End of Project Report

A New Direction for the Payment of Milk: Technological and Seasonality Considerations in Multiple Component Milk Pricing of Milk (Liquid and Manufacturing) for a Diversifying Dairy Industry

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Summary

The main objectives of this study were to compare a Multiple Component Pricing system with the current milk pricing practice in Ireland and to estimate the marginal values of the three main milk components (fat, protein and lactose) in the context of the Irish milk processing industry. A representative linear programming model of an average Irish milk processor was developed in order to determine the marginal values of the milk components and to compare the value of milk under the Multiple Component Pricing system with the value under the current milk pricing practice. This study also examined the effect of product mix, milk supply and milk composition on the marginal value of the milk components.

The marginal values of the milk components and in turn the value of the milk varied according to the product mix of the processor. The value of milk determined by the linear programming model that was developed compared very favourably with the actual milk price that was paid by Irish milk processors in the corresponding time period. However, the Multiple Component Pricing system proved to be a more efficient and equitable system of milk pricing than the existing constituent or semi-constituent/liquid pricing system's that are being practiced by Irish processors.

Introduction

The value of milk to the dairy industry is a function of its composition and the aggregate profit of the product mix manufactured from the milk. Therefore, the

value of manufacturing milk (i.e. all milk with the exception of liquid milk) is directly dependent on its solids composition rather than the volume of milk. The primary objective of any milk pricing scheme should be that the price paid for milk reflect as accurately as possible the amount and value of products that can be made from it *as well as the transport and processing costs incurred*.

Multiple Component Pricing (MCP) of milk is the payment of milk on the basis of more than one of its components. Examples of MCP schemes would include payment for milk on the basis of fat and protein, fat, protein and lactose or fat and solids-non-fat.

The principal objectives of this study were

1) to conduct an investigation of milk pricing options into the future.
2) to assess the merits and demerits of MCP pricing versus the existing milk pricing systems.
3) to estimate marginal values for the milk components fat, protein and lactose.
4) to assess the effects of changes in product mix, seasonal supply pattern and compositional improvement on processing values for milk.

In addition to assessing the merits and demerits of MCP, the study also examined the potential of the pricing model as a decision support tool for the milk processing industry.

A linear programming (LP) model of a dairy-processing firm was developed in order to determine the marginal values of the three principal milk components (fat, protein and lactose). The model optimised processor returns from a given portfolio of products subject to constraints such as market demand for products, milk intake, milk composition and processing capacity.

Criteria for Evaluating Milk Payment Schemes

There are a number of criteria on which a milk pricing system can be judged and the principal ones include its transparency, the extent to which it is equitable to producers and the incentive structure it provides to encourage desirable changes in milk composition.

Equity in Milk Pricing Schemes

The pricing system should be equitable in the sense that the price paid for milk reflect as accurately as possible the market returns that can be obtained from that milk in terms of processed product. As noted by Keane (1989, p.4) “the basic principle for a payment scheme is that those suppliers with above average solids levels in their milk will generate a higher return from the marketplace and, in strict equity terms, should be entitled to a higher price per gallon/litre.” While Emmons *et al* (1990 a) cited that "the primary objective of MCP is that the prices paid or received for milk reflect as accurately as possible the amount and value of products that can be made from it". Therefore, a payment scheme that pays some producers more than the true value of milk according to its composition while other producers are under-paid for milk of better composition is inequitable.

Transparency

A milk pricing system should be transparent in the sense that milk suppliers can easily understand how their milk price has been determined. This should

permit producers to assess whether or not they are receiving fair market value for their milk according to its solids composition. The system should clearly indicate to producers the relative values of individual milk components within the overall milk price.

Incentives

The milk payment system has a pivotal role in signalling market values of individual milk components to the producer. The incentive structure provided by the pricing scheme should encourage improvements in milk composition and provide opportunities for producers to enhance profitability through the production of more valuable milk. While in the past butter-fat was the most important constituent to the processor, changes in the market environment such as the demand for low fat products and increased consumption of cheese as well as the expansion in the ‘food ingredients’ sector has increased demand for milk proteins and to some extent lactose. It is important that the pricing system should adequately reflect changing market requirements and thereby signal these to producers.

Milk Pricing Practice in Ireland

Current milk pricing schemes operated by Irish dairies fit into one of two categories

(i) a constituent pricing system with a payment based on fat and protein

(ii) a semi-constituent/liquid system or differential pricing system with a lower price paid for fat and protein and also a liquid payment.

There is considerable variation between dairies in the component differentials paid i.e. the values for protein and fat in the pricing equation. Table 1 compares the milk pricing systems of Irish milk processors over the period 1998 to 2001. The average value for butterfat was 1.36 cent per 0.1% (+ or - change in butterfat content) per gallon, however this ranged from 1.01 to 1.72 cent (Table 1). In the case of protein values, there was even greater variation, the highest average protein payment was 2.53 cent per 0.1% (+ or - change in protein content) per gallon compared to the lowest, which was 1.29 cent per 0.1% per gallon, while the average value was 2.05 cent per 0.1% per gallon. The average protein to fat value ratio was about 60:40, however the highest protein to fat value ratio was almost 70:30 while one processor placed a higher value on fat than protein (see Table 1). Moreover, for many of the dairies, fat and protein values combined only amounted to a proportion of the total milk price paid and a further constant was added to give the total price. This is the semi-constituent/liquid system referred to earlier. The magnitude of this constant varied considerably (Table 1) between dairies with nine having a constant amounting to more than 15 per cent of the milk price paid while 12 of the dairies had a constant of less than 5 per cent of the milk price paid.

Table 1: Key Aspects of Pricing Schemes for Dairies in the Irish Farmers' Journal, Milk Price League (January 1998 to October 2001)

	Minimum	Average	Maximum
Protein (Pence per 0.1%)	1.29	2.05	2.53
Fat (Pence per 0.1%)	1.01	1.36	1.72
Ratio Protein value: Fat value	45:55	60:40	69:31
Constant (% of price)	0.0	10.9	31.7

International Comparisons

To gain a perspective on the merits of current pricing policies operated by Irish dairies it is useful to examine milk-pricing systems in other countries with major dairy industries. Milk pricing schemes in Denmark, the Netherlands and New Zealand are considered in the following section.

Denmark

The Danish milk pricing system is comprised of a number of components: a value for fat based on the intervention price for butter minus manufacturing costs, a value for protein based on the intervention price for skim milk powder minus manufacturing costs, and a number of deductions and bonuses (Keane, 2000).

The Netherlands

The Dutch payment for milk is based on an A+B-C system. Under this system there is an initial high valuation for fat and protein with a fixed deduction for milk handling and other costs as well as a number of additional premiums (Keane, 2000). Both systems included supplementary payments based on company performance as part of the final price paid to producers.

New Zealand

The New Zealand system for payment of milk is essentially based on kg of fat multiplied by cents per kg plus kg of protein multiplied by cents per kg. The protein to fat value ratio is approximately 70:30 under the New Zealand system.

Issues Emerging from International Comparisons

There is considerable variation in fat and protein differentials applied by Irish dairy processors. Some of this variation can be explained by differences in product mixes among companies but, even allowing for this, the range appears extreme. Moreover, it remains unclear how processors determine their values for fat and protein.

A proportion of Irish dairies include a significant positive constant in their milk pricing schemes. This contrasts sharply with the payment schemes operated in the other countries considered above where a negative term in the pricing equation recognises the cost of handling and removing water in product manufacture. For example, the Danish volume charge is approximately 7 per cent of the basic price while in the Netherlands the volume penalty equates to around 15 per cent of the base price. A positive value for volume sold as fluid milk could be explained, however, a positive volume payment for manufacturing milk, as is the case with a number of Irish milk processors, is difficult to explain. The inclusion of a positive constant in Irish payment schemes is an undesirable feature as it reduces the value placed on milk solids and thereby diminishes the incentive for improvement in fat and protein content.

Principles of Multiple Component Pricing

Milk is a flexible raw material as its components can be combined in different proportions to produce many different dairy products. Multiple component pricing (MCP) of milk is defined as the pricing of milk directly on the basis of more than one component: such as fat and protein or fat, protein, lactose and carrier (volume). As stated earlier the primary objective of MCP is that the price paid or received for milk reflect as accurately as possible the amount and

value of products that can be made from it (Emmons, *et al*., 1990a). This is of particular relevance given the variation in milk composition both seasonally and between producers and the fact that yields of products such as butter, skimmed milk powder (SMP) and cheese are directly dependant on the solids composition of milk supplied to the processor. In the strictest sense, the economic value of the solids components of milk should be based on the value (price) of the products in which they are used, less processing and marketing costs and costs of other ingredients (Hillers, *et al*., 1980).

The task of estimating component values based on their values within the marketable dairy products is a difficult one. Component values vary according to the product mix into which the milk is processed. Different milk products contain different proportions of milk components and have varying market prices and processing costs. For example, milk protein is likely to have a higher economic value when manufactured into a more profitable product like cheese than into a less profitable one such as SMP. A MCP system involves the processor paying directly for milk components as reflected in end products of visible market value (i.e. butter, cheese, etc). The value, or cost, of each component must be closely related to its value, or cost, to the processor. While milk solids constituents have positive values, the value of water (volume) is generally negative as it must be transported, handled and removed in processing. The cost of processing milk therefore increases with increased volume.

A MCP system should ensure that the dairy firm pays only what the milk is worth in terms of the amount and value of products produced. Conversely, it should ensure that the producer receives full and fair reward for milk supplied according to its composition and the market return it produces as processed product. Consequently, the milk price under MCP should reflect the values (or costs) of all the key constituents in the milk supplied, i.e.:

Value of butterfat

+ Value of protein

+ Value of other solids (lactose and minerals)

- Cost of handling/removing fluid carrier (water)

This comprehensive MCP model could be referred to as a 'plus/plus/plus/minus' scheme accurately assigning the positive values of milk solids as well as the cost associated with the fluid carrier or water.

MCP in an Irish Context

While Irish dairies have for many years priced milk on the basis of fat and protein components, the industry has stopped short of implementing a comprehensive MCP system. The main deviations in current Irish milk payments from the MCP model described above are:

- The inclusion of a positive constant for volume in many of the pricing policies. This fails to recognise that volume actually is a cost to the processor.
- The omission of solids other than fat and protein from the pricing schemes. Even though fat and protein constitute the most valuable milk components, to ignore other solids in payment schemes can result in the milk price failing to reflect fully the true processed value of that milk. For example, lactose is becoming an increasingly valuable component in milk processing and that value should be reflected in the milk price.
- Use of a base price per gallon, albeit with quality adjustments, tends to place the focus on price per unit volume. This may confuse producer incentives by reducing the perceived importance of milk solids. In practice it would be more transparent to establish unit values for each component and to price milk directly on the basis of number of units of each component supplied (i.e. cents per kg multiplied by number of kg supplied).

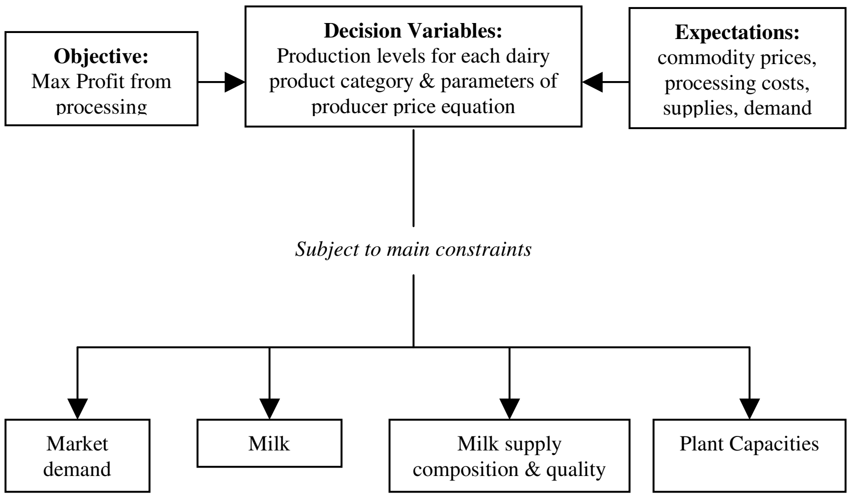
In the remainder of this paper some implications of a comprehensive MCP (plus/plus/plus/minus) system are considered for the Irish dairy industry. Comparisons are drawn with the existing differential payment (DP) schemes currently operated by Irish dairies.

Methodology

A wide range of approaches have been identified in the milk pricing literature ranging from partial budgeting or costing models (Caskie, 1992; Brog, 1969; 1970; Hillers *et al*., 1980), through to more sophisticated methods employing differential calculus (Ladd and Dunn, 1979) and LP (Bangstra *et al*., 1988; Breen, 2001). Much of the difficulty in deriving component values arises due to the multi-product nature of many dairy processors. Often a product mix is manufactured comprising various dairy products that contain fat, protein and lactose in many different combinations. In this study, a LP approach was chosen as the technique lends itself more readily to decision-making in a multi-product context.

A representative LP model of a dairy-processing firm was constructed according to the general structure presented in Figure 1. The model maximised an objective of the processor's net revenue across a multi-period planning horizon that comprised 12 time periods, each period representing one month of the year. The use of a multi-period framework enabled the model to incorporate the effects of the seasonal pattern of milk supplies within the Irish dairy sector. The model included a portfolio of products reflecting the predominant product mix of the Irish dairy industry. These products included fluid milk, butter, cheddar cheese, casein, whole milk powder (WMP), skimmed milk powder (SMP), dried lactose and whey powder (WP).

Figure 1: Schematic Diagram of the Modelling Framework



The decision variables of the model were the levels of each dairy product produced in each month of the quota year. The firm's production decisions were assumed to be influenced by its expectations for product prices, market demand, raw milk supplies as well as production costs for different product lines. Specifically, the quantities of individual products that could be produced in a given month were limited by a series of technical constraints comprising:

- Monthly market demand for each product line according to the firm's market share and supply commitments.
- Processing plant capacity for each product line, e.g. dryer plant capacity in the case of milk powders.
- Monthly milk supplies from farmers in the processor's milk pool reflecting aggregate milk quotas and seasonal supply pattern of producers.

- Solids composition of the milk supplied to the processor, which directly influences the volume of products that can be produced.

Manufacturing costs in the model were categorised as either 'fixed' or 'variable.' Fixed costs were assumed to remain constant in total for a given volume of milk regardless of the solids content of the milk. These costs included milk collection, reception of milk at the processing plant, administration and general overhead costs. Variable costs change with the solids content of the milk being processed. These costs were obtained on a product-by-product basis and included direct labour, fuel/power, added ingredients, packaging, product storage, product transportation and effluent disposal.

Solution of the model produced two main categories of results. Firstly, the optimum product mix that maximised the market returns from dairy product manufacture subject to the constraints listed above. Secondly, the shadow prices or marginal values for three principal milk solids: fat, protein and lactose. These marginal values, calculated in terms of € per kg of each milk component, represent the imputed value to the processor in terms of the net revenue obtained from the last kg of each milk component supplied. The component marginal values estimated by the model form the basis of a multiple component pricing equation, which expresses the value of milk as a function of its solids composition. Under the system producer payment for a given volume of milk would be determined by the equation:

$$PR = (VF \times YF) + (VP \times YP) + (VL \times YL) +/- (AP \times Vol) - (CV \times Vol)$$

PR = Producer Revenue

VF = Marginal Value Fat (€/kg) YF = Fat Yield (kg)

VP = Marginal Value Protein (€/kg) YP = Protein Yield (kg)

VL = Marginal Value Lactose (€/kg) YL = Lactose Yield (kg)

AP = Additional Payments/deductions (€/gal)

CV = Fixed Costs per unit Volume (€/gal) Vol = Volume (gal)

Using the marginal values of the individual milk components multiplied by component yield in the milk supplied, it is possible to ascertain the marginal value of a gallon of milk (MVGM) of given composition to the processor. The MVGM plus or minus supplementary payments (e.g. quality bonus/deduction, seasonal incentives) and minus a volume related deduction for collection, assembly and overhead costs would represent the milk price per gallon that would be paid to a producer under the MCP system.

Model Results

Marginal values of milk components were estimated under five product mix scenarios. These comprised a number of 'specialist' processing channel options and an 'average product mix' scenario reflecting the approximate actual proportions of each product produced by the Irish dairy industry as a whole. The four 'specialist' scenarios comprised discrete processing channels for cheese, casein and butter, SMP and butter and WMP and were used to estimate component values according to each of these specific product lines. In each of the five specialist scenarios the focus was on the production of the primary product with secondary products produced as by-products from the remaining milk components. For example, in the specialist cheese scenario the focus was on the production of cheese, however some butter was also produced from surplus butterfat as well as WP from whey.

Discussion of Results

The LP MCP model constructed can be used to analyse a variety of scenarios ranging from product mix to policy reform and processor capacity constraint scenarios.

Table 2 illustrates the quantities of product produced under the different scenarios. In the 'average product mix' scenario the quantity of liquid milk, cheese and casein that could be produced was constrained in order to ensure that it would be representative of the national average product mix. While the specialist scenarios focussed on the production of a particular product or product line, such as SMP and butter, the 'average product mix' scenario had the highest Total Net Revenue at 48.25m euro followed by the cheese scenario with 47.48m euro. The total net revenue in the SMP and WMP scenarios were lower at 44.86 and 44.36m euro, respectively.

Table 2: Product Yield and Total Net Revenue of the Scenarios

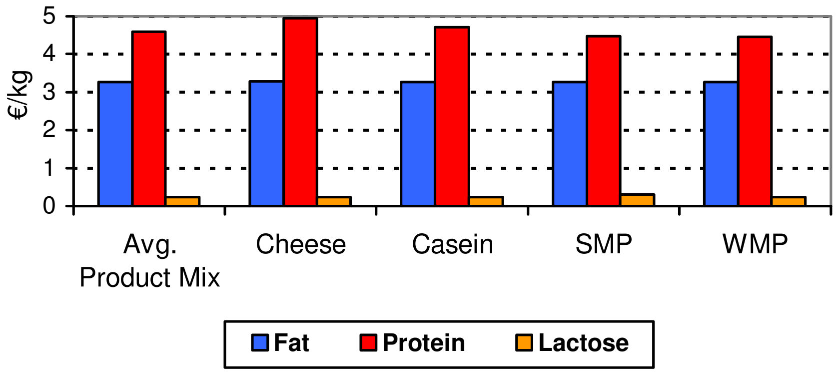
	Avg.	**Cheese**	**Casein/ Butter**	**SMP/Butter**	**WMP**
	tonne	tonne	tonne	tonne	tonne
Butter	5,792	265	7,923	7,954	-
Cheese	3,489	19,635	-	-	-
Casein	1,372	13	6,390	-	-
Liquid	19,583	-	-	-	-
SMP	8,956	-	-	17,672	-
WMP	-	-	-	-	24,206
WP	4,706	12,015	12,194	1	-
Total Net Revenue (€m)	48.25	47.48	45.82	44.86	44.36

Milk Component Values

The MCP model calculates the MV of the three principal milk components: fat, protein and lactose. (See Figure 2) The MV for fat varied from €3.26 to €3.28 and was determined by the production of butter in all five scenarios. The MV for protein varied considerably from €4.95 per kg in the cheese scenario to €4.46 in the WMP scenario. The MV for protein was €4.60 per kg in the 'average product mix' scenario and was determined by the production of casein in months with a low level of milk supplied and SMP in months of peak milk supply. The MV for lactose was smaller, €0.24 per kg in the 'average product mix' and specialist cheese, casein and WMP scenarios and was determined by the production of WP. The MV was higher in the SMP scenario (€0.30 per kg) and this reflects the higher value of lactose in the production of milk powders.

However the relatively small values for lactose reflect its modest value and its use in the production of residual products such as WP in the specialist cheese and casein scenarios.

Figure 2: Component Marginal Values

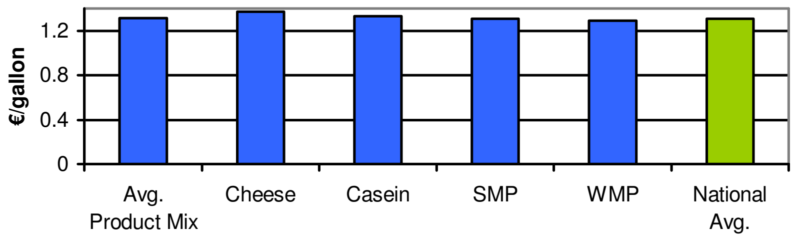


The protein to fat value ratios estimated by the model ranged from 60:40 under the cheese scenarios and 58:42 for the SMP/Butter scenario. The actual average protein:fat value ratio of Irish processors was 60:40 over the same period (1998 to 2002 inclusive). Clearly, component values vary according to the product mix produced from the milk and this would suggest that it is not possible to obtain one set of component values that accurately represents the true value of milk for all product channels. Consequently, the best strategy might involve the use of a 'blended' formula where a weighted average of component values is used according to the proportion of milk allocated to each product channel.

These MVs are converted into a marginal value per gallon of milk (MVGM) using the MCP equation outlined earlier. The MVGM for milk of 3.6% fat, 3.3% protein and 4.6% lactose was then compared with the actual average milk price paid in the 1998/2002 quota year for milk of 3.6% fat and 3.3% protein (see Figure 3). The highest MVGM was €1.37 per gallon under the specialist cheese scenario. The MVGM under the average product mix scenario was €1.31 per gallon while the MVGM under the SMP and WMP scenarios were €1.30 per gallon. The milk price therefore calculated under the average product mix scenario compares quite favourably with the national average milk price paid in '98/'02 which was €1.30 per gallon and this would suggest a high degree of accuracy in the model.

In converting the MVGM to a net producer price a volume charge in cent per gallon is deducted to cover cost of milk collection, assembly, administration and general overheads. It was estimated that this charge would be approximately 7 cent per gallon (Breen, 2001).

Figure 3: Marginal Values per Gallon of Milk (exclusive of volume costs)



Incentive for Improved Milk Composition

An important aspect of a milk-pricing scheme is that it should provide an incentive for desirable improvements in milk composition. Milk with higher solids concentration is more valuable to the processor and it is important that this increased value is accurately reflected in the milk price. One of the main failings of any milk-pricing scheme that pays for milk on the basis of volume or composition plus volume is that it does not adequately reward improvements in milk composition as there is a volume payment included in the milk pricing equation. The degree of responsiveness of current pricing schemes is inversely related to the magnitude of a constant term in the payment structure. Consequently, the average figures are presented for dairies grouped according to the proportion of milk price accounted for by a constant term in their payment schemes.

In contrast to this the MCP system outlined in this paper pays for milk purely on the basis of its milk composition and therefore offers a greater incentive for improvements in composition. Table 3 below compares the incentive for improvements in milk composition under the MCP system with actual

incentives offered by Irish milk processors over the same time period. We can see from the table that the MCP system paid a price incentive of over 7 cent per gallon in all five scenarios. While the price incentive paid under the current milk pricing practice varied from 7.4 cent per gallon for those processors with a constant of less than 5% to 6.0 cent per gallon for those processors with a constant greater than 15%. The 'Average product mix' scenario would pay 1.4 cent more per gallon than those processors with a constant of greater than 15% in their milk price. While a difference of 1.4 cent per gallon may not seem that significant, it is important to note that this would be equivalent to €700 for a farmer producing 50,000 gallons of milk.

Table 3: Producer Price Incentive for Improved Solids Composition

	Milk Price for milk of 3.5% fat & 3.2% protein (cent/gallon)	Milk Price for milk of 3.7% fat & 3.4% protein (cent/gallon)	Difference (cent/gallon)
Multiple Component Pricing Scenarios			
Average Mix	127.5	134.9	7.4
Cheese	132.6	140.3	7.7
Casein/Butter	129.2	136.6	7.4
SMP/Butter	127.1	134.3	7.2
WMP	125.6	132.8	7.2
Current Differential Pricing Systems			
Constant < 5%	127.0	134.4	7.4
Constant 5-15%	126.7	133.7	7.0
Constant >15%	127.4	133.4	6.0

Volume versus Composition

In the case of dairies with a large positive constant in their pricing equations, increased volume is rewarded over improvements in solids concentration. This issue was examined using the MCP model. Two deliveries of milk were evaluated both containing exactly the same quantities (kg) of each milk component, however, one of the deliveries involved a volume of 1,050 gallons while the other had a volume of 1,000 gallons (see Table 4).

Table 4: Volume and Composition of Two Milk Deliveries

	DELIVERY A 1,050 gal @ 3.6%F, 3.3%P, 4.6%L	DELIVERY B 1,000 gal @ 3.78%F, 3.465%P, 4.83%L
Milk (kg)	4915.2	4681.1
Fat (kg)	176.9	176.9
Protein (kg)	162.2	162.2
Lactose (kg)	226.1	226.1

In this example the value of both milk pools in terms of processed product should be the same as they contain the same amount of milk solids and therefore will yield the same quantities of product. Moreover, the delivery with lower solids concentration will actually have higher costs in terms of transportation and fluid removal. As indicated in Table 5, the MCP system correctly identified the processed value of both milk deliveries as exactly the same. In contrast, the differential payment systems operated by processors actually paid more for the volume increase than they paid for the increase in solids concentration. This inefficiency in the differential-based systems varied with the prominence of a constant term within the pricing policy. For dairies in the Milk Price League with a constant component of more than 15 per cent the amount paid for the higher volume of milk was on average about €13.8 more

than for the delivery of milk with higher solids concentration. This difference occurred despite the fact that both deliveries would yield the same amount of processed product and the added volume would entail more handling costs.

Table 5: Efficiency of Milk Pricing Systems

	DELIVERY A 1,050 gallons @ 3.6% F, 3.3% P, 4.6% L €	DELIVERY B 1,000 gallons @ 3.78% F, 3.465% P, 4.83% L €
Current Pricing Systems		
With constant < 5%	1372.4	1370.3
With constant 5 – 15%	1367.0	1361.7
With constant > 15%	1368.9	1355.1
MCP Scenarios		
Average Mix	1377.8	1377.8
Cheese	1439.0	1439.0
Casein	1395.6	1395.6
SMP/Butter	1372.4	1372.4
WMP	1356.5	1356.5

Greater Control over Unit Cost of Finished Product

The single largest cost to the dairy processing sector is the milk that is used in the production of its products. Hence, from a processor point of view, an important benefit of MCP is that it provides more accurate control of unit costs of milk per kg of final product. Emmons et al. 1990a stated that "It is important that the processor pays no more than the milk is worth in terms of the amount of products that can be produced and that the producer receives full value in those same terms" This is a cornerstone of the MCP argument, processors should pay for milk on the basis of the true value of its milk components which would be derived from the value of products produced from that milk.

Keane *et al* (1998) estimated that milk accounted for between 84 and 88% of the TVCs in the production of milk powders. Therefore overpayment for milk would seriously undermine the profitability and performance of the dairy processor as was illustrated by Emmons *et al*. 1990a who stated that "one can conclude that small differences in the cost of milk per unit of product have a major impact on processors." And they went on to say that "Indeed differences in cost of milk per unit of product have likely been an underlying cause of some plant failures."

Variation in cost of milk per kg of final product arises where the pricing formula does not accurately reflect differences in product yield as milk composition varies. Thus some milk may be over-valued in terms of the product yield that can be obtained from them while other milk compositions may be under-valued. One of the merits of MCP is that it would provide the processor with greater control over the unit cost of processed product. A MCP system of milk pricing would pay for milk on the basis of the MV of the last unit of the milk components and this would be determined by the price of the finished product. Therefore the processor would be paying the true value of the milk.

If we consider two pools of milk both containing 1,000 gallons, pool A is comprised of 3.6 per cent fat, 3.3 per cent protein and 4.6 per cent lactose and pool B is comprised of 3.5 per cent fat, 3.2 per cent protein and 4.5 per cent lactose. Assuming the two pools of milk are processed into the same product line and under the same processing conditions then pool B will have lower

yield of finished product as it has a lower milk composition. Table 6 below illustrates the difference in the "True Value" of the two pools of milk if it were processed into three different product lines. For example if both pools of milk are processed into cheese then the true value of pool A is €1,370.36 while the value of pool B is €1,330.68, giving a difference of €39.68 per 1,000 gallons of milk. Under a MCP cheese pricing equation the difference in price paid for these two pools of milk would be €39.68 per 1,000 gallons. The MCP system pays on the basis of the milk composition and the MV's of the milk components, which are determined by the product prices, and therefore pays the true value for the milk and will neither overvalue nor undervalue the milk. In comparison under the differential pricing system the reduction in the price paid is generally less than the reduction in the true value of the milk. Therefore it would appear that the current pricing system does not accurately reflect the effect of changes in milk composition on product yield and the true value of milk. As a result the differential pricing system may overvalue milk of poor composition. As already stated milk is the single largest variable cost of production and consequently overvaluing milk could seriously undermine processor profit. In comparison the MCP system outlined in this paper pays a price to producers that accurately reflects the yield of products obtained and therefore places the true value on the milk. This is a major benefit to processors in ensuring greater control over their largest input cost of raw milk.

Table 6: True Values of Two Milk Compositions Compared with Value under Differential Pricing Schemes employed by Dairies

	Milk A Value of 1,000	Milk B Value of 1,000	Difference

	gallons @ 3.6%F, 3.3%P, 4.6%L	gallons @ 3.5%F, 3.2%P, 4.5%L	
	€	€	€
True Value of Milk (MCP model)			
Cheese	1,370.36	1,330.68	-39.68
Casein/Butter	1,329.37	1,290.96	-38.41
SMP/Butter	1,303.56	1,269.20	-34.36
Differential Pricing Systems			
Constant > 15%	1,291.08	1,262.83	-28.25
Constant 5 - 15%	1,303.28	1,268.71	-34.56
Constant < 5%	1,303.43	1,266.13	-37.30

Conclusions

The MV of the milk components is dependent on the product mix of the milk processor. In all five scenarios butter was produced, as a result, the MV for fat was determined by the production of butter and was the same in all five scenarios. In contrast the utilisation of protein varied according to the product mix of the scenario and therefore the MV for protein varied also, from a maximum of €4.95 per kg in the cheese scenario to €4.46 in the specialist WMP scenario. The MV for lactose was €0.24 per kg in four of the five scenarios and was slightly higher, €0.30 in the SMP scenario.

The true value of milk is a function of its solids composition and therefore the most equitable and efficient system of milk pricing would be one that pays for milk on the basis of these milk components.
There are a number of benefits to the MCP system proposed in this paper:

- more equitable system of milk pricing in that it pays the true value of the milk components being processed
- provides greater incentives to suppliers for improvements in milk composition
- paying for milk on the basis of kg of milk solids would encourage improvements in milk solids content rather than in milk volume
- gives processors greater control over the unit cost of raw milk than a volume or volume plus composition payment system
- helps to align the objectives of Processors and Producers, as it would value milk on the basis of its composition rather than its volume and under a MCP system both the processor and producer profit would be a function of milk composition rather than milk volume.

The LP approach used allows us to effectively incorporate the multi-product nature of milk processing into the milk pricing equation. In contrast, a number of existing pricing schemes are focused on the price of key products only, such as butter, SMP or Gouda cheese. The LP approach also effectively handles the inter-relationships that exist in milk processing such as the separation of milk into fat and skim. The milk price generated by the LP model compared favourably with the actual milk price paid over the corresponding time period and with other approaches used in the determination of a milk price for Ireland.

The LP model is very user friendly and produces the component MVs for fat, protein and lactose, which the model then converts into a producer milk price and this approach, could, be easily adopted by the milk processing industry.

Finally the LP model has the added potential of being a useful management and decision support tool. The model can be used in the decision making process of the processor to determine the effect of a change in the milk supply pattern on the product mix of the firm or the effect of a reduction in processing constraints (e.g. addition of extra plant capacity) on the optimum product mix, the total net revenue of the processor and milk price payable to farmers.

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