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REFEREED ARTICLE

DETERMINANTS OF THE FARM GATE PRICE OF MILK: QUANTIFYING THE IMPACT OF MILK CONTRACT AND SELLING ARRANGEMENTS

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Recent variability in farm gate milk prices has led to increased interest in milk selling arrangements. Analysing data for 220 conventional English dairy producers reveals significant differences in the milk contract and selling arrangements of producers receiving the top 25% of milk prices, when compared to producers receiving the bottom 25% of milk prices. Hedonic regression analysis estimates the value of the individual attributes of milk selling arrangements. Milk price variation is likely to hasten further structural change in dairying.

Key Words Milk Contracts, Pricing, Hedonics, Profit, Dairy

Introduction

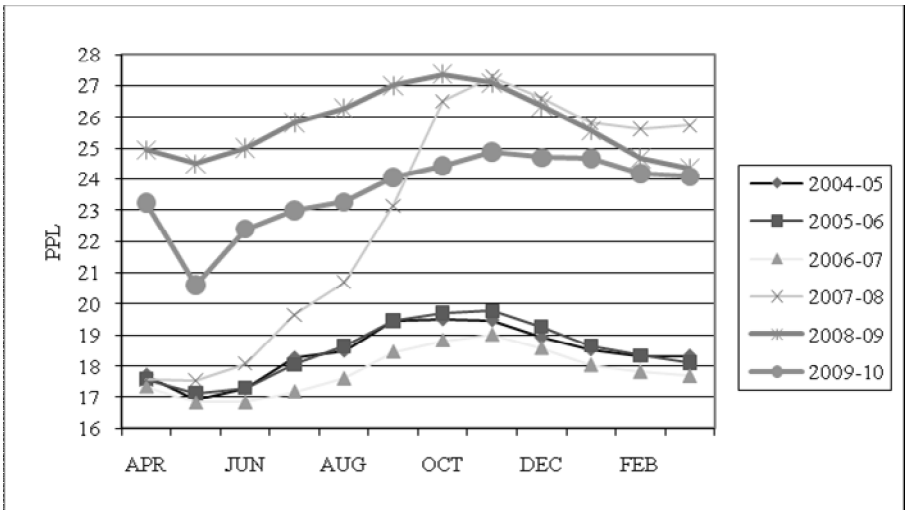
UK dairy farming accounts for £3.1bn (16%) of agricultural output, producing 13.2bn litres of milk per annum (Defra 2010a). For milk producers, the price received is one of the key determining factors in dairy profitability (Wilson, 2011). The UK dairy industry has undergone substantial structural change in recent years, as the number of producers has decreased, countered in part by an increase in average herd size (Robertson and Wilson, 2009). Milk contracts on offer to producers can be grouped into four main categories: i) retailer contracts with producers aligned to dedicated retailers supplying liquid milk; ii) non-aligned liquid milk contracts (e.g. Arla, Wiseman, Dairy Crest); iii) contracts to supply manufacturers of higher value cheeses (e.g. mature cheddar, stilton), with the co-ops broadly falling within this sector; iv) milk sold to commodity product markets (Promar, 2009). A further milk selling arrangement is whereby milk producers sell or transfer their milk to their own milk processing unit.

DairyCo (2010) note that following the collapse of Dairy Farmers of Britain (DFoB) in 2009, the two largest UK milk co-operatives are First Milk and Milk Link, with both offering contracts in terms of the milk price, plus returns on investment in the co-operative. Other major milk purchasers are Arla Foods UK, Dairy Crest, Meadow Foods, Müller and Robert Wiseman Dairies, with these buyers offering different contract options in terms of regional coverage, bonus payments linked to milk quality, links to market conditions and length of contract exit period. DairyUK (2009) details the variation in milk processing activities amongst some of the major players, noting the scale of the sector with 524 processing plants, of which 453 process 5 million litres or less, accounting for 1.4% of milk by volume; by contrast 23 plants of over 100 million litres throughput account for 89.5% of milk by volume (DairyUK 2009).

The milk market has recently witnessed specific drivers of change linked to structural aspects; the UK's continual fall in milk production represents the

visible output of structural change with recent data indicating that UK milk deliveries were "under quota" by 1300 million litres, equating to 9.1% of quota (MDC Datum 2010). This fall in production has led to some relatively variable milk prices over recent years. Figure 1 shows UK average producer ex-farmgate milk price (including seasonality; net of delivery charges) from 2004-05 to 2009-10. The summer of 2007 saw a substantial increase in milk price, with buyers seeking to secure supplies, leading to prices peaking at 27.3 pence per litre (ppl) in November 2007. Throughout 2008 prices fell back but largely remained above 25 ppl, albeit by the end of the 2008/09 milk year prices dipped below this 25ppl mark. The average price during 2008/09 (2007/08) was 25.75 (22.9) ppl. The milk year 2009/10 witnessed the collapse of (DFoB), and this collapse had a large effect on the average milk price received by producers in May and June of 2009.

Figure 1: Farmgate Milk Prices (UK)



Source: Defra (2010b)

Issues of dairy production, profitability and milk pricing have received considerable attention in both academic and industry arenas, particularly since deregulation in the sector in 1994. Bates' (1996) assessment of the impact of deregulation provides an overview of milk prices across different milk buyers and notes the importance to farmers in understanding the market fundamentals in addition to milk quality attributes. Bates and Pattisson (1997) analyse farmers' decisions to join the then large co-operative Milk Marque, citing 'strength in numbers' as the highest ranking influencing on farmers' decision to join Milk Marque, whilst, 'price' was found to be the most important factor for producers supply other buyers and processors. Franks (2001) finds evidence that prior to 1993/94 smaller herds tended to receive higher milk prices, but after this date, this trend reversed with larger herds increasingly attracting higher prices, citing an 8.2% advantage of the larger herds over smaller ones, and noting that this shift in the market followed deregulation,

"freeing" farmers to choose their milk buyer. Franks (2002) provides a further analysis of the determinants of milk price including significant factors of milk content and hygiene attributes, volume of milk sold, seasonality, breed and location of the farm; this large sample size and depth of data enabled a regression analysis that explained 77.5% of the variation in milk price to be presented. Franks (2002) also finds that Milk Marque suppliers achieved 1.5ppl less than non Milk Marque suppliers. In a further analysis of the milk market Franks (2003) argues that farmers need to adopt marketing strategies to counteract supermarket negotiating power, and also finds evidence that the market support mechanisms in the dairy sector have frequently not delivered a sustainable milk price to farmers; Franks thus calls for combined action by farmers to redress imbalances in the market.

Given recent price variability in the milk market, interest in milk selling arrangements has received growing attention. A National Farmers Union (NFU) survey found that 29% of milk producers were not satisfied with their milk contracts, with substantial variation being observed with respect to levels of satisfaction, with the co-operative group First Milk receiving the lowest satisfaction levels, and Wiseman's recording the greatest level of satisfaction (Campbell-Gibbons, 2010). The results also demonstrated that 73% of producers supplying to a PLC were very or fairly satisfied, whilst only 55% of those supplying a co-op were very or fairly satisfied. Campbell-Gibbons also found a link between contract satisfaction levels and volume of milk supplies; specifically that 76% of producers supplying less than 2m litres are very or fairly satisfied with their contract, whilst only 55% of those supplying over 2m litres note this level of satisfaction.

Milk represents a broadly homogeneous product; however quality parameters with respect to product content (protein and butterfat) and hygiene attributes (bactoscan and somatic cell count), and the influence of these parameters on milk price, are well understood across the industry, with milk buyers and levy boards providing pricing details based upon content, hygiene and volume of milk variables, e.g. interactive milk price calculator tools (DairyCo, 2011), also freely available data on milk price variability over time exists (e.g. Defra, 2010b). However, whilst certain attributes are more transparent in the industry it is less transparent how milk buyers value the individual attributes of a particular farm supplying milk (e.g. location, daily or every other day collection, number of buyers from which the farmer can choose to supply to) and moreover, how the characteristics of the contract (e.g. sales to a co-operative versus a processor; retailer linked contracts) influence milk price independently of product content and hygiene attributes.

For England, Wilson and Darling (2010) provide evidence that for conventional and organic producers combined, producers supplying co-operatives or buying groups received the greatest milk price; however when examining data for conventional producers alone, it was producers supplying non co-operative processors that received the greatest milk price. Wilson and Darling note that a higher proportion of lowland producers are satisfied with their milk contract than their LFA counterparts, and that for conventional producers, those operating under long term contracts received higher milk

prices than those operating under shorter contract arrangements; LFA producers were typically more constrained in their choice of milk buyers than producers in the lowlands. Additionally, Wilson and Darling find that a higher proportion of LFA and organic producers had their milk compulsorily collected on an every other day basis (EoD) (Wilson and Darling, 2010).

The above literature indicates that factors beyond content and hygiene attributes can significantly impact on the farm gate price of milk and the level of satisfaction milk producers have with their milk contracts and buyers. However, it is generally not possible to directly observe the market value or impact of non-content / hygiene attributes on the price of milk; the impact of these factors can only be observed when they are either combined with other attributes (i.e. single analysis which compares co-operative to processor supplied milk) or quantified through an estimation procedure which seeks to decompose the overall price or value of the product into its constituent attribute parts. The literature on understanding and quantifying the value of individual attributes of products has grown from the work of Lancaster (1971). Previous empirical research on valuing product attributes covers many different product types and market environments. Within this there is a considerable literature in relation to agricultural and food products including: dairy products in the USA (Chavas and Kim, 2005); wine in British Columbia (Carew and Florkowski, 2010); bread wheat in Turkey (Karaman *et al.*, 2009); milk in the UK (Franks, 2002) and the USA (Lenz *et al*., 1994); labelling attributes of French wines in the British market (Steiner, 2004); thoroughbred broodmares (Neibergs, 2001); chickpeas in India (Agbola *et al*., 2002); regional analysis of fresh tomato prices (Huang and Lin, 2007); apples in British Columbia (Carew, 2000); Swedish wine (Nerlove, 1995); cottonseed prices in the USA (Misra, 2000); and sheep and goats in Southern Nigeria (Jabbar, 1998). The literature shares a common overall concept in eliciting unobservable values of attributes from observable product price data; these papers generally consider different model specifications and functional forms in order to obtain the optimal model outputs in terms of explanatory power and significance of the parameter estimates, taking into account model efficiency and complexity.

Whilst the UK milk market is well defined with respect to the price of milk linked to particular product and hygiene factors, the factors behind milk price determination, that flow as a result of different milk selling arrangements, are less well-defined or visible. Findings from Cambell-Gibbons (2010) and Wilson and Darling (2010) provide contemporary insights into the contract selling arrangements of producers, but these studies do not offer an analysis of the milk contract arrangements associated with particular milk price bands, nor do they seek to determine the value of individual attributes of milk selling arrangements as in previous studies of the UK milk market (Franks, 2002). The aim of this paper is therefore to analyse the milk contract arrangements associated with different groups of producers, as defined by the milk price they received, together with a further analysis that explicitly quantifies the individual attributes of milk selling arrangements on milk prices.

Data and Methods

The data were derived from the Farm Business Survey (FBS) for England (2008/09), combined with a subset of 220 conventional dairy producers, who took part in a telephone survey of their milk selling arrangements in February and March 2010 undertaken by Rural Business Research. The physical and financial data from the FBS returns comprised of: milk production per farm; milk value produced per farm; yield per cow; price of milk (milk value divided by milk produced)[1] and herd size. In addition data from the FBS detailed lowland or Less Favoured Area (LFA) status of the farm, together with the EU Super Region in which the farm is located. Data derived from the telephone survey included the following broad data categories: type of organisation to which milk is sold (e.g. co-operative, processor); whether or not the producer changed milk buyer during 2008/09; reasons for changing milk buyer; length of milk contract with buyer; flexibility to switch milk buyer; prevalence and extent of retailer-driven premium; prevalence and nature of price guarantee contracts; intention to change milk buyer in 2011; number of milk buyers the producer had to choose from; frequency of milk collection and reasons associated with this. These combined data provide a unique set of 220 observations on physical, financial, attitudinal and contract information, and is a subset of the data used in Wilson and Darling's (2010) analysis; the data used in this paper relate to conventional producers only.

The data were analysed in terms of number of producers associated with each of the broad categories from the telephone survey. In addition, in order to explore the link between the price producers received and the milk contract arrangements under which they were operating, the sample of 220 producers was divided into milk price quartiles, with quartile A representing the producers receiving the highest 25% of prices, followed by quartiles B, C and D, with the latter representing the producers receiving the lowest 25% of prices. Within each data category, a Chi-Squared test was performed to test the hypothesis that there was no significant difference in the milk contract arrangements or attitudes across the four milk price quartiles. For continuous variables on herd size (cows), production (litres), value of sales (£), yield (litres/cow) and milk price (ppl) ANOVA tests were undertaken to test the hypothesis of no difference in the mean values across the four milk price quartile groups. These series of Chi-Squared and ANOVA tests provide an initial indication of the factors that should be included in an analysis to quantify the value of individual milk selling arrangement attributes.

Following the above statistical tests, hedonic regression equations were constructed drawing upon the evidence derived from these tests. Initial regression equations were constructed including those non-continuous variables where a significant difference of 99.9% was detected from the Chi-squared tests. Moreover, ANOVA tests of the continuous data were used to inform model construction by inclusion of the continuous variables of herd size and yield. In order to assess and test for the most robust model a two-

1. Milk price does not include dividends paid on capital invested in a milk buying organisation, and thus returns to investment in milk buying organisations lie outside of this analysis. The value of milk (and hence milk price) accounts for on-farm milk consumption to reflect the true volume and value of milk produced irrespective of destination

stage estimation procedure was undertaken. Firstly, four model specifications were detailed to examine the impact of the following function forms: i) linear; ii) linear-log; iii) log-linear and iv) log-log as detailed below in equation 1:

$$D=\alpha_o+d_1B+d_2R+d_3CL+\beta_4CB+\beta_5FC+\beta_6H+\beta_7Y+e \quad (1)$$

Where:
a_0, d_k (k=1,…7) are coefficients to be estimated

D Dependent variable: Price of milk in pence per litre (P) or natural logarithm of the price of milk in pence per litre (LnP)

B Buyer variable: 1 if sold to a processor; 0 if sold to co-operative / group

R Retail contract variable; 1 if sold under retail contract; 0 otherwise

CL Cost-linked variable: 1 if sold under cost-linked contract; 0 otherwise

CB Choice of buyers variable: 1 if have choice of 3 or more buyers; 0 otherwise

FC Frequency of milk collection variable: 1 if milk collection is every other day; 0 otherwise

H Herd size of the farm (H) or natural logarithm of herd size (LnH)

Y Average milk yield for the farm (Y) or natural logarithm of yield (LnY)

e Disturbance term with the usual properties.

The choice of appropriate model form was made on the basis of goodness of fit and the number of significant parameter estimates. Note that in previous regressions (not presented), herd size and yield per cow were replaced with volume of milk produced, however, this offered no advantage in the explanatory power of the regressions and the significance of parameter estimates. The second stage of analysis used the preferred model form and undertook likelihood ratio tests (Judge *et al.* 1985) to examine the statistical difference between reduced models and the preferred full model form from stage 1.

Results

Production, location and price characteristics are shown in Table 1. Average herd size from the sample was approximately 128 cows, averaging 6,884 litres per cow (l/cow), producing an average of 924,000 litres of milk per farm; an average sale price of 25.93 pence per litre (ppl) generated an average £244,000 of milk value with significant difference for these continuous variables noted across the four milk price quartiles. Herds in the

lowlands dominate the sample (163 herds), with 57 in the LFAs. The EU North, East and West regions respectively accounted for 79, 48 and 93 of the producers in the sample. Within Table 1 it can be seen that the highest milk price quartile group (A) is represented by an average herd size of 170 cows, yielding 7,346 l/cow and achieving an average milk price of 28.28ppl. Milk price quartile groups B and C do not differ greatly in their average herd size (130 and 122 respectively), however, with respective average yields and milk prices of 7,315 l/cow at 26.54ppl and 6,814 l/cow at 25.36ppl, the average value of milk between these two groups differs by nearly £45,000 per farm. Milk price quartile group D is characterised by a relatively smaller herd size (90 cows) producing 6,058 l/cow averaging 23.54ppl to generate a milk value of £138,200. Comparing the value of milk from quartile groups A and D, a difference of £219,000 is observed, with the average output in quartile D representing 38.7% of the value from quartile group A, from a herd size equal to 52.9 % of that in quartile A. The typology and regional characteristics of the quartile groups are also provided in Table 1. There is a significant difference (see Table 6 which presents the overview of all the Chi-squared tests undertaken on the observed data in this section) with respect to the number of producers in the lowlands across the quartile groups, with the number

Table 1: Production, Location and Price Characteristics of the Sample and Milk Price Quartile Groups

	A	**B**	**C**	**D**	**All**
Herd Size***	169.82 *80.94*	129.68 *84.26*	121.64 *68.75*	90.27 *57.57*	127.85 *78.46*
Production (litres)***	1,269,814 *677,508*	987,751 *712,337*	856,646 *573,302*	580,101 *478,750*	923,578 *661,630*
Value of sales (£)***	357,471 *190,202*	262,314 *189,512*	217,592 *146,714*	138,204 *118,045*	243,895 *181,172*
Yield (litres) ***	7,346 *1,305*	7,315 *1,393*	6,814 *1,372*	6,058 *1,446*	6,884 *1,467*
Price (pence / litre)***	28.28 *1.81*	26.54 *0.32*	25.36 *0.31*	23.54 *1.02*	25.93 *2.03*
Lowland	48	42	39	34	163
LFA	7	13	16	21	57
EU North	10	23	22	24	79
EU East	14	12	10	12	48
EU West	31	20	23	19	93
n	*55*	*55*	*55*	*55*	*220*

Standard Deviation in italics for continuous data; n = number of observations; statistical significance of continuous variables at 99% (***); statistical tests for discrete variables are provided in Table 6

Figure 2: Number of Conventional Producers by Price Received ppl Bands

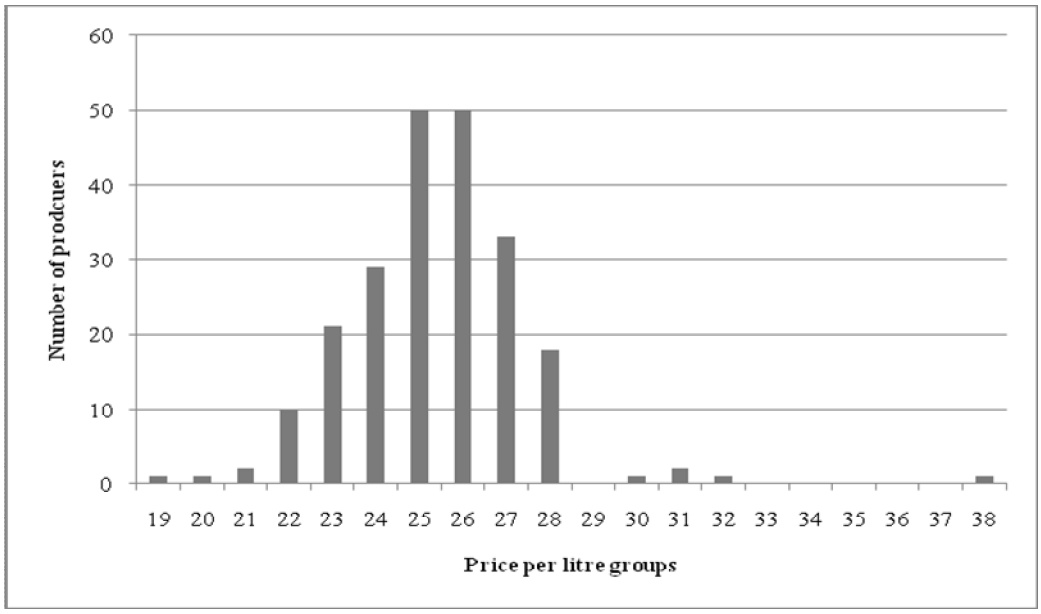


Table 2: Number of Producers by Milk Selling Arrangements, Changes in Milk Buyer and Reasons for Change

		Milk price quartile group				
		A	**B**	**C**	**D**	**All**
Organisation to which milk is sold	Co-op / group with no processing capacity	2	4	5	6	17
	Co-op / group with some processing capacity	10	13	31	43	97
	Other Processor	43	38	19	6	106
Change in milk buyer*	No change in milk buyer in year	53	50	51	50	204
	Changed buyer once	2	5	4	5	16
Reasons for change in milk buyer*	Not applicable (not change)	53	50	51	50	204
	Concerns over viability of DfoB	1	0	1	2	4
	Previous buyer ceased trading	0	0	0	1	1
	Previous buyer not willing to collect milk	0	0	0	0	0
	Better terms offered by new buyer	0	4	2	2	8
	Other	1	1	1	0	3
n		*55*	*55*	*55*	*55*	*220*

n = number of observations; * Unable to undertake Chi-Squared test due to observed values <5 per cell

of producers located in the Less Favoured Areas (LFAs) increasing as the average milk price decreases. Moreover, there is a significant difference in the regional location of producers against milk price quartiles with more producers in quartile A being located in the EU West region, and fewer Northern producers located in this quartile; the converse holds true with respect to the numbers of producers in quartile group D.[2]

Figure 2 shows the number of producers classified by pence per litre price band. Within Figure 2, each price band represents a one-pence band, for example the 19ppl band includes producers receiving prices of 19ppl to less than 20ppl. Figure 2 represents a broadly normal distribution of milk prices across the sample.

Table 2 shows the number of producers by type of organisation to which their milk was sold, together with the number of producers who changed milk buyer in 2008/09 and the associated reasons for this change. It is instructive to note that whilst the majority (43) of producers in quartile A sold their milk to a non co-operative / buying group processor, only 12 producers from this quartile sold milk to a co-operative (with or without processing capacity). Conversely 49 producers from quartile D sold their milk to a co-operative or buying group, with significant differences (Table 6) being observed across the quartile groups in respect to the organisation to which milk was sold. The majority of producers in each quartile group did not change milk buyer in 2008/09; the main reasons cited for changing milk buyer was the better terms offered by the new buyer. The relatively small number of observations on changing milk buyer meant that cell size was not sufficient to undertake statistical tests on these data.

The length of contract and flexibility to switch contract can be considered as measures of contract stability and freedom which may influence milk price received. From Table 3 it can be seen that the most popular contract type was a one year contract (either rolling or fixed term) followed by long term contracts of 10 years or more (including evergreen contracts). However, note from Table 3 that over 50% of producers in quartile D operated on the basis of a one year contract, and only 20% of this group held long term contracts of 10 years or more. However, no significant differences were observed across the quartile groups with respect to length of contract held. Most producers were required to give at least 12 months notice to avoid penalties on exiting their milk contracts, however quartile groups C and D were more likely to have to give 12 months notice than producers in quartiles A and B. Whilst no clear patterns emerge with respect to contract flexibility across the performance groups, statistically significant differences with respect to contract flexibility were found across the groups.

The presence of retailer-linked contracts, the nature of guaranteed prices on milk contracts and the intention to change buyer are presented in Table 4.

2. For the purpose of presenting the milk price quartile groups, no data outliers were excluded. However, for the upper quartile price group (A), excluding one outlier at the high price end produced an average price of 28.08ppl (*cf.* 28.28ppl), whilst excluding the five highest milk price observations reduced the average price for quartile A to 27.82ppl. Excluding the two lowest milk price observations in quartile D increases the average milk price to 23.66ppl from 23.54ppl.

Table 3: Number of Producers by Milk Contract Length and Flexibility to Switch Buyer

		Milk price quartile group				
		A	**B**	**C**	**D**	**All**
Length of Milk Contract	Under 0.5 years #	6	1	2	0	9
	0.5 to < 1 year #	3	4	3	10	20
	1 year (fixed and rolling)	15	24	21	27	87
	1.5 to < 3 years λ	6	4	2	1	13
	3 to < 6 years λ	4	4	7	1	16
	6 to < 10 years λ	4	3	0	5	12
	10 years or more (inc. evergreen contracts)	17	15	20	11	63
Flexibility to switch buyer	Penalty irrespective of notice given #	4	3	5	3	15
	Penalty unless 12 months notice given #	25	30	36	32	123
	Penalty unless 6-12 months notice given	9	14	8	6	37
	Penalty unless 3-6 months notice given	11	5	2	5	23
	Penalty unless 1-3 months notice given λ	0	0	2	5	7
	No penalty payment λ	6	3	2	4	15
n		*55*	*55*	*55*	*55*	*220*

n = number of observations; # or λ = groups combined within category for the purpose of Chi-Squared test

Whilst quartile groups A and B include 15 and 21 producers who respectively supplied 100% of their milk under a retailer-linked contract, only six and one producer from quartiles C and D respectively operated under such a contract. Most producers in quartile groups C and D did not operate under these contract arrangements and this difference is statistically significant. There is a significant difference in the number of producers in each quartile that operated under a production-cost link contract or some other form of price guarantee. Whilst 136 of the 220 producers were satisfied with their buyer, 33 noted that they would not be changing buyer because they have no alternative to change to; nearly one-half of this group of producers are contained within quartile group D. Those producers most satisfied with their current buyer were found in groups A and B.

The number of buyers from which producers can choose to supply milk to is presented in Table 5 alongside data on the frequency of milk collection. It is striking to note that of the 55 producers in quartile group D, 20 had the choice of only one buyer, whilst a further 17 had the choice of only two buyers. By contrast there are 18 producers in quartile group A that were constrained to only one or two buyers. It is interesting to note that whilst there is a significant difference across the quartile groups with respect to the number of choice of

Table 4: Number of Retailer Linked Milk Contracts, Nature of Price Guarantees and Intention to Change Milk Buyer

		Milk price quartile group				
		A	**B**	**C**	**D**	**All**
Retailer linked milk contracts and proportion of milk guaranteed associated with this.	None	33	30	46	51	160
	Paid on <25% milk#	2	3	2	2	9
	Paid on 25to <50%milk#	0	0	1	0	1
	Paid on 50to <75%milk#	0	1	0	0	1
	Paid on 75to<100 milk#	5	0	0	1	6
	Paid on 100%of milk#	15	21	6	1	43
Nature of contract Price guarantee	None	34	38	40	40	161
	Linked to prodn. costs#	12	5	1	0	18
	Other#	9	12	14	6	41
Intention to change milk buyer	Definitely not; would like to but no alternative	1	8	9	15	33
	Definitely not, satisfied with current buyer	42	40	31	23	136
	Possibly#	7	7	7	6	27
	Probably#	1	0	1	2	4
	Definitely yesλ	4	0	6	6	16
	Other / not applicableλ	0	0	1	3	4

n = number of observations; # or λ = groups combined within category for the purpose of Chi-Squared test

buyers, 16 producers in quartile C had the choice of five or more buyers. A clear, and statistically significant, pattern with respect to the frequency of milk collection is noted (Table 6), where producers in quartile groups C and D are more likely to have their milk collected every other day, either voluntarily or compulsorily when compared with producers in quartile groups A and B, where daily collections are more common.

Table 7 provides the results of four hedonic regression equations specified in the first stage of the regression analysis. With respect to interpretation of the non-continuous variables in Table 7, a value of 0 for these variables represents milk sales to co-operatives or buying groups, without a retailer-linked contract, the choice of one or two milk buyers, a non production cost linked contract, and with milk collected daily. The continuous variables of herd and yield per cow (or their logarithmic counterparts) indicate the change in dependent variable from a one unit change in these independent variables. The

Table 5: Number of Producers by Buyer Choice and Frequency of Milk Collection

		Milk price quartile group				
		A	**B**	**C**	**D**	**All**
Number of buyers producers had to choose from	One	7	7	9	20	43
	Two	11	15	17	17	60
	Three	22	22	10	8	62
	Four	6	6	3	5	20
	Five or more	9	5	16	5	35
Frequency of Milk Collection	Daily (voluntary)	9	8	7	7	31
	Daily (compulsory)	23	26	10	6	65
	Every other day (voluntary)	16	13	30	27	86
	Every other day (compulsory) #	7	8	8	14	37
	Other / not applicable #	0	0	0	1	1
n		*55*	*55*	*55*	*55*	*220*

n = number of observations; # = groups combined within category for the purpose of Chi-Squared test

results from models 1 and 2 (with milk price specified as the dependent variable) demonstrate that the additional milk price from sales to a processor are approximately 1ppl (1.012 to 1.067ppl). A retailer linked contract is estimated to provide an additional 0.577 to 0.611ppl. A cost-linked contract is estimated to provide an additional 0.727 to 0.781ppl, with the choice of three

Table 6: Summary of Chi-Squared Tests

Category	Chi-Squared Probability	Signifi-cance level
Typology (Lowland or LFA)	0.0210	95%
EU Region	0.0883	90%
Organisation to which milk is sold	7.59E-14	99.9%
Length of Milk Contract	0.2244	NS
Flexibility to switch buyer	0.0459	95%
Price guarantee and proportion of milk	3.54E-06	99.9%
Nature of contract price guarantee	0.0108	95%
Intention to change milk buyer	0.0009	99.9%
Number of buyers producers had to choose from	0.0007	99.9%
Frequency of Milk Collection	0.0002	99.9%

Table 7: Results from Hedonic Regression Analyses Stage 1

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Milk Price (P)	Milk Price (P)	Log Milk Price (LnP)	Log Milk Price (LnP)
Independent Variables				
Constant	25.767 (0.000)***	10.970 (0.0084) ***	3.126 (0.000)***	2.644 (0.000)***
Buyer Organi-sation (B)	1.067 (0.000)***	1.012 (0.000)***	0.0425 (0.000)***	0.0404 (0.000)***
Retailer Con-tract (R)	0.577 (0.028)**	0.611 (0.019)**	0.0218 (0.032)**	0.0232 (0.021)**
Cost-Linked Contract (CL)	0.781 (0.060)*	0.727 (0.075)*	0.0284 (0.077)*	0.0263 (0.0968)*
Choice of buy-ers (CB)	0.227 (0.282)	0.203 (0.330)	0.0101 (0.215)	0.0092 (0.2558)
Frequency of collection (FC)	0.141 (0.511)	0.164 (0.480)	0.00506 (0.580)	0.00598 (0.507)
Herd (H)	0.00583 (0.000)***	-	0.220E-03 (0.0001) ***	-
Yield (Y)	0.000206 (0.0098) ***	-	0.854E-05 (0.0057) ***	-
Logarithm of Herd (LnH)	-	0.958 (0.000)***	-	0.0364 (0.000)***
Logarithm of Yield (LnY)	-	1.077 (0.0317)	-	0.0453 (0.0196)**
Adjusted R^2	0.359	0.377	0.365	0.384
Log Likelihood	-390.91	-387.81	321.00	324.21
Log likelihood test value	104.46	110.66	106.84	113.28
Chi-Sq Critical	14.07	14.07	14.07	14.07

Statistical significance at 99% (***); 95 % (**); 90% (*). Observations = 219, one data outlier excluded from hedonic regression analysis

Table 8: Results from Hedonic Regression Analyses Stage 2

	Model 4a	Model 4b	Model 4c
Dependent Variable	Log Milk Price (LnP)	Log Milk Price (LnP)	Log Milk Price (LnP)
Independent Variables			
Constant	2.669 (0.000)***	2.646 (0.000)***	2.654 (0.000)***
Buyer Organisation (B)	0.0394 (0.000)***	0.0406 (0.000)***	0.0430 (0.000)***
Retailer Contract (R)	0.0220 (0.026)**	0.0223 (0.024)**	0.0276 (0.003)***
Cost-Linked Contract (CL)	0.0243 (0.118)	0.0242 (0.119)	-
Choice of buyers (CB)	0.00853 (0.287)	-	-
Frequency of collection (FC)	-	-	-
Logarithm of Herd (LnH)	0.0362 (0.000)***	0.0372 (0.000)***	0.0378 (0.000)***
Logarithm of Yield (LnY)	0.0431 (0.0239)**	0.0457 (0.0160)**	0.0443 (0.0197)**
Adjusted R^2	0.386	0.385	0.381
Log Likelihood	323.98	323.40	322.143
Log likelihood test value	0.46	1.62	4.14
Chi-Sq Critical	3.84	5.99	7.81

Statistical significance at 99% (***); 95 % (**); 90% (*). Observations = 219, one data outlier excluded from hedonic regression analysis

3. Note also that this contrasts with the broad finding in Table 6, but reinforces the value of undertaking a hedonic regression analysis to estimate the value of individual attributes taking into account other determining factors.

or more buyers providing an additional 0.203 to 0.227ppl, however these later estimates are not statistically significant. Having milk collected every other day is noted to be valued at an additional 0.141 to 0.164ppl but these estimates are insignificant.[3] For every 10 extra cows, model 1 estimates an additional milk price of 0.058ppl, whilst for every extra 1000 litres produced per cow, this model indicates an extra value of 0.206ppl. Model 2 presents the influence of herd size and yield in logarithmic terms, indicating that increasing herd size by 10 cows from the average 128 cows will lead to an increase in milk price of 0.072ppl, whilst for herds increasing yield by 1000 litres per cow from the average of 6884 litres, an additional milk price of 0.136 ppl would accrue. Models 3, 4, 4a, 4b, and 4c specify the dependent variable as the natural logarithm of milk price, and the model results cannot be interpreted directly. However, the additional impact of these estimates are calculated to be as follows: selling to a processor (0.580 to 0.987ppl); retail contract (0.321 to 0.501ppl); cost linked contract (0.355 to 0.655ppl), choice of more than two buyers (0.124 to 0.231ppl); every other day collection (0.084 to 0.115ppl); an additional 10 cows to average herd size (0.029 to 0.050ppl); an additional 1000 litres per cow to average yield (0.124 to 0.160ppl).

The adjusted R^2 results indicate that across all models in Tables 7 and 8, approximately 36 to 39% of the variation in the milk price can be explained by the factors included in the hedonic regression equations.

Whilst the R^2 results are modest, these indicate that up to two-fifths of the variation in milk price within this sample can be explained by these factors alone. Whilst most variables are statistically significant, this does not universally hold. In order to provide a judgement on the preferred model function, the R^2 values and the number of significant variables was used to determine the preferred functional form from those models presented in Table 7. On the basis of this judgement, model 4 was determined to provide the most appropriate functional form. Note that models 1 to 4 inclusive were each statistically superior to a "null" model which regressed the dependent variable against the constant in isolation of other independent variables.

Discussion and Conclusion

The results presented above show that those producers receiving the highest 25% of milk prices tend to have larger herds of higher yielding cows, reinforcing the findings of Franks' (2001) analysis of milk prices. The findings show that a greater proportion of the 'top 25% milk price' producers are located in the lowlands and the EU West region. Milk price quartile groups A and B contained a greater number of producers who sell milk to a non co-operative processor, concurring with Bates and Pattisson's (1997) findings that producers supplying to non-co-operative milk buyers ranked 'price' as their highest ranking influence. The lowest milk price quartile group (D) contained a greater number of producers on one-year contracts, and moreover, quartile groups C and D were more likely to have to give more notice (e.g. 12 months) on their contracts than groups A and B. This reinforces Campbell-Gibbons (2010) who cites equal termination rights as the fifth most important aspect of milk contracts from producers' perspective. Greater numbers of producers in quartiles A and B held retailer-linked milk contracts, corresponding with

Campbell-Gibbons findings that those producers supplying processors were more satisfied with their milk contract. Milk price quartile group A also contained significantly more producers operating under production-cost linked contracts. Producers in quartiles A and B were more likely to have the choice of three or more buyers and have their milk compulsorily collected daily, whilst most producers in quartile D had the choice of only one or two buyers and most had their milk collected every other day.

The results of the preferred hedonic regression equation have estimated the individual impact on the price of milk from selling to a non co-operative processor, holding a retailer-linked contract, and increases in herd size and yield. The results presented show that selling to non-co-operative processor adds 0.624ppl to milk price, whilst holding a retailer-linked milk contract adds a further 0.398ppl. Franks (2002) found that selling to the co-operative Milk Marque reduced milk price by 1.5ppl; hence the results from this current study potentially find that the gap between co-operative and non co-operative milk price to have narrowed, albeit that that the combination of a retail-linked contract to a non-co-operative milk buyer will provide an additional 1.02ppl over the estimated base price. Current milk price profiles (DairyCo, 2011) indicate that retailer-linked contracts offer 2-3ppl premiums over non-aligned contracts, arguably being indicative of the increasingly tight milk supply conditions that exist in the market (Robertson and Wilson, 2009). It should be noted that the co-operatives tend to offer a return on the price of milk plus a return on the investment in the co-operative. However, it can be argued that any dividends accruing from the investment in the co-operatives should be viewed as a separate return on investment and not linked to milk price.

The results of this study show that increasing herd size and yield (and hence volume of milk) both provide significant increases in the milk price. Franks (2002) notes an increased value of 0.82ppl for a supply of 1.5 million litres compared with 1 million litres; the results presented here indicate increased prices of 0.27ppl, from an increased herd size, or 0.38ppl, from an increase in yield, over the same production levels, whilst industry results currently return typical premiums of 0.2 to 0.3ppl for this increased volume (DairyCo, 2011). Hence whilst the results presented here indicate a lower marginal value for increased production than the results of Franks (2002), they are broadly in-line with contemporary industry practice. The results presented reinforce the findings of Bates (1996) that producers need to understand both market fundamentals, the value of milk quality attributes and, increasingly, contractual arrangements.

Comparing the statistical power of the hedonic regression presented here with previous studies, provides a useful indication of the value of this approach. The preferred model explains 38% (R^2=0.38) of the variation in milk price and this contrasts with: Franks' (2002) analysis of milk price (R^2=0.775); Agbola *et al.*'s (2002) analysis of chickpea prices in India produced (R^2 of 0.80 to 0.87); Jabbar's (1997) analysis of sheep and goat prices in Nigeria (R^2 of 0.68 to 0.76); Huang and Lin's (2007) regional analysis of fresh tomato prices (R^2 of 0.306 to 0.510). Hence the goodness of fit measure reported herein is at the lower end of reported values in the

literature. Nevertheless, it is argued that the limited data availability and the significant parameter estimates obtained, serve to reinforce the importance of analysing the factors considered in this study which have clear impacts on the dairy sector. These findings suggest considerable variation in milk price exists across regions, between the lowlands and the LFAs, the organisation to which the milk is sold and the intended destination of the milk. Additionally milk price variation exists in respect to length of milk contract, the flexibility that producers have to switch buyer and the frequency of milk collection. This study suggests that volume of production, supplying to a non co-operative processor and holding a retailer-linked contract have individually demonstrable benefits with respect to the milk price obtained. These findings concur with previous research and industry observations.

As the number of dairy farmers continues to decline and the cost of transport fuel continues to increase, it is likely that milk buyers will continue to look for increased efficiencies in the milk supply chain by attracting producers that can supply large volumes of high quality milk. For some producers the choice of milk buyer is highly restrictive and a more restrictive choice leads to a lower milk price; producers in the LFAs are more likely to face this limited choice, though this is not exclusively an LFA issue. For those producers operating under production cost linked retail contracts, the price of milk is substantially greater than for those operating outside of these arrangements, and this is argued to be driven in part by the greater number of buyers that these producers typically have to chose from. The price of milk is one of the key determinants of profitability for producers (Wilson, 2011) and the results presented here suggest that LFA producers who are constrained in their choice of milk buyer will need to operate at lower production costs if they are to compete with typically larger, higher yielding herds located in the lowlands and selling their milk under cost-linked retail contracts.

Given the importance of economies of scale in milk production (Wilson, 2011), it is likely that the current structural change in the dairy sector will continue for some time to come. Dairy farmers who intend to remain in the sector will arguably need to adopt a strategy of investment for growth in supply and increased specialisation to achieve high quality production, or seek niche marketing opportunities through processing of their own milk. Given the range of market and environmental pressures that exists in the sector, the findings of this study serve to reinforce the relative price pressure that many smaller dairy farmers in the LFAs face; these pressures are unlikely to abate in the near future and will lead many in the sector to consider ceasing milk production, whilst a selection of larger lowland herds will expand to gain further economies of scale.

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