<u>Structural Change and Policy Reform in the UK Dairy Sector</u>

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Abstract

Estimation of a cost function for a representative sample of UK dairy producers allows future re-structuring of the industry to be simulated using a model which incorporates producers' differential costs and milk prices. Consideration is also given to reductions in producer prices and to the introduction of an A/B quota system. The results indicate that despite the history of quota trading in the UK there is considerable scope for further restructuring in the industry to take advantage of differential incentives between producers. It is also projected that UK milk supply would increase if quota restrictions were removed.

Keywords: dairy, quota, policy, reform, simulation

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1. Introduction

The UK dairy sector is experiencing both uncertainty over future policy and falling producer prices. Average farm gate milk prices in the UK fell by 27% from 1996 to 1999 (25.02 to 18.35 pence per litre)[1] and they continued falling until November 2000 when prices increased by around 2ppl. This paper presents the results of modelling structural change the UK dairy sector and draws on work commissioned by a number of government departments (Colman *et al.* 1998). The results presented here concern projections of future restructuring of the industry, reductions in producers' milk prices, and a formulation of an 'A' and 'B' milk quota system.

A particular feature of the analysis reported here is the incorporation of a separate milk price for each farm. These, in addition to differences in production costs across farms, lead to variations in net marginal revenues which, in turn, lead to differential incentives to expand or contract production.

The paper begins by critically reviewing some alternative approaches to econometric modelling of dairy sector restructuring to provide some context for the description of the model which follows it. The estimation results for the England and Wales cost function are then reported and the procedure used to extend the model to the other regions of the UK is outlined. Details of the scenarios to be analysed, and the projected outcomes of these are then presented.

2. Modelling Transferable Milk Quota in the EU

There have been a number of studies that have modelled the transfer of milk quota between individual producers in the EU. Because of the national nature of the existing regime these have focussed on intra-national transfers (although there is no reason why an investigation into the loss of efficiency due to maintaining national boundaries on quota trade should not be undertaken, assuming the relevant quota supply functions could be identified for all EU countries). In this section we briefly review three such studies (Burton 1995, Guyomard *et al.* 1996 and Boots *et al.* 1997) which share a common methodological framework, but with different approaches to the econometric and simulation aspects of the problem.

The common framework can be condensed to a simple statement. Individual milk producers are assumed to be profit maximisers, with milk production initially constrained by the quota. Differing cost and/or output price conditions lead to differing shadow prices of quota among farms, leading to the existence of mutually advantageous quota trade. For given milk quota prices, individual quota supply functions can be identified, and the quota market clears when aggregate excess supply of quota is zero. Having identified this equilibrium clearing price of quota one can retrieve the implied changes in milk production, herd sizes and other variables of interest.

Guyomard *et al*. (1996) give a full standard, mathematical statement of such a model, as well as a graphical representation for the (stylised) case where there are only two farms. This exposition is not reproduced here, but the empirical approach they employ is discussed below. In the appendix to this paper there is a complete statement of the model employed in this study.

[1] Source MAFF datasets website.

The main determinant of an individual farm's quota supply function is the marginal cost of production (which should include the full opportunity costs of devoting resources to milk production as opposed to alternative agricultural activities). The statistical identification of the marginal cost curve is one area where the three papers diverge. However, it should be noted that the general methodological structure outlined above is, in its essentials, independent of the method of identifying the marginal cost curve.

Burton (1995) estimates an essentially *ad hoc* average cost function for milk production alone, which is then manipulated directly to yield the marginal cost function. An alternative is the estimation of a formal, theory-consistent set of relationships, based on either the production function or dual relationships. Good examples of this alternative approach are given in Boots *et al.* (1997) and Helming *et al.* (1993), both of which relate to the Dutch dairy sector, or Guyomard *et al.* (1996) which deals with French producers.

Advantages of the *ad hoc* specification include the fact that it can focus solely on the product of interest, it allows for flexibility in the representation of the cost function, and can lead to a relatively straightforward development of the simulation model. A potential restriction on the use of this approach is that one has to be able to identify the costs specifically associated with milk production, which on multiple enterprise farms is not always possible.

Where there are multiple outputs and it is not possible within the data to identify costs that are specific to the dairy enterprise, the use of a formal system such as a multiple output profit function allows one to account for the impact of alternative enterprises on costs, and provides an integrated approach to incorporating alternative output opportunities. This is not the approach always employed however, Guyomard *et al.*, for example, appear to maintain the level of the alternative output as fixed in the simulation (see their equation 3.3, p216). Where the data are available joint estimation of, for example, input demands and a profit function while maintaining the cross equation parameter restrictions will improve the efficiency of estimates. However, the formal models often resort to restrictive functional forms, leading, for example, to marginal costs that are linear in output (Boots *et al.* 1997, Guyomard *et al.* 1996). Although linearity may be a reasonable approximation *in the region of the observed data*, this may be less appropriate in simulation exercises where one is examining potentially large changes in output.

The second distinguishing feature of quota trade models is the treatment of time, and the assumed rate of adjustment. The estimated cost functions often imply that farms are currently substantially smaller than the economic optimum, and the assumption of economic rationality in the transfer of quota implies a substantial structural change in the simulations. For example, the cost curves estimated in Burton (1995) imply a minimum average cost at a herd size of 216 cows. Those of Guyomard *et al.* (1996) imply (infeasibly) large expansions in milk output, even in the short run with quasi-fixed factors[2]. As a result, arbitrary constraints are often imposed on the degree to

[2] Evaluating their equation 3.3 using the estimated parameters and sample means for the quasi-fixed factors, alternative output and milk price (199FF/hectolitre) generates a milk output which implies a milk yield of 33,000 litres per cow if the quota price is zero. If the quota price is set at 120FF/hectolitre the expansion in milk output implies a yield of 11,000 litres. These increases are achieved only by changes in the variable inputs. The average yield in the sample is 4,600 litres.

which expansion of output can occur. Burton (1995) restricts this to a maximum of a 20% increase. Guyomard *et al.* (1996) impose a restriction on expansion based on the degree to which the farm is technically inefficient, based upon a stochastic production function.[3]

Ideally constraints on structural adjustment should be determined empirically rather than imposed within the simulations.

3. The Empirical Implementation

The model presented here employs the ad hoc approach outlined above. This is in part due to the data available. The empirical basis of the model is the1996/97 survey of 377 England and Wales dairy farms which were collected for the Special Study of the Economics of Milk Production (SSEMP), and full details of this survey can be found in Farrar and Franks (1998). The SSEMP identified detailed milk production costs, but had little information on alternative enterprise outputs. As the focus of the study is on milk production *per se* there is no need to identify input demand functions and hence the benefits of specifying a flexible functional form for the cost function are judged to outweigh the statistical advantages of a formally derived system. An explicit constraint on the maximum expansion in herd size, set at 20%, is also employed in the simulations reported below. This follows the use of such a constraint in Burton (1993, 1995) and is justified on the basis of unobserved costs of adjustment which lead to incomplete movement towards the industry's long run equilibrium. If the equilibrium herd size is zero, complete adjustment (exit from the industry) is permitted.

Furthermore the *ad hoc* approach employed allows the analysis to be extended to Scotland and Northern Ireland (NI). This is necessary because quota can be transferred across the whole of the UK (apart from a few small and remote 'ring-fenced' areas) and policy developments should therefore be evaluated on this basis. However, there is no equivalent data set available for these regions. The approach taken to represent these producers is outlined in Section 3.1 below.

3.1 Estimation of the Cost Functions

A number of ad hoc functional forms have been suggested when estimating cost curves of this type (Oxley *et al*., 1989, Burton, 1995, Mukhtar and Dawson, 1990, Burton *et al.*, 1993, Hubbard, 1993), but a relatively simple quadratic, based on that of Burton (1995), has been selected here. The estimation of this function for England and Wales is described below, with details of the incorporation of the samples from Scotland and Northern Ireland following it.

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[3] It should be noted that this approach has some serious implications for individual behaviour and model consistency. There is no rationalisation of why the inefficient producers move to the frontier, and those farmers identified as on the efficiency frontier cannot expand at all. There are two representations of the production technology used in the model, one by the stochastic frontier production function and one by the total cost curve; estimation of the cost curve and its use to derive profit maximising output responses assumes that the observed costs are generated from cost minimising input use, but the stochastic production function explicitly assumes that for some producers input use is not optimal.

England and Wales

A farm level cost function is estimated directly for the 377 sample farms from the SSEMP for the year 1996/97. This cross-section cost function approach is motivated partly because we are principally interested in the evolution of long-run average costs as output varies. Also, because an objective of the model is to analyse changes in quota allocation, it is appropriate that the effects of changes in quota level on long-run marginal costs should be a core relationship in the model.

The dependent cost variable for each farm, expressed in pence per litre (ppl), is defined as the total cost[4] divided by expected milk output. There is an important issue here regarding the use of *ex-post* or *ex-ante* milk production in determining the average cost. The use of expected milk output implies that all costs are committed at the time of planning by the producer. If this is not the case, and it is possible for producers to alter costs in the response to a "shock" to the system, such as BSE, then expected yield is unlikely to equal actual yield. The inclusion in the SSEMP of questions concerning differences between production levels anticipated before the BSE crises and production levels actually achieved, allowed for the effect of any deviations from expected yield to be explicitly included in the cost function. Some individual farms were affected by this in 1996/97 and the "yield deviation" term in the cost function captures this effect.

Average cost is specified as a function of herd size, farm area, milk yield, region, concentrate feed costs, wage rates and yield deviation. The assumption is that yield per cow is fixed for each farmer, and represents the management abilities and strategy of the farmer; otherwise it is necessary to explain why there is such a wide range of yields (mean: 5636 litres, st.dev:1102 litres), which presumably cannot all be due to choice. Farm area is used as a 'shifter' which affects both the position and level of the minimum average cost. As a result the principal control variable for the farmer is the number of cows, which, given the fixed yield, will determine milk output. The assumption is that average costs follow a quadratic functional form in cow numbers, which gives an 'upward' sloping portion of the marginal cost curve at some level.

[4] Total cost is defined as variable costs plus all attributable fixed costs.

Table 1. The Estimated Average Cost Function (pence per litre)

Variable	Coefficient	t value
Constant	0.4273	9.98
$Cows_i$	$-0.383*10^{-3}$	5.17
$Cows_i^2$	$0.2841*10^{-6}$	1.41
$Cows_i/Area_i$	-0.0310	2.91
$Cows_i/Area_i^2$	0.5089	4.66
$Cows^2_i/Area_i$	$0.1219*10^{-3}$	1.96
$Yield_i$	0.0854	5.88
$Yield_i^2$	$0.6212*10^{-8}$	4.82
Yield adj_i.	0.00376	4.44
$Wage_i$	0.00333	2.04
$Concentrate_i$	0.00833	0.79
Wales	0.00896	1.02
N.West.	0.00985	1.16
East.	0.0499	6.30
South	0.0191	2.03
S.West	0.00917	1.01

$R^2 = 0.53$

Where:

Cows = cow numbers (cows),
Area = total farm area (hectares),
Yield = yield per cow (thousand litres),
Wage = wage rate (£/hour),
Yield adj. = deviation from expected yield (hundred litres),
Concentrate = concentrate feed cost (£ per tonne),
Wales = dummy variable for Wales,
N.West = dummy variable for North-West England,
East = dummy variable for East England,
South = dummy variable for South England,
S.West = dummy variable for South West England.

The function is quadratic in herd size, yield and farm area. The estimation results are presented in Table 1. The coefficients on the $cows_i$ and $cows_i^2$ terms indicates that there are economies of size available to producers by expanding the herd size, however, average costs per litre then rise as the herd reaches a certain size. The level at which these economies of size cease to be available to producers varies across the sample because of the set of interaction terms which relate herd size to $area_i$ and $area_i^2$. Thus total farm area will affect both the level of the minimum of the quadratic cost function (i.e. the lowest average cost per litre attainable on the farm), and also the herd size at which this minimum average cost is achieved.

Inspection of the underlying components of costs suggest that it is the labour costs of running small herds which are particularly onerous. Data from the SSEMP (Farrar and Franks, 1998) indicate that on lowland UK dairy farms the average dairy specific labour costs of milk output fall from 7.5ppl on farms with herds between 10 and 40 cows, to 2.84ppl on farms with herds in excess of 150 cows. When considering these labour costs it should be noted that they include an imputed cost for unpaid family labour, which is calculated according to MAFF guidelines. This imputed component of dairy labour costs is far more significant for smaller farms. On farms with herds between 10 and 40 cows 'farmer and spouse' labour accounts for 52% of costs per cow compared to 15% for farms with herds over 150 cows. This imputed cost component has implications for the scale and pattern of industry restructuring that is discussed in the following sections.

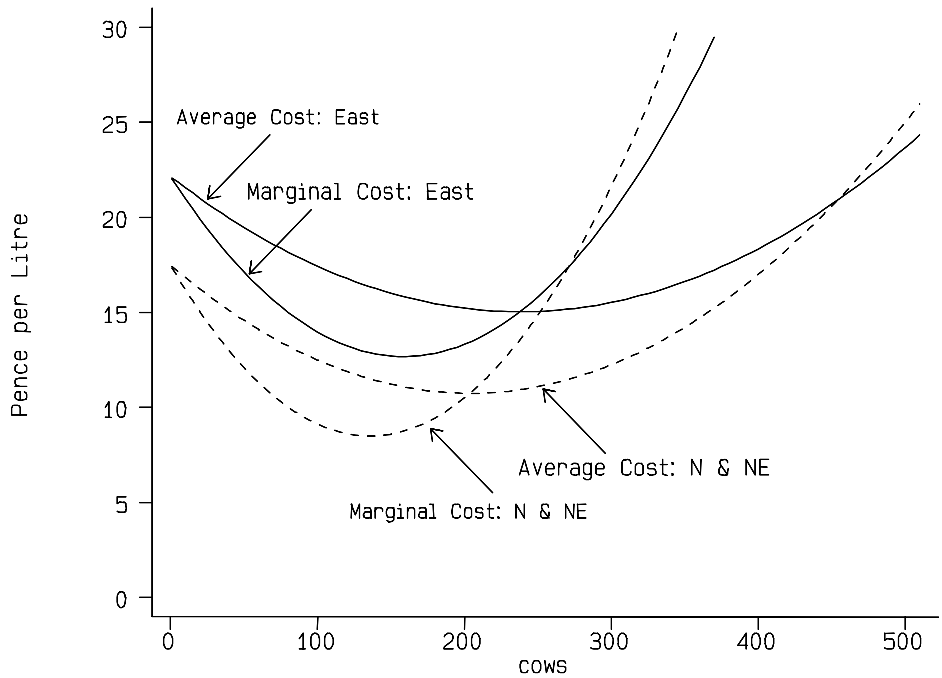
Because milk yields and area are assumed to be fixed, each farm's cost function can be reduced to a simple quadratic of the form:

$$CPL_i = a_{1i} + a_2.cows_i + a_3.cows_i^2 \qquad (1)$$

The first 11 variables (including the constant) in Table 1 can be collapsed to give a farm specific constant, a_{1i} ,and the last three interactive terms can be combined into the $cows_i$ and $cows_i^2$ terms by deriving the appropriate parameters a_{2i} and a_{3i}.

The cost curves for a particular producer in the sample will depend upon farm area, milk yield, herd size, location, wage rate paid and the price of concentrates. Typical examples of the cost curves generated by this procedure are shown in Figure 1. The estimated average and marginal cost curves for representative farms from the 'East' and the 'North and North East'(NNE) regions of England are shown. These curves have been estimated from the mean observed levels of farm area, milk yield and other variables, for each region.

Figure 1.
Estimated average and marginal cost curves for representative “Eastern” and “North & North Eastern” farms



At low herd sizes the regional difference in the average cost of producing milk is large, with an average cost per litre of 17.2 pence in the NNE compared to 21.8 pence in the East. For the NNE farm increasing returns are observed until a herd size of about 205 cows is reached, while in the East the level is about 240 cows. Only at herd sizes in excess of 440 cows are the average costs of production of the East farm estimated to fall below those of the NNE farm.

Northern Ireland and Scotland

A sample of 184 dairy Farm Business Survey (FBS) records for Northern Ireland and 82 for Scotland for 1996/97 are available. The FBS collects a different set of data to the SSEMP, and the cost data for these two FBS samples was insufficient in detail to permit cost functions, which are comparable to those for England and Wales, to be estimated. Thus it is assumed that the basic cost function for each Northern Ireland and Scottish farm (by herd size, area and milk yield, all of which are available in the FBS data) is fundamentally the same as its England and Wales counterpart (i.e. takes the form and with the same parameter values as reported in Table 1). However the value of the intercept term, and the opportunity cost of land used in the simulation are specified to reflect local conditions. Thus, for Scotland both are assumed to be the same as that for those farms in the North and North East of England, because of the similarity in climatic and geographical conditions in which many dairy producers in the two regions operate. In this way long-run average costs for these farms can be simulated despite the lack of a full dataset for them.

However differences between the production system typically employed on dairy farms in Northern Ireland and those in the rest of the UK required a slightly different approach. The use of concentrate feeds in N.I. dairy systems averages about two-thirds of the level fed per cow in mainland Britain, and there is greater emphasis on summer milk production, resulting in lower costs per unit of output. Therefore the intercept (a_{1i}) used for each farm in the Northern Ireland sample was taken as 90% of the average estimated for the Welsh sample. Rental and opportunity costs from the Welsh sample of the SSEMP are substituted across for the N.I. farms.

3.2 Raising Weights

The estimated cost function is based upon a random sample of 377 milk producing businesses in England and Wales selected to be representative of the industry as a whole. Each one is treated as a representative business (by region, herd size, and total farm area), and raising weights, based on the fraction each farm represents of the population, are applied to produce projections of output and behaviour at the England and Wales level. These raising weights were derived from the June 1996 Agricultural Census.

For Northern Ireland and Scotland, the 1996 June Census number of holdings, and their distributions, were accepted as good estimates of the number of businesses. Thus census based raising weights were applied directly to the 1996/97 sample of 184 dairy Farm Business Survey records for Northern Ireland and 82 for Scotland. Applying these weights to the total of 643 representative farms generates a raised total UK figure for milk marketed of 14 029 million litres for 1996/97. This compares to wholesale and direct quota sales for 1996/97 of 13 953 million litres. Hence a sample of 643 farms, from across the UK, are represented in the model as profit-maximising producers with differential production costs and differential milk prices. Their weighted output is equal to total UK output and trade in quota may be simulated between them with the resulting changes in industry structure and equilibrium quota price observed.

4. Results

In each of the scenarios discussed below changes may be modelled under the assumption of complete, unconstrained adjustment to equilibrium herd size, or under constrained adjustment of 20%. These restricted adjustment results are comparable to those expansions in production on the basis of quasi-faxed factors in Guyomard *et al.* (1996). In all cases any farm may cease production and lease out quota equal to its 1996/97 production level.

4.1 Projected Restructuring and Reductions in Milk Price

Equilibrium is observed where the weighted sum of outputs of the individual farms throughout the UK equals the 1996/97 national quota. Quota is freely tradable in the model between farms. Milk prices are held at the level received in 1996/97, with each representative farm having its own actual average milk price. Average milk prices received show a remarkable variance among farms and are assumed to be a major factor in determining the decisions farmers will take about their dairy farming future. Concentrate feed prices and wages (which are factors in determining costs) are also held at 1996/97 levels. The model finds the quota price at which the quota market clears if long-run costs are to be covered.

The 20% constrained run produces an equilibrium lease price of 7.2ppl[5]. The model indicates that at lease prices below (above) 7.2ppl there would be an excess demand for (supply of) quota. Hence at a lease price of 5ppl, desired national output would be approximately 1.2 billion litres greater than the quota system permits.

Table 2 compares projected outcomes under the different adjustment assumptions. In the unconstrained run the number of producers contracts to a third of current numbers. This must be seen as a possible long-run outcome. However, it is not thought feasible in the medium run for herds to grow at the rate required for this outcome, and while it is dangerous to speculate how long such a restructuring might take, it could be of the order of 20 to 25 years. In the shorter run the restricted adjustment projections seem more convincing, with the 20% run possibly reflecting likely events in around 5-7 years. In both cases a substantial reduction in producer numbers is (realistically) envisaged, with Northern Ireland displaying a slower rate of decline than the other three countries.

Table 2 Projected Changes in Producer Numbers, by Country

	England	Wales	Northern Ireland	Scotland	U.K.
	Adjustment restricted to 20%.				
Producers leaving	7,372	1,701	1,153	773	10,999
Producers continuing	13,517	2,852	4,467	1,806	22,642
	Unrestricted adjustment.				
Producers leaving	14,200	3,228	2,969	1,959	22,356
Producers continuing	6,690	1,325	2,651	620	11,286

Under all scenarios Northern Ireland emerges as gaining quota and increasing milk output at the expense of the other three countries. Some of the effects of the simulated restructuring of the dairy industry are displayed in Tables 3 and 4 in terms of the regional distribution of production and regional changes in average herd size.

Table 3 Distribution of Production, by Country (million litres)

	England	Wales	Northern Ireland	Scotland	U.K.*
1996/97 raised production.	9,806	1,633	1,432	1,158	14,029
Adjustment restricted to 20%	9,707	1,586	1,580	1,219	14,092
Unrestricted adjustment.	9,172	1,500	2,575	799	14,046

* The slight variation in UK total production is explained in the Appendix.

[5] This lease price might seem low compared to the average lease price in 1996/97, but the model uses full costs whereas the lease market is more likely to reflect variable costs. Indeed, a version of the model estimated using variable costs produces an equilibrium lease price of 11.7ppl.

Table 4 Average Herd Size per Business, by Region/Country

	England					Wales	N.I.	Scotland
	NNE	NW	East	South	SW			
1996/97	75	94	93	112	88	94	55	91
Adjustment restricted to 20%.	100	134	150	161	124	129	71	119
Unrestricted adjustment.	205	209	223	284	206	206	176	217

Because there is a very simple relationship in the model whereby a fall in average milk price of 1ppl causes a fall in equilibrium quota price of the same amount, the effects of price reductions with quota in place are straightforward. Therefore reducing the milk price of all producers by the same amount, while maintaining the 1996/97 price differentials between producers, leaves the pattern of adjustment completely unchanged as long as the quota price is positive. That is, under the 20% adjustment constraint, precisely the same farms expand or contract milk output by the same amounts at a milk price of 18.3ppl as they do at 24.3ppl. Hence the results in Tables 2 to 4 hold at all positive lease prices.

In the base period, 1996/97, the weighted average milk price of the 643 representative UK dairy farms was 24.3ppl. Interestingly, that implies that the average milk price could fall to 17.1ppl (24.3ppl - 7.2ppl) before equilibrium quota price falls to zero, and before there would be any likelihood of UK milk production falling below the current quota-constrained level. The average price in 2000 will not be greatly above this level, and as of October 2000 milk deliveries are a few percent below the total of recent years, although the expectation is that by the end of March production will be close to the quota target.

What this result also implies is that, if the quota restriction were to be eliminated, UK output would be expected to be above current quota levels at any average price above 17.1ppl. These results imply that the UK milk industry can survive further reform pressure, but at the cost of the sorts of restructuring indicated in Tables 2 to 4. The results of the constrained adjustment scenario suggest that milk production might not decline if all EU price support were to disappear (which is unlikely), and indeed that it could even expand in the long-run.

4.2 Introduction of ‘A’ and ‘B’ Quota

In this scenario only ‘A’ quota output is eligible for price support. ‘B’ quota is available only for unsubsidised exports. ‘A’ quota is set at 95% of the 1996/97 baseline level for the model, and ‘B’ quota is set at the balancing 5%. Both types of quota are tradable. The price of ‘A’ milk is remains at the observed 1996/97 level with price differentials maintained among producers. The ‘B’ price used is a flat rate of 16ppl for all producers, a price intended to represent a world market price. The precise choice of this ‘B’ price is flexible, and the value of the world price of milk is difficult to gauge, however some (MDC, 1998) have estimated a liberalised world market price of 16ppl.

Producers are now able to produce ‘A’ and/or ‘B’ milk or exit the industry as before. What is observed when simulating this policy environment is that producers either produce ‘A’ milk only, produce ‘B’ milk only, or exit dairying and use the land released for alternative activities (represented through the regional opportunity costs).

It is the market for ‘A’ and ‘B’ quota, rather than a fixed feature of the model, which means that producers sell *either* to the ‘A’ market *or* to the ‘B’ market. The price differentials received by individual producers are a crucial determinant of how the model works, since the amount that a producer will be prepared to pay to lease in ‘A’ quota will depend on the differential between the ‘A’ and ‘B’ prices received. Those with the greatest difference between ‘A’ and ‘B’ price will be those prepared to pay the most to obtain ‘A’ quota, since it is of greatest relative value to them. The producers price differentials observed in the UK market are therefore a critical factor in the choice as to whether to produce for the price differentiated ‘A’ market or the flat rate ‘B’ market.

Hence there will be a bidding process by which the ‘A’ quota will be bought up by producers who will only produce ‘A’ milk. There will be a simultaneous bidding process in which ‘B’ quota is held by producers only producing ‘B’ milk, and a third set of producers will exit the industry. With ‘A’ and ‘B’ milk prices available in this system, equilibrium is defined as the combination of ‘A’ and ‘B’ lease prices which generates ‘A’ output equal to 95% of the baseline UK output level, and ‘B’ output equal to 5% of the baseline UK output.

Given the assumption of 20% adjustment towards optimal herd size by producers, equilibrium conditions are satisfied by an ‘A’ lease price of 7.08ppl and a ‘B’ lease price of 0.07ppl. The presence of a marginally positive ‘B’ quota price indicates that if the world price was indeed 16ppl, then with ‘A’ quota set at 95% of current production, ‘B’ output would just exceed the 5% limit imposed here. One might argue that such a ‘B’(or world) market should not be constrained in terms of output as it is here at 5%. However the possible introduction of an ‘A’ and ‘B’ milk quota scheme, similar in essence to that of the EU sugar regime, takes place in the context of (a) the EU’s binding WTO commitments constraining the volume of milk products which can be exported with the aid of subsidies, and (b) the fact that about 20% of all EU milk produced is disposed of internally or externally with the aid of product subsidies. With these factors operating it seems unreasonable to consider the possibility that introducing an ‘A’ and ‘B’ quota system might be used to justify increasing the total UK milk quota. Thus the option explored here is that ‘B’ quota could only be introduced by splitting the existing quota between ‘A’ and ‘B’. Given the assumption of a ‘B’ price of 16ppl, there is very little practical difference, however this would be more of an issue with, for example, of a ‘B’ price of 17ppl.

Producers selling to the ‘B’ market will have production costs below 16ppl for all but the marginal unit of output. Producers with costs above 16ppl throughout the range of production (mainly small producers with high imputed labour costs) will be unable to produce profitably for the ‘B’ market. These producers have two choices - to sell to the ‘A’ market or leave the industry. If their ‘A’ milk price is sufficiently high to meet the direct costs of production as well as the cost of obtaining ‘A’ quota they will produce for the ‘A’ market, otherwise they will leave the industry in the long-run.

It is not surprising that the regional distribution of ‘A’ and ‘B’ production, shown in Table 6, indicates that there are no ‘B’ producers in the South where producers receive the highest ‘A’ price of all (a 1996/97 average of 25.4ppl). There are also no ‘B’ producers in the South West and negligible numbers in the North and North East and North West of England. ‘B’ production is concentrated in Scotland and Northern Ireland where producers received an average ‘A’ price of 23.8ppl and 23.6ppl respectively. For these producers it pays to lease out all their ‘A’ quota at 7.08ppl and sell milk on to the ‘B’ market at 16ppl.

Table 5 Regional Distribution of ‘A’ & ‘B’ Milk Production
Adjustment restricted to 20%

Region	‘A’ producers	‘A’ output (million litres)	‘B’ producers	‘B’ output (million litres)
NNE	3384	1886	89	17
NW	2956	2205	53	24
East	838	778	0	0
South	2444	2350	0	0
SW	3903	2511	0	0
Wales	2852	1587	0	0
Scotland	1037	752	510	365
N Ireland	2836	1151	727	306
TOTAL	**20250**	**13220**	**1379**	**712**

5. Conclusions

The 1996/97 SSEMP data reveals major differences between milk producers in terms of prices received and the cost of production per litre of milk. In general, larger herds in businesses with more land possess economic advantages, but some smaller herds achieve high levels of efficiency and are estimated to be capable of prospering. Economic logic dictates that competition should lead more profitable enterprises to expand and the others to contract or cease production. Where there is a market in quota, adjustment requires those expanding to lease or buy quota rights from the others. Structural change in dairy farming in the past is consistent with this, and our model projects it is a pattern which will continue.

The model used to evaluate the effects of policy reforms is based on long-run cost functions estimated from 1996/97 farm level data. It solves for the redistribution of quota which would lead all those in the UK producing milk in 1996/97 to maximise their annual profit from the combination of producing milk and either leasing out quota or leasing it in. If the modelling allowed producers to take full advantage of economies of size, the most efficient producers (those with low costs and contracts paying high milk prices) would expand their businesses greatly, to herd sizes of over 400 cows in many cases.

Since most producers cannot in reality expand in this way, because convenient parcels of land are not available and there are capital and tenancy constraints, modelling restrictions have been placed on the extent to which they can expand, and the extent to which small herds will be driven out. An additional issue here is the fact that a major component of the economies of size in the model are imputed labour costs. These imputed costs are particularly significant for smaller producers. If such producers value their labour at a lower rate than that which is used by MAFF to calculate these imputed costs then the economies of size available are reduced. The projected reduction in producer numbers is likely to be reduced if this is the case.

Using observed 1996/97milk prices and a 20% adjustment constraint, the optimal annual lease price was found to be 7.2ppl, and the number of producers in the UK was projected to decline from 33,641 to 22,642. The interpretation of these estimates is that if 1996/97 conditions had persisted for a number of years (perhaps between 5 and 7) and every producer maximised profit, this would be the annual lease price of quota, and change in producer numbers. This projected restructuring may initially seem severe but, we would argue, is quite plausible given (a) past and current rates of loss from the industry, and (b) the predictions by accountants Deloitte Touche that 20% of dairy producers could be forced out of business over a two year period (cited in AgraFood Europe, 1998).

An implication of the estimated 7.2ppl equilibrium lease price in the solution with 20% adjustment is that the price of milk could fall by this amount from its 1996/97 level (which averaged 24.3ppl) before output would decline below the national quota level, and before the lease price of quota would drop to zero. That is to say, according to the 20% restricted model, the average milk price could fall to 17.1ppl without causing output to fall or for there to be any further adjustment in producer numbers. This is only a little below the average price in 1999/2000.

At any milk price above 17.1ppl, the restricted adjustment model projects the following changes from 1996/97 in the levels of regional output. Production in England falls by 1.0%, Wales is projected to lose 2.8% of its 1996/97 output, while Northern Ireland and Scotland gain 10.3% and 5.3% respectively. This picture is regarded as not unreasonable.

In considering A/B quota it is assumed that 5% of current quota is available for unsubsidised export production at 16ppl while the remaining 95% attracts observed 1996/97 prices with differentials maintained. The solution, which obeys strict economic logic, is intriguing in that turns out to be illogical for producers to produce both ‘A’ and ‘B’ milk. For those producers at the bottom end of the distribution of margins per litre of ‘A’ milk produced, it is optimal to lease out all their ‘A’ quota to those best equipped to exploit the ‘A’ market and to lease in ‘B’ quota. The equilibrium lease prices are 7.08ppl for ‘A’ quota and 0.07ppl for ‘B’ quota. The very low ‘B’ quota lease price indicates that if the ‘B’ market was not constrained by quota then, at a ‘B’ milk price of 16ppl, output would be only marginally greater than the 5% of national quota assumed here.

Taking all the results together, the model suggests that UK dairy farming is probably able, with considerable restructuring, to adapt to the various reform scenarios currently envisaged. Incomes will only be maintained if enterprise sizes are considerably increased and producer numbers reduced, as has already been happening for many years at a steady rate.

Appendix 1.

Profits per farm are defined as:

$\pi_i = mp_i.cows_i.my_i - [CPL_i].cows_i.my_i - OC_r.my_i.cows_i - rentpl_i.my_i.cows_i - qp.my_i.cows_i$ (1)

where:

mp_i	=	milk price per litre of output (pence)
$cows_i$	=	herd size
my_i	=	milk yield per cow (litres)
cpl_i	=	cost per expected litre of output (pence)
oc_r	=	opportunity cost per litre of output (pence), by region *r*.
$rentpl_i$	=	land rental per litre of output (pence)
qp	=	quota price per litre of output (pence)

For reasons outlined above, the representative farmers' milk yields are assumed to be fixed, as also is the area they farm. Thus all projected adjustment in the model will be in terms of cow numbers milked (and by implication of quota held). Hence the cost function (which includes all variable costs, and attributable fixed costs other than imputed rent- see section 3 for the estimated function.) for any representative farm may be expressed in a simplified form by combining terms as

$$CPL_i = a_{1_i} + a_2.cows_i + a_3.cows_i^2 \quad (2)$$

Differentiating profit with respect to herd size gives:

$$d\pi_i/dcows_i = mp_i.my_i - a_1.my_i - 2.a_2.my_i.cows_i - 3.a_3.cows_i^2.my_i - OC_r.my_i - rentpl_i.my_i - qp.my_i \quad (3)$$

The behavioural assumption regarding producers is one of profit maximisation and therefore the optimal output level is identified by the equality of marginal revenue and marginal cost.

With the following definitions:

$$b_1 = mp_i.my_i - a_1.my_i - OC_i.my_i - rentpl_i.my_i - qp.my_i \quad (4)$$
$$b_2 = -2.a_2.my_i \quad (5)$$
$$b_3 = -3.a_3.my_i \quad (6)$$

the optimal herd size, $cows_i$*, defined by solving equation 3 for the cow number which gives a non-negative change of profit approaching zero, is given by :

$$cows_i^* = \{-b_2 - SQRT\,(b_2^2 - 4.b_1.b_3)\} / 2.b_1 \quad (7)$$

Farm level excess demand for quota, XS_i, is defined as

$$XS_i = Q_i - my_i.cows_i \qquad (8)$$

where Q_i is the farm's initial allocation of quota, which is assumed to be equivalent to the observed level of output in 1996/97

Farm weights, W_i, allow the individual levels of excess supply of quota, XS_i, to be aggregated to give the industry level excess supply. Equilibrium in the market is observed where

$$\Sigma_i XS_i . W_i = 0 \qquad (9)$$

A value of *qp*, the lease price of milk quota influences an individual's excess demand through b_1. The market clearing value of *qp* is found, by simulation, such the market is cleared across all farms and hence the individual farms' output level and demand for quota are identified.

The simulation model is operated using STATA 5.0 (Statacorp, 1997). An incremental range of quota lease prices is created and the model identifies the profit maximising levels of output and quota leasing for each farm, subject to any adjustment constraints being imposed. At each of these quota lease prices the weighted sum of farm outputs represents the total milk output for the UK. The smaller the incremental changes in lease price, the smoother the path of desired national outputs generated. In most of the scenarios presented the increments in lease price are 0.05ppl. However, even this causes the path of national outputs to be slightly "lumpy". It is this that causes the total UK quota figure, presented in Table 3, to vary by a small amount. This variation, never more than a 0.5% change from the baseline figure, does not impair the results.

At "low" quota lease prices the weighted sum of optimal outputs will be greater than the UK allocation of quota and therefore the industry can not be considered to be at equilibrium since the national quota is assumed to be fixed. There is therefore excess demand for quota. At "high" lease prices, the weighted sum of output will be less than the national quota and hence there is excess supply of quota. It is possible to identify that quota lease price which generates a solution where the sum of the farms' weighted outputs is equal to the national quota, and hence identify the equilibrium lease price. At this price demand and supply for the leased quota are in balance.

References

AgraFood Europe (1998) “20% of UK farmers could quit dairy sector” May 1998: 25.

M Bent, (1993)(Ed) *Livestock Productivity Enhancers: An Economic Assessment*. CAB International, Wallingford.

M Boots, V Oude Lansink, J Peerlings (1997) Efficiency losses due to Distortions in Dutch Milk Quota Trade. *European Review of Agricultural Economics* **24**, 31-4

M P Burton, A Ozanne and C Collinson (1993) Long-run Average Cost Curves in the England and Wales Dairy Industry - Comment *Journal of Agricultural Economics* **44**, 502-506.

M P Burton (1993) *The Use of Econometric Models in the Evaluation of Livestock Productivity Enhancers: An Economic Analysis.* In M Bent Ed) CAB International.

M P Burton (1995) The Impact of rBST on the Structure of the England and Wales Dairy Sector. *Technological Forecasting and Social Change* **50**, 93-104.

D Colman, M Burton, D Rigby J and Franks (1998) *Economic Evaluation of the UK Milk Quota System.* Final Report to MAFF, WOAD, DANI and SOAEFD. CAFRE, University of Manchester.

P J Dawson and L Hubbard (1987) Management and Size Economies in the England and Wales Dairy Sector. *Journal of Agricultural Economics* **38**, 27-38.

P J Dawson (1991) ‘The Simple Analytics of Agricultural Production Quotas’, *Oxford Agrarian Studies* **19**, 127-130.

J Farrar and J R Franks (1998) *The Economics of Milk Production in England and Wales, 1996/97*. Farm Business Unit, The University of Manchester, Manchester.

H Guyomard, X Delache, I Xavier and L-P Mahé (1996) A Microeconometric Analysis of Milk Quota Transfer: Application to French Producers. *Journal of Agricultural Economics* **47**, 206-223.

J Helming, A J Oskam, G J and Thijssen, (1993) A Micro-Economic Analysis of Dairy Farming in the Netherlands *European Review of Agricultural Economics* **20**, 343-363.

L Hubbard, (1993) Long-run Average Cost Curves in the England and Wales Dairy Industry *Journal of Agricultural Economics* **44**, 144-148.

Ministry of Agriculture, Fisheries and Food (various) United Kingdom Milk Prices. MAFF Statistics, Government Statistical Service: various issues.

Milk Development Council (1998) *An Economic Analysis of the Impact of Market Liberalisation on Dairy Farming in the EU*. Publication 33 (02/98).

S Mukhtar, and P J Dawson, (1990) Herd Size and Unit Costs of Production in the England and Wales Dairy Sector, *Journal of Agricultural Economics* **41**, 9-20.

G Oxley, G Fox and G Moschini, (1989) An Analysis of the Structural and Welfare Effects of bST on the Ontario Dairy Industry. *Canadian Journal of Agricultural Economics* **37**, 393-406.

A J Oskam and D P Speijers, (1992) Quota mobility and quota values: influence on the structural development of dairy farming. *Food Policy*, February 1992, 41-52.

Statacorp (1997) *Stata Statistical Software: Release 5.0* College Station, TX: Stata Corporation 1997.