr	273,746	410,621	273,746	410,621
FAT	t/yr	(10,106)	(15,159)	(10,324)	(15,486)
PRO	t/yr	(9,123)	(13,684)	(9,137)	(13,706)
LAC	t/yr	(12,606)	(18,909)	(12,565)	(18,848)
Capacity maxima					
RawMilk	t/mo	41,300	55,544	41,300	41,300
Butter[2]	t/mo	1,050	1,442	1,050	1,050
WMP[2]	t/mo	298	447	298	447
Dryer[2]	t/mo	2,250	4,083	2,250	2,250
Labour pool	h/mo	11,520	15,840	11,520	15,840
Financial specifications					
RawMilk coll. hand. UVC, w.avg.[3]	Cents/kg RawMilk	9.73	9.18	9.01	8.44
Investment FC[4]	€/Year 1	0	5,265,377	0	0
RawMilk capacity expansion	€/Year 1	(0)	(2,065,000)	(0)	(0)
Butter capacity expansion	€/Year 1	(0)	(444,127)	(0)	(0)
Dryer capacity expansion	€/Year 1	(0)	(2,756,250)	(0)	(0)

[1]Adapted from Heinschink (2014: 133, 171). PreE = pre-expansion; Expan = post-expansion; Avg = average degree of supply seasonality; Low = low degree of supply seasonality; WMP = whole milk powder; LAC = lactose.
[2]Adapted from Quinlan (2013).
[3]RawMilk coll. hand. UVC, w.avg. = RawMilk collection and handling unit variable costs, annual weighted average; Heinschink (2014: 127). Adapted from Quinlan *et al*. (2011).
[4]Investment FC = investment fixed costs; comprising all plant capacity expansion projects = depreciation (15 yr useful life) + financing costs (5%/yr on outstanding loan, Year 1).

a post-quota situation relative to a quota-constrained one. Even though most of the AC items undercut those of the pre-expansion reference cases, the expansion caused the gross surplus per kilogram of RawMilk to decline by 0.51 cents in Expan-Low and by 3.6 times as much (1.86 cent) in Expan-Avg, which was mostly due to the product mix OC (Expan-Avg: 1.98 cents; Expan-Low: 1.64 cents). The product mix OC are explained by the changes in capacity utilisation and sales revenue per kilogram of RawMilk. Compared to the PreE situations, the capacities of the more-rewarding products were better utilised in both Expan situations due to augmented milk supplies in the trough months. However, a larger proportion of the annual RawMilk pool was processed into lower-margin output during the peak period. As a result, the average sales revenue per kilogram of RawMilk decreased in both Expan cases. The decline in total AC did not make up for the reduction in sales revenue; thus, the product mix OC were elevated in the Expan case compared to the respective PreE reference. No investment-related costs arose in Expan-Low, whereas the required plant upgrade in Expan-Avg incurred 1.28 cents of investment fixed costs (Table 2).

Costs incurred by a combined strategy

Of all the strategy changes analysed, moving from a smooth milk supply pre-expansion to a seasonal one post-expansion entailed the highest financial deterioration (TC in PreE-Low → Expan-Avg: 2.73 cents). The savings per kilogram of RawMilk in processing, labour used and general overheads did not compensate for the less-profitable product mix and the extra costs entailed by investment, stock holding and surplus labour (Table 2). These results suggest that it is strongly preferable for processing businesses with a fairly smooth supply distribution at present to retain a low degree of seasonality in a quota-free market. In contrast, converting from a seasonal situation pre-expansion to a smoother supply pattern post-expansion emerged as the only strategy change by means of which the processor gross surplus increased following the expansion of the RawMilk pool (PreE-Avg → Expan-Low: 0.36 cents/kg of RawMilk). The extra RawMilk could be processed without capacity increases. In addition, total AC and the OC of surplus labour per kilogram of RawMilk declined relative to PreE-Avg. The product mix OC were due to the higher proportion of Cheddar, milk powders and WheyP compared to the initial case; however, they were the lowest among all expansion scenarios (1.21 cents) (Table 2). These results suggest that Irish processing businesses could benefit from smoothing the supply distribution in the future market environment.

Marginal producer milk price

The weighted average MPMP per kilogram of RawMilk was 24.09 cents in PreE-Avg, 22.12 cents in Expan-Avg, 24.69 cents in PreE-Low and 24.68 cents in Expan-Low (Table 1). The MPMP was compared to identify its development in the event of a strategy change (Table 2). It is apparent that a lower degree of seasonality entailed a higher MPMP than the situations characterised by a seasonal milk supply curve (PreE-Avg → PreE-Low: 0.60 cents; Expan-Avg → Expan-Low: 2.56 cents). This was due to the smaller share of lower-margin products, reduced variable costs of RawMilk collection and the higher total fixed costs in the Low cases compared to the Avg ones. The MPMP declined when the RawMilk quantity was expanded in a seasonally operated market (PreE-Avg → Expan-Avg: -1.97 cents). Likewise, this development is mostly explained by a larger proportion of lower-margin products and elevated total fixed costs. Switching from a seasonal quota-constrained to a smooth post-quota situation (PreE-Avg → Expan-Low) was the only expansion strategy resulting in a modest increase in the MPMP of 0.59 cents. This amount represented the mark-up that a processor could pass on to the milk supplier under the assumed strategy change.

Discussion

Implications of strategy changes

The costs arising to an average Irish milk-processing business in the course of certain strategy changes, namely adaptation of the supply distribution and/or annual milk volume, were examined by means of scenario analysis. It is therefore important to consider the results against the background of the model and scenario specifications.

In the seasonality analysis, it was found that the processor achieved a poorer financial performance per kilogram of RawMilk in the scenarios characterised by a more seasonal milk intake profile both before and after expansion. For instance, the processor's gross surplus in the Avg cases fell short of that in the Low cases by -3.1% (–0.87 cents) in the PreE-Avg → PreE-Low comparison and by -7.9% (-2.21 cents) in the Expan-Avg → Expan-Low comparison. Moreover, the MPMP was lower when the RawMilk deliveries were highly seasonal, namely by -2.4% (-0.60 cents) in the PreE-Avg → PreE-Low comparison and by -10.4% (-2.56 cents) in the Expan-Avg → Expan-Low comparison. The results reported for the expansion analysis suggest that the processor's financial performance *per kilogram of RawMilk* is likely to decline in a quota-free environment. The processor's gross surplus decreased by -6.7% (-1.86 cents) in the PreE-Avg → Expan-Avg strategy change and by -1.8% (-0.51 cents) in the PreE-Low → Expan-Low strategy change. At the same time, the MPMP declined by -8.2% (-1.97 cents) in the PreE-Avg → Expan-Avg strategy change but remained almost unchanged in the PreE-Low → Expan-Low strategy change (-0.0%, -0.01 cents). When the RawMilk pool was upscaled and the degree of seasonality was reduced (PreE-Avg → Expan-Low), the processor surplus increased by 1.3% (0.36 cents) and the MPMP by 2.4% (0.59 cents)/kg of RawMilk.

Producer–processor trade-off

Given its seasonal supply curve, the Irish dairy sector has the following two principal strategic options with respect to the post-quota profile of milk supplies: (a) maintenance of a high degree of seasonality (PreE-Avg → Expan-Avg) or (b) reduction of the degree of seasonality (PreE-Avg → Expan-Low). Unlike the PreE-Avg → Expan-Avg situation, the strategy change of PreE-Avg → Expan-Low improved both the processor's overall financial performance (+0.36 cents) and the MPMP (+0.59 cents) per kilogram of RawMilk in the expansion scenarios. In practice, it may, however, be the case that the processor's benefit from a smoother milk intake curve is offset by the extra costs arising to the milk producer (e.g. Keane and Killen, 1980; Davis and Kirk, 1984; Geary *et al*., 2012, 2013), especially due to a larger dependence on concentrates, extra labour requirements and often higher investment in housing. For example, Finneran *et al*. (2012) confirm and quantify a substantial cost advantage of grazed grass compared to alternative feeds on Irish farms. Hence, the mark-up available for the producer's milk price may fall short of the extra milk production costs incurred by a move away from spring calving.

Irish milk processors have traditionally used liquid milk contracts with seasonal bonuses to incentivise autumn/winter calving, thereby inducing greater off-peak milk supplies. Data from the Teagasc eProfit Monitor farm benchmarking programme suggest that production costs per litre are markedly higher for herds focussed on winter milk production compared to spring-calving herds (Connolly, personal communication, Summary 2009–2013. Teagasc Dairy eProfit Monitor Data, 5 September 2014). Specifically, over the period 2009–2013, total variable costs per litre were on average 1.17 cents/L (9.8%) higher for winter production herds than for spring-focussed herds that participated in the eProfit Monitor programme. Moreover, eProfit Monitor data also indicated that some fixed costs such as labour and machinery also tended to be higher (together by ~1.00 cent/L) for winter milk production herds. Accordingly, based on these data, modifying calving dates to reduce seasonality may be quite costly for producers.

Plant capacities and sunk costs

An important aspect of milk supply seasonality is capacity utilisation: Ireland's processing capacities were utilised at 61% in the year 2001, which was notably lower than the utilisation of major continental competitors, i.e. 92% in Denmark and 93% in the Netherlands (Prospectus, 2003: 30). On the one hand, slack processing capacities allow a greater degree of flexibility in the product mix: where margins of individual product lines are low or volatile, the processor can allocate milk more freely to the manufacture of the more-profitable product lines (Keane, 1980). On the other hand, spare plant and labour capacities impose a financial burden on the processing business due to higher fixed costs. Due to the absence of supply peaks, plants operating a flatter milk distribution evidently get by with smaller capacities compared to plants with more seasonal milk deliveries. The scenario results further suggest that smoothing the supply curve improves processor profitability. The processor may therefore consider reducing the degree of milk supply seasonality. However, if the investment in plant infrastructure has been already carried out, no infrastructure-related fixed costs savings are possible through flattening the supply profile when the annual milk pool is maintained (PreE-Avg → PreE-Low, Expan-Avg → Expan-Low). These sunk costs need to be considered in the choice of the post-quota strategy. No investment was required in the PreE-Avg → Expan-Low strategy change, which illustrates that sunk costs could be avoided post-quota by reducing the prevalent degree of supply seasonality and simultaneously expanding the annual milk pool (Heinschink *et al*., 2012: 240).

Conclusion

The analysis conducted in this paper indicates that Irish processors would derive a small financial benefit from smoothing the seasonal profile of milk deliveries, especially in the context of post-quota expansion. In such a scenario, the industry could avoid investment costs of additional capacity construction while elevating the average utilisation rates of existing plants. A thorough evaluation of Irish dairy strategy requires an industry-level perspective, assessing costs and benefits to all agents in the supply chain (e.g. Davis and Kirk, 1984; Downey and Doyle, 2007; Geary *et al*., 2012, 2013; Heinschink *et al*., 2012). It is noted that smoothing the Irish milk supply profile is likely to generate additional costs for milk producers. Taking into consideration the potential impact on producer costs, the advantage of smoothing production becomes more finely balanced. Based on the model input data used in the analysis, it is concluded that the financial gains to the processor of smoothing the supply profile are likely to be more than offset by the resulting increases in farm-level production costs.

The chosen strategy defines the supply chain's physical and cost structures, product types manufactured, markets serviced and market conditions to be met (e.g. seasonal price fluctuations). Operating a seasonal dairy industry implies servicing different market segments (i.e. lower-margin bulk commodities) and being exposed to certain risks (i.e.

price volatility on international markets). Hence, although a seasonal strategy may be preferable in the Irish context under the commodity market conditions observed in recent years, there are no guarantees that this will remain true in the longer term. A seasonal strategy involves extra costs (particularly regarding sunk costs due to plant capacity expansion), which manoeuvres the industry into a pathway that focusses on a narrow product base of a few bulk commodities. Announcements concerning new or recently completed investments in processing plants suggest that seasonality will remain a dominant feature of the country's milk production. This may be justified economically where a grass-based, low-cost milk production generates a higher financial surplus for the entire system of producer and processor taken together.

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