Dairy Farms without Quotas: Simulations Based on a Multi-output Multi-input Cost Function

Baudry A. [1], Henry de Frahan B. [1], Polomé P. [2] and Howitt R. [3]

[1] Economie Rurale, Université catholique de Louvain, Louvain la Neuve, Belgium
[2] Groupe d'Analyse et de Théorie Economique, Université de Lyon 2, Lyon, France
[3] Agricultural and Resource Economics, University of California, Davis, USA

Abstract— **This paper evaluates the farm level supply and income effects from removing milk quotas and reducing producer prices with increasing direct compensatory payments. Using a panel of Belgian dairy farms, we first estimate long-run flexible multi-output multi-input marginal cost curves for each farm of the sample. Second, we embed each estimated long-run farm cost function in the objective function of a profit maximisation programming model built for each farm of the sample. Simulations show that, without quotas, aggregated milk supply and farm gross margin increase by 18 per cent and 37 per cent respectively from their reference level. A 20 per cent decline in producer prices and a compensation rate set at 30 per cent of the price decline maintain the aggregated milk supply and farm gross margin at their reference level. Dairy farms adjust differently to change in prices and compensation rates.**

Keywords— **flexible cost function, micro-simulation, dairy reform**

I. INTRODUCTION

On several occasions in 2007, the European Commissioner for Agriculture and Rural Development, Mariann Fischer Boel, made it clear that the milk quota system that regulates the Common Market Organisation (CMO) for milk and dairy products in the European Union (EU) should not be renewed when it expires in 2015. The Communication from the Commission of the European Communities (2007) for preparing the so-called "Health Check" review of the Common Agricultural Policy (CAP) reaffirms its determination to end milk quotas by March 2015 and asks for measures to ensure a smooth transition to a more-market-oriented dairy policy before the milk quota system runs out in 2015. The Agriculture Commissioner sees no justification in continuing a system that is strongly anti-competitive and, hence, can no longer fit in with the reformed CAP. In 2009, she intends to propose transitional measures to prepare dairy farmers and the industry for the elimination of milk quotas in 2015. There is no guarantee that her proposal will be favourably endorsed by the European Commission and, then, accepted by the 27 Member States of the EU. The United Kingdom, Denmark, Italy and Sweden have often expressed their dissatisfaction with the current quota system and lobbied for its removal. But some Members States, in particular France, worry that the removal of milk quotas would jeopardize one of the few farming activities left in some of the least favourable regions, including the mountainous regions.

Several studies have evaluated the economic and welfare effects of the removal of milk quotas used either a partial or a general equilibrium framework to endogenize changes in market prices and quantities of milk and dairy products. Bouamra-Mechemache *et al*. (2002a, b) use a spatial partial equilibrium model that takes into account the supply of milk, the processing industry and the demand for processed products for nine different regions within the EU. A simulation scenario in Bouamra-Mechemache *et al*. (2002a) shows that the removal of milk quotas with a 30 per cent reduction in subsidised exports and a doubling of import access for all dairy commodities increases milk supply by 3 per cent and decreases milk price by 27 per cent for the EU-15 as a whole. A different simulation scenario in Bouamra-Mechemache *et al*. (2002b) shows that a quota removal with complete elimination of production, consumption and export subsidies but maintenance of import quotas and tariffs at Uruguay Round GATT 2000 levels increases milk supply by 1 per cent and decreases milk price by 28 per cent for the EU-15 as a whole.

Benjamin *et al*. (1999) use a static multi-sector computable general equilibrium model of the French economy. A simulation scenario similar to the one in Bouamra-Mechemache *et al.*(2002b) shows that a quota removal with elimination of intervention support, domestic subsidy programs and export subsidies but maintaining import tariffs reduces milk supply by 3 per cent and milk price by 28 per cent. Declines in milk supply and price may, however, vary widely depending on the value at which the quota rent is taken with respect to the milk price. Additional simulation scenarios illustrate to what extent marginal costs of production, compensatory payments granted to dairy farmers as well as import tariffs on dairy products affect the outcome of a quota removal. Lips and Rieder (2005) use a modified version of the applied general equilibrium model of the Global Trade Analysis Project (GTAP) to analyse the elimination of milk quotas and export subsidies for dairy products in the EU at a Member State level. The EU(15)-wide effects for milk production are an output increase of 3 per cent and a price decline of 22 per cent. A systematic sensitivity analysis, however, shows that the choice of the milk quota rent has a major influence on both price and quantity changes.

As expected, simulation results of quota removals from these studies depend in particular on critical parameters used to calibrate milk supply such as supply elasticities and quota rents which are defined as the differences between producer prices and marginal costs evaluated at the quota level. These studies use simple upward sloping milk supply functions with price elasticities that are chosen arbitrarily and quota rents that are taken from other studies. For example, Bouamra-Mechemache *et al*. (2002a, b) use long-term supply elasticities ranging from 1 to 1.5 depending on land and substitution possibilities of the EU region and unit quota rents from three different sources ranging from 30 to 45 per cent of farm price depending on the EU region. Lips and Rieder (2005) use unit quota rents ranging from 0 to 31 per cent, depending on the Member State, that they determine from country-specific quota rent estimations provided in Bouamra-Mechemache *et al*. (2002c). One main weakness of the modelling framework of these studies is the aggregate level analysis using one single marginal cost function per MS or EU region and, hence, ignoring dairy farm heterogeneity within each MS or region.

Published studies that estimate marginal cost curves with farm data obtain inelastic responses of milk output to prices and evidence of scale economy. Boots *et al.* (1997) estimate a system of input demands and milk output supply that is derived from a symmetric normalized quadratic restricted profit function. With panel data for specialised Dutch dairy farms covering the period 1973-92, they obtain a price elasticity of milk supply of 0.26. Colman *et al.* (2002) regress a simple *ad hoc* average cost function for milk production that is squared in herd size, milk yield and farm area. Using cross-sectional dairy farm data for England and Wales in 1996/97, they find economies of size available to producers by expanding the herd size up to a certain number. Colman *et al*. (2005) estimate an *ad-hoc* simultaneous two-equation system of milk yield and gross margin responses. With panel data for specialised dairy farms in two regions of England for the period 1990-94, they obtain short-run price elasticities of milk supply ranging from 0.4 to 1.2.

Bouamra-Mechemache *et al*. (2002c) estimate a marginal cost function that is derived from an *ad hoc* restricted cubic cost function. Using the European Farm Accountancy Data Network (FADN) of three Member States for the period 1996-98, they obtain marginal cost curves that are U-shaped and decreasing at actual average milk quota level. Pierani and Rizzi (2003) estimate an input demand system derived from a multi-input symmetric generalised McFadden (SGM) cost function with several quasi-fixed inputs from a balanced panel of Italian dairy farms from the FADN covering the period 1980-92. The null hypothesis of constant returns to scale (CRTS) is rejected. Scale economies exist in the short run and, to a lesser extent, in the long run. Using the same SGM cost function but with a multi-output specification, Wieck and Heckelei (2007) estimate an input demand system from an unbalanced panel data set of the FADN covering eight EU regions during the period 1989-2000. The null hypothesis of constant returns to scale is also rejected. They obtain marginal cost elasticities with respect to milk output that are negative ranging from -0.03 to -0.23 for seven of the eight EU regions.

In this paper, we are interested in evaluating the potential supply and income effects from removing milk quotas and reducing progressively producer prices. To account for production and market heterogeneity among dairy farms, we evaluate this dairy reform at the farm level using a panel of Belgian dairy farms of the FADN. The next section specifies the long-run cost functions. The third section presents the data and some statistics of the Belgian FADN sample of dairy farms that are used in this paper. The fourth section gives the econometric estimates, discusses the test statistics and provides key elasticities. The fifth section defines the long-run optimisation model and the simulation scenarios. It then presents and discusses the simulation results. The last section concludes.

II. MODEL SPECIFICATION

We use flexible cost functions as formally defined in Pierani and Rizzi (2003) and Wieck and Heckelei (2007) for several reasons (Chambers, 1988). First, under some regularity conditions, flexible cost functions that are twice continuously differentiable in all their arguments are consistent with theory and well-behaved. Second, these flexible cost functions provide a second-order differential approximation to unknown cost functions at any point. Third, among the class of flexible quadratic cost functions, there is one particular function for which the curvature properties can be imposed if needed without destroying its second-order flexibility (Diewert and Wales, 1987). This is the multi-output multi-input SGM cost function that we estimate and use in our simulations of policy reforms.

Since the approximation properties of this flexible form are only local, we still need to interpret with caution the results from simulations that run outside the initial panel data set. In particular, the SGM functional form of the cost function implies marginal costs that are linear in output. As Colman *et al.* (2002) show, linearity may be a reasonable approximation in the region of the observed data set but it could be less relevant in simulation exercises where potentially large changes in output may occur. To temper this potential problem, we add dichotomous variables to the squared term of milk output in the flexible functional forms that we estimate to allow the slope of the marginal costs to vary according to farm sizes.

Diewert and Wales (1987) propose the second-order flexible SGM functional form mostly to impose concavity restrictions in input prices without destroying flexibility of the form. Subsequently, Kumbhakar (1989) and Rask (1995) extend the SGM cost function to introduce quasi-fixed inputs. Kumbhakar (1994) extends it to multiple outputs. Pierani and Rizzi (2003) use the restricted SGM cost function that accommodates quasi-fixed inputs and variable returns to investigate scale economies and time-varying efficiency of Italian dairy farms. Wieck and Heckelei (2007) use the restricted SGM cost function with several outputs to provide evidence on determinants, cost differentiation, and development of short-term marginal costs for dairy farms in selected regions of the EU.

The SGM cost function satisfies linear homogeneity in input prices and is flexible in the output space. In addition, this cost function can easily accommodate zero values for outputs and quasi-fixed inputs as may happen for some farms and periods of the panel data set. Following the specification provided in Wieck and Heckelei (2007) but adding dichotomous variables to the squared term of milk output for reasons outlined above, we estimate the following long-run multi-output multi-input SGM cost function written in algebraic notation for the farm *f* at year *t*:

$$C_{ft} = \left(\sum_m \phi_m Y_{mft}\right)\left[\frac{\sum_i \sum_j e_{ij} W_{irt} W_{jrt}}{2\left(\sum_i \theta_i W_{irt}\right)}\right] + \sum_i c_i W_{irt}$$

$$+\sum_i b_{it} W_{irt} t\left(\sum_m \phi_m Y_{mft}\right)+\sum_i \sum_m c_{im} W_{irt} Y_{mft}$$

$$+b_{YS}\left(\sum_i \theta_i W_{irt}\right) D_S Y_{1ft}^2 + b_{YM}\left(\sum_i \theta_i W_{irt}\right) D_M Y_{1ft}^2$$

$$+\left(\sum_i \theta_i W_{irt}\right)\left[\sum_m \sum_n g_{mn} Y_{mft} Y_{nft}\right]+\mu_{ft} \qquad (1)$$

for f = 1 to F, r = 1 to R and t = 1 to T,

where *i, j* denote variable inputs {index is 1 for other animal specific inputs, 2 for crop specific inputs and land, 3 for dairy cows, 4 for other intermediate inputs, 5 for purchased feeds},

where *m, n* denote outputs {index is 1 for milk output for sales, 2 for other animal output for sales, 3 for crop output for sales},

where C_{ft} is the total variable cost for the farm *f* at year *t*, Y_{mft} is the output *m*, W_{irt} is the regional Törnqvist price index of the aggregated input *i* for farms belonging to region *r*, *t* is a time trend capturing technical change and μ_{ft} is the error term.

The two inner products $\left(\sum_m \phi_m Y_{mft}\right)$ and $\left(\sum_i \theta_i W_{irt}\right)$ can be interpreted as a fixed-weight output quantity and input price index, respectively.[1] The parameters D_S and D_M are dichotomous to capture possible changes in the squared term of the cost function with respect to farm sizes. D_S takes the value of 1 when milk output is lower than 250 000 litres and 0 if not. D_M takes the value of 1 when milk output is between 250 000 and 400 000 litres and 0 if not.[2] Family labour is captured in the farm-specific effects of the estimation procedure and, thus, considered constant over time.

The parameters b_{it}, b_{YS}, b_{YM}, c_i, c_{im}, e_{ij}, g_{mn} are the unknown parameters to be estimated. The parameters e_{ij} are elements of the matrix **E**, which must be negative semi-definite for global concavity in input prices (Diewert and Wales, 1987). The symmetry conditions are imposed, such that $e_{ij} = e_{ji}$ for all *i*, *j*, and $g_{mn} = g_{nm}$ for all *m*, *n*. The adding-up constraints for the matrix **E** are imposed, such that $\Sigma_j e_{ij} = 0$ for all *i*. Concavity in input prices is not *a priori* imposed but tested after the estimation. Parameters c_{im} and g_{mn} are respectively elements of matrices **C** and **G**.

For estimation, the total cost function is completed with a set of cost minimizing variable input demands that are derived from the cost function applying Shephard's lemma:

$$\frac{\partial C_{ft}}{\partial W_{irt}} = X_{ift} = \left(\sum_m \phi_m Y_{mft}\right)\frac{\sum_i e_{ij} W_{irt}}{\left(\sum_i \theta_i W_{irt}\right)}$$

$$-\frac{\theta_i}{2}\left(\sum_m \phi_m Y_{mft}\right)\left[\frac{\sum_i \sum_j e_{ij} W_{irt} W_{jrt}}{\left(\sum_i \theta_i W_{irt}\right)^2}\right]+c_i$$

$$+b_{YS}\theta_i D_S Y_{1ft}^2 + b_{YM}\theta_i D_M Y_{1ft}^2$$

$$+b_{it} t\left(\sum_m \phi_m Y_{mft}\right)+\sum_m c_{im} Y_{mft}$$

$$+\theta_i\left[\sum_m \sum_n g_{mn} Y_{mft} Y_{nft}\right]+\varepsilon_{ift} \qquad (2i)$$

for i = 1 to 5 where X_{ift} is the derived demand and ε_{ift} is the error term.

The system of equations is composed of (1) and (2i) with *f* = 1 to F, *i* = 1 to 5 and *t* = 1 to T as in Kumbhakar (1994). This system is estimated using the PROC MODEL provided by the SAS software with the iterative three-stage least squares (IT3SLS) procedure to address the issue of endogeneity as all

[1] Parameter $\theta_i = \frac{1}{T}\sum_t\left[\sum_f X_{ift} \Big/ \sum_i \sum_f X_{ift}\right]$ and parameter $\phi_m = \frac{1}{T}\sum_t\left[P_{mt} \Big/ \sum_m P_{mt}\right]$ where P_{mt} is the Törnqvist price index of output *m* for year *t*. These parameters need to be non-negative, not all zeroes, and exogenously given for the SGM cost function to keep its flexibility if the curvature properties need to be imposed (Diewert and Wales, 1987; Kumbhakar, 1994).

[2] These ranges correspond to about the 33rd and 67th percentiles of milk supply in the sample. Ranges corresponding to deciles of milk supply are also tested.

the variables based on outputs are considered endogenous. In addition to the system's exogenous variables, we use lagged outputs as instrument to ensure identification. Because the Törnqvist input price indices are constructed on the basis of input quantities, they are endogenous to the systems of equations. However, we consider that regional, instead of individual farm, Törnqvist input price indices can be treated as exogenous. Other regressors, including quasi-fixed input quantities, are equally treated as exogenous. Both medium- and long-run systems are estimated using the *within* procedure for fixed effects, that implies dropping the parameters c_i from the estimation but also removing them from the cost function.[3] A random-effect panel estimator of these systems, with cross-equations restrictions, is not routinely implemented in econometric packages and is not explored.

III. DATA AND VARIABLE CONSTRUCTION

The farm data set consists of an unbalanced panel of 143 Belgian dairy farms located in the Region of Wallonia covering a ten-year period between 1996 and 2005 taken from the FADN database provided by the *Direction Générale de l'Agriculture* (DGA) of the Belgian Ministry of Wallonia.[4] This sample is, however, reduced to 89 dairy farms for the simulations after removing dairy farms whose marginal costs for milk output are found in preliminary estimations either in the lowest 2.5 percentile or the highest 97.5 percentile of the marginal cost distributions.

The 89 dairy farm sample includes 74 specialised dairy farms and 15 cattle farms in combined dairying, rearing and fattening.[5] Among these 89 dairy farms, 27 have exclusively grass land and no crop land over the whole period. The other 62 dairy farms mainly grow silage maize, wheat, spelt, barley, oat, fodder beet, grain maize, flax and potatoes in decreasing order of crop area. Table 1 shows the accuracy of the representation of the sample of the dairy farms in the region by comparing characteristics of the dairy farms in our sample with the population of similar farms in the Region of Wallonia. The average milk output and dairy herd per farm are slightly smaller for the farms of the sample than the farms of the population, the average milk yields being about the same. Average agricultural area, especially crop land, is 25 per cent smaller for the sample than the population. Average family labour per farm is also lower for the sample than the population. Farms in our sample are on average slightly smaller in terms of milk output, crop land and family labour and benefit on average from a slightly better milk price than the farms in the population. To account for these differences, the estimation and simulation results are corrected with the frequency weights of each individual dairy farm of the sample within the population that are provided by the DGA.

Table 1 Comparison of sample and population for 2005

Farm characteristics	**Sample**	**Region of Wallonia**[a]
Number of dairy farms	89	3001
Average milk output / farm (1000 l)	314.4	353.1
Average dairy cows / farm (LU)	81.1	87.9
Average cropland / farm (ha)	13.3	37.1
Average grassland / farm (ha)	49.8	53.7
Average agricultural area / farm (ha)	63.1	84.3
Average family labour per farm (WU)	1.59	1.97
Average milk yield (1000l/LU)	3.8	3.9
Milk output per land (1000l/ha)	5.4	4.7
Milk output per family labour (1000l/WU)	201.4	184.1
Share of dairy farms with cropland (%)	31.2	81.3
Share of rented agricultural land (%)	76.3	51.9
Milk price (€/1000 l)	282	274
Total milk output (Million l)	27.4	1059.7

Source: FADN
[a] TEO 41 (specialized in milk) and 43(mixed milk and breeding)
Note: l for litre, WU for work unit, ha for hectare, LU for livestock unit.

[3] Although these missing terms are captured by the error term μ_{ft} bringing some endogeneity into the estimation, we believe that the inclusion of this cost function into the derived demand system provides informational gain (see Kumbhakar, 1994).

[4] The panel includes dairy farms that have at least 40 per cent of their total gross margin from dairying but excludes dairy farms that produce sugar beets to avoid the modeling of sugar quotas. In 2005, the sample includes 94 dairy farms.

[5] Specialised dairy farms are defined as farms for which more than two thirds of the total standard Gross Margin (GM) come from dairy cattle and more than two thirds of the dairy's GM from milk cows. Cattle farms in combined dairying, rearing and fattening are defined as farms for which more than two thirds of the total GM come from cattle and more than a tenth from milk cows, excluding the specialised dairy farms.

Because we are interested in the potential supply and income effects from removing milk quotas and reducing producer prices at the farm level, to account for the production and market heterogeneity among dairy farms of the region, we choose two criteria: milk output per farm as an indicator for farm size and the agricultural region as an indicator for soil, climatic and market conditions. Previous studies have shown evidence of economies of size in dairying in the EU and cost variability across EU regions. Two agricultural regions in the Eastern area of the Region of Wallonia (High Ardenne and Grazing Area) are particularly suitable for it and dominated by dairying.

FADN provides farm data on variable input expenditures, some variable input prices, output quantities and farm gate prices of raw milk but not on some other input and output prices. The Belgian National Institute of Statistics (INS) and Eurostat provide the missing farm gate prices on variable inputs. Table A.1 of the Appendix gives an overview of the definitions of all the input and output variables and their descriptive statistics for the years that are used for estimations. Variations around the mean are particularly large for the quantities of all the variables which confirms heterogeneity of dairy farming in the region. All prices of the input and output variables, except for the farm gate prices of milk, are expressed as Törnqvist indices with base year 2004. These indices use either the sample input expenditures or sample revenues of each individual input or output as weights as shown here for the input price index W_{irt} for variable input i in region r at time t:

$$W_{irt} = \prod_{q \in i} \left(\frac{P_{qrt}}{P_{qr0}} \right)^{0.5(g_{qrt} - g_{qr0})} \quad \text{with} \quad g_{qrt} = \frac{\sum_{f \in R} V_{qft}}{\sum_{q \in i} \sum_{f \in R} V_{qft}},$$

for i = 1 to 5 (3)

where P_{qrt} represents the regional input price of the individual input q belonging to the input variable i for region r and year t and V_{qft} is the expense on the individual input q belonging to the input variable i for farm f at year t. When the individual input price P_{qrt} is not available at the regional level, then either the national price is taken from INS or the average of the farm gate prices over the farms belonging to the same region r is taken from FADN. Implicit quantities of inputs and outputs are obtained as the ratio of value and the price index. Because the Törnqvist price indices vary over years t but not over farms belonging to the same region r, differences in the composition of an input or output variable, or quality differences, across farms are reflected in the quantities. Variations around the mean are particularly small for the regional price indices of the two input categories 'Other animal specific inputs' and 'Other intermediate inputs' (Table A.1).

IV. ECONOMETRIC ESTIMATIONS AND RESULTS

A. Specification tests

The estimated parameters of the derived input demand system from the IT3SLS are not reported because of lack of space. The proportion of significant parameters at the 10 per cent probability level is about 76 per cent for both specifications, with and without the dichotomous variables for class size. The dichotomous variables for class size are significant. However, the specification with these dichotomous variables leads to estimated long-run marginal cost functions that fail to be increasing in milk output for the medium-size class and in the other outputs. This violates a necessary condition for the existence of a stable equilibrium with profit maximisation (Chambers, 1988, p. 139). The specification with the dichotomous variables is, therefore, disregarded in favour of the specification without dichotomous variables. The selected long-run cost function is non-decreasing in outputs, an additional property of a well-behaved cost function.

Global concavity with respect to input prices of the SGM cost function are tested by a bootstrap technique. These tests indicate that concavity in input prices are not violated at the 95 per cent confidence level. The same bootstrap technique reveals that convexity of the SGM cost functions with respect to outputs is not violated at the 95 per cent confidence level either (results are not shown due to lack of space). Based on these tests, we conclude that the estimated SGM cost function satisfies the curvature properties globally and can be used to derive elasticities and maximise profit functions.

The tests of collinearity not shown because of lack of space indicate that the condition numbers are small enough to reject significant levels of collinearity. A Chow test is used to test whether the estimations of the derived input demands of the sample of dairy farms with exclusively grass land are statistically identical to those of the sample of dairy farms with crop land in addition to grass land. We find no significant structural difference between the two sub-samples and, hence, both sub-samples are pooled. A Wald test is used to test whether the cost function exhibits economies of scale. For both specifications, the null hypothesis that implies that the elements of matrices **C** and **G** are equal to zero is rejected at less than 1 per cent probability level indicating that these cost functions do not exhibit CRTS. A closer examination of the overall return to scale indicates a significantly but slightly increasing return to scale (1.06).[6] Finally, a Wald test is used to test whether the cost function exhibits any exogenous change over time. The null hypothesis of the coefficients b_{it} being equal to zero is rejected at less than 1 per cent significance level. Consequently, the production function does not exhibit time stability suggesting that technical change occurs over the period 1996-2005.

B. Elasticities, marginal costs and quota rents

The elasticities of variable input demands with respect to their prices are calculated for each farm f and year t as follows:

$$\frac{\partial X_{ift}}{\partial W_{jrt}}\frac{W_{jrt}}{X_{ift}} = \frac{W_{jrt}}{X_{ift}}\left\{\frac{e_{ij}}{\sum_i \theta_i W_{irt}} - \frac{\left[\theta_j \sum_j e_{ij} + \theta_i \sum_i e_{ij}\right] W_{irt}}{\left(\sum_i \theta_i W_{irt}\right)^2} + \theta_i \theta_j \left(\sum_m \phi_m Y_{mft}\right) \frac{\sum_i \sum_j e_{ij} W_{irt} W_{jrt}}{\left(\sum_i \theta_i W_{irt}\right)^3}\right\} \quad (4ij)$$

for i, j = 1 to 5.

[6] Return to scale for milk output is significantly decreasing (0.75). Return to scope is significant (1.15). See Kumbhakar (1994) for the calculation of these indicators.

Table 2 reports the means and the standard deviations of the price elasticities for variable input demands that are calculated over the sample for the selected specification. In general, large variations of elasticities exist across farms and years. All the own-price elasticities are negative and most of the cross-price elasticities are positive indicating net substitution among variable inputs. Among the elasticities that are significant for the sample, input demand responsiveness to price changes are rather low. Own responsiveness is the highest for the 'other intermediate inputs' category (-0.40) but the lowest for farm land associated with crop specific inputs (-0.01). The cross-elasticities indicate a significant low complementarity of milk cows with purchased feeds (-0.13). Despite this, there is no significant substitution between the crop inputs and land category and purchased feeds, in contrast to the substitution that we would expect between farm-grown and purchased feeds.

Table 2 Price elasticities of variable input demands (sample means and standard deviations)

	Input price				
Input demand	**Other bovine inputs**	**Land & crop inputs**	**Milk cows**	**Other inputs**	**Pur-chased feeds**
Other bovine inputs	-1.30	0.20	0.17	0.92	0.02
	(1.41)	(0.21)	(0.20)	(0.99)	(0.02)
Land & crop inputs	0.04*	-0.01*	0.00	-0.01	-0.02
	(0.02)	(0.01)	(0.00)	(0.00)	(0.01)
Milk cows	0.11*	0.00	-0.07*	0.09*	-0.13*
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
Other inputs	0.25*	-0.01	0.04*	-0.40*	0.12*
	(0.08)	(0.01)	(0.01)	(0.12)	(0.03)
Purchased feeds	0.01	-0.04	-0.08	0.18	-0.07
	(0.01)	(0.06)	(0.14)	(0.31)	(0.11)

*: Significant at the 10 per cent level.

Marginal costs for farm outputs are calculated using the following relationship:

$$\frac{\partial C_{ft}}{\partial Y_{mft}} = \phi_m \left[\frac{\sum_i \sum_j e_{ij} W_{irt} W_{jrt}}{2\left(\sum_i \theta_i W_{irt} \right)} \right] + \sum_i b_{it} W_{irt} t \phi_m$$

$$+ \sum_i c_{im} W_{irt} + \left(\sum_i \theta_i W_{irt} \right) \left[2 \sum_n g_{mn} Y_{nft} \right] \quad (5m)$$

for m = 1 to 3.

Table 3 reports the means and the standard deviations of the marginal costs for milk output by size class that are calculated at the farm level for 2005. The variations of the marginal costs around their means are not much greater than the variations of the producer prices of milk reported in the same table. The derived quota rents show more variability, confirming production and market heterogeneity across dairy farms in the sample. Further investigation would be needed to identify the characteristics of the farms showing low versus high marginal costs to explain this distribution in marginal costs and quota rents.

Table 3 Milk price, estimated marginal cost and quota rent for 2005 (€/1000 litres)

Size class	Variable	Mean	Std dev.	Min	Max
Small	Milk price	273.8	18.7	247.0	328.6
	Marginal cost	156.4	32.1	85.0	206.8
	Quota rent	117.4	32.1	60.1	188.2
	Rent/price (%)	42.9	11.4	22.5	68.9
Med.	Milk price	286.9	15.8	257.7	313.1
	Marginal cost	191.8	39.0	79.6	249.1
	Quota rent	95.1	36.6	21.3	188.0
	Rent/price (%)	33.2	13.2	8.1	70.3
Large	Milk price	287.2	17.5	241.4	312.9
	Marginal cost	231.7	32.4	168.9	265.6
	Quota rent	55.5	35.7	9.9	136.3
	Rent/price (%)	19.1	11.9	3.7	44.7

The small farms show the lowest variable marginal costs on average, and the highest and least variable quota rents while the medium and large farms show higher marginal costs and lower average quota rents. The values of these marginal costs estimated for 2005 are of the same order of magnitude as the marginal cost value of €195 per 1000 litres found for Belgium for the period 1996-98 in Bouamra-Mechemache *et al.* (2002c) with quadratic and translog functional forms. The quota rents amount to €117, €95 and €56 per 1000 litres for the small, medium and large farms respectively. Expressed in terms of the percentage of milk prices, these quota rents range from 43 per cent for the small farms to 19 per cent for the large farms. Although these quota rents may appear large, they are actually lower than the quota rents estimated by Wieck and Heckelei (2007) for eight EU regions in 1991 and 1999. They are also in range with the average rental rate of €96 per 1000 litres that was observed during the same period on 934 transactions in the FADN data base of the Region of Wallonia.

The elasticities of the marginal cost, i.e., the cost flexibilities, of one particular output *m* with respect to another particular output *n* can be calculated for each farm *f* and year *t* as follows:

$$\varsigma_{mn} = \frac{\partial \left(\partial C_{ft} / \partial Y_{mft} \right)}{\partial Y_{nft}} \frac{Y_{nft}}{\left(\partial C_{ft} / \partial Y_{mft} \right)}$$

$$= \left(\sum_i \theta_i W_{irt} \right) \left[2 \times g_{mn} \right] \frac{Y_{nft}}{\left(\partial C_{ft} / \partial Y_{mft} \right)} \quad (6mn)$$

, for m = 1 to 3.

Table 4 reports the means and standard deviations of the own-output marginal cost elasticities for milk output by size class. These flexibilities range from 0.38 for the small farms to 0.74 for the large farms. Although it is not the purpose of this paper, to calculate and discuss cost flexibilities with respect to the other outputs, the variable inputs could help specify the determination of these different variables on marginal costs and, hence, quota rents. As in Wieck and Heckelei (2007), other indicators can be correlated with marginal costs. They found a negative correlation of marginal costs with degree of specialisation, herd size and milk yield but a positive correlation with grass land share and farm specific milk prices. The reciprocal of the marginal cost flexibilities gives high long-run milk supply elasticities that amount to 1.35, 1.85 and 2.63 for the large, medium and small farms respectively. With a greater milk supply elasticity for the small farms than the larger farms, we anticipate that the small dairy farms would be more price responsive than larger dairy farms in simulations.

Table 4 Cost flexibilities for milk output by size class

Size class	Mean	Standard deviation	Minimum	Maximum
Small	0.38	0.11	0.11	0.92
Medium	0.54	0.12	0.33	1.49
Large	0.74	0.21	0.51	2.27

V. POLICY SIMULATIONS AND RESULTS

After defining the optimisation model, a series of simulations on producer prices and compensations for a price decline are carried out with the removal of milk quotas. Simulation results are discussed and qualified.

A. Definition of the long-run optimisation model

We focus here on using the estimated flexible cost functions to simulate the removal of milk quotas with a gradual reduction in producer prices. Since past agricultural policy reforms in the EU have compensated farmers from agricultural price reductions with direct payments, the simulations are also accompanied with compensatory direct payments.[7]

Each estimated long-run farm cost functions is embedded in the objective function of a profit maximisation programming model with several constraints as follows:

$$\underset{Y_{mfs}}{Max} \quad \sum_f \left[(\rho_s \times P_{1fb})(Y_{1fs}) + (P_{2fb} Y_{2fs}) + (P_{3fb} Y_{3fs}) + S_{fs} - \hat{C}_{fs}(W_{rs}, Y_{fs}; T) \right] \quad (7)$$

, for T = 2005

where $\boldsymbol{P}$ denotes the producer price (index is 1 for milk output for sales, 2 for other animal output for sales, 3 for crop output for sales), $\boldsymbol{S}$ direct payments aggregated into the single farm payment, $\hat{\boldsymbol{C}}$ the estimated long-run cost function (1), $\boldsymbol{\rho}$ the ratio of the simulated producer price with respect to its reference level declining from 1 to 0.5, *b* the reference period, *s* the simulation period, and the other notations already defined above, subject to the following three constraints.[8]

1. Exchanges of farm land are restricted within the same agricultural region *r*:

$$\sum_{f \in r} \left[X_{2fs} \right] \leq \sum_{f \in r} \left[X_{2fb} \right], \text{ for } r = 1 \text{ to R} \quad (7.1r)$$

with the following estimated long-run derived demands for farm land (with $i = 2$):

$$\boldsymbol{X}_{2fs} = \hat{\boldsymbol{X}}_{2fs}(\boldsymbol{W}_{rs}, \boldsymbol{Y}_{fs}; \boldsymbol{T}), \text{ for } f = 1 \text{ to F} \quad (7.2f)$$

2. Compensatory direct payments for declines in producer milk prices are calculated as follows:

$$\boldsymbol{S}_{fs} = \boldsymbol{S}_{fb} + \gamma_s * (1 - \boldsymbol{\rho}_s) * \boldsymbol{P}_{1fb} * \boldsymbol{Y}_{1fb} \quad (7.3f),$$

for $f = 1$ to F

with the compensation rate $\boldsymbol{\gamma}_s$ rising from 0 to 0.5.

3. The increase in milk supply per farm is limited to twice the reference supply given constant quasi-fixed input in family labour:

$$\boldsymbol{Y}_{1fs} \leq 2 * \boldsymbol{Y}_{1fb}, \text{ for } f = 1 \text{ to F} \quad (7.4f).$$

B. Simulation results and discussion

This long-run optimisation model can be used to simulate quota removal, producer price decline and compensatory direct payments. When dairy quotas are eliminated, but the producer prices are kept at their reference level. Weighted aggregate milk supply expands by 18 per cent from its reference level. Weighted aggregate milk supply returns to

[7] Because the 2006 sugar reform determines the compensation amount based on the delivery right of sugar beet owned by the sugar beet grower in the historical reference period of 2000-02 (Commission of the European Communities, 2005), we proceed the same way but using the last period that is available, i.e., 2005 for most farms, as the reference period. Also, because Belgium has opted for maintaining coupled direct payments solely for suckler cows, which constitute a marginal source of revenue for dairy farms, the direct payments *S* are considered completely decoupled to production in these simulations.

[8] The reference scenario does not account for the decrease in the intervention prices of butter and milk powder in 2006 and 2007, the accompanying increase in direct payments and the increase in dairy quotas in 2007 and 2008 that are part of the 2003 mid-term review of Agenda 2000.

its reference level under a 20 per cent decline in producer milk prices. Because of differences in their quota rents and supply elasticities, dairy farms, however, respond differently to quota removal and price declines. With larger quota rents and supply elasticities, small dairy farms respond the most, followed by the medium and large dairy farms respectively. Figure 1 illustrates these different supply responses to quota removal and price decline by showing the long-run milk supply responses of these farms when their responses are aggregated by farm size.

Table 5 Farm gross margin (GM) responses to price reductions and compensation rates by class size (%)

Milk price level	Compen-sation rate	Small farms	Medium Farms	Large farms	All farms
80%	0%	109	86	90	90
	30%	120	99	101	103
	50%	128	107	111	112
	70%	134	116	120	121
60%	0%	72	58	60	56
	30%	85	80	79	80
	50%	100	97	98	98
	70%	114	113	117	115

Note: 100% = reference level

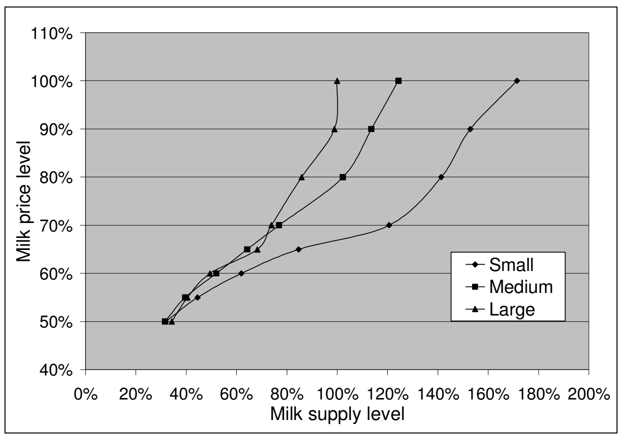

Figure 1 Long-run supply responses to price reductions by farm size class (%)

In addition to supply responses by farm size, agricultural region or other criteria of aggregation, the optimisation model allows the analysis of the impact of quota removal and price decline on the farm gross margins. It also allows the calculation of a compensation rate that could offset the decline in gross margins that would result from a price decline. Table 5 reports the long-run farm gross margin responses to quota removal with a 20 and 40 per cent decline in the milk price for different compensation rates when these farm responses are aggregated by farm size. The removal of the milk quota with a 20 and 40 per cent decline in milk price without compensation reduces the aggregated farm gross margin by 10 and 44 per cent respectively, resulting in 3 and 11 per cent of dairy farms from the sample with a negative farm gross margin respectively. Farm gross margins of small farms tend to be less affected by the decline in milk prices than the medium and large farms. For a 20 per cent decline in milk price, a compensation rate of about 30 per cent of this price decline needs to accompany such price decline to offset the depletion in the aggregated farm gross margins. For a 40 per cent decline in milk price, it is a compensation rate of about 50 per cent of this price decline that is needed to accompany such price decline to offset the depletion in the aggregated farm gross margins. Note that some dairy farms could be overcompensated by the compensatory payments, in particular the small farms under the scenario with a 20 per cent decline in price and a 30 compensation rate. Some of these farms actually expand their milk supply and, hence, their farm gross margins. With such compensation rates, the proportion of dairy farms from the sample with a negative farm gross margin is reduced to 2 per cent.

In sum, this simulation exercise shows that the removal of dairy quotas with a reduction in milk price of about 20 per cent for the sample would induce an aggregated milk supply close to its reference level. At that price level, only 3 per cent of the dairy farms of the sample do not have a positive gross margin to cover family labour. For such a price decline, a compensation rate set at 30 per cent of the price decline would still generate farm gross margins close to its reference level.

Dairy farms of small size that are, in particular, located in two agricultural regions tend to take more advantage of this scenario by expanding their farm supply. This result seems to contradict the more common view that larger farms would expand even further their milk supply than smaller farms, when quota removal and price decline are combined. In contrast, this simulation exercise shows that when dairy farms can adjust all their production factors, including farm land, to a new economic context free of production rights, then small farms tend to expand their milk supply more than the large farms along their upward sloping marginal cost curve until their marginal costs reach their marginal revenues. Adjustment of these dairy farms to quota removal along these estimated marginal curves is, however, most likely to be biased if, for different reasons, the existing regional quota is inefficiently allocated among dairy farms. In that case, the individual supply curves and, hence, the aggregate supply curve may be biased upward.

This evaluation of a policy reform for dairy farms located in this particular Belgian region, however, does not take into account that the removal of the quota system puts the dairy farms of this region in direct competition with other dairy farms located in other EU regions. Wieck and Heckelei (2007) show, for example, medium-run estimated quota rents in eight important dairy production regions of the EU that are all greater in 1999 than the quota rents estimated for this region. Although most dairy farms in our region of study could bear a price reduction of 20 per cent, it is still another question whether they could stand competition in the long run with more efficient dairy farms located in these EU regions or, possibly, in other regions of the world. We should, therefore, qualify the implications of our results that are obtained from simulations, since they are conducted in the context of a dairy economy without external competition.

VI. CONCLUDING COMMENTS

Micro-simulations have the advantage of taking into account the production and market heterogeneity of the farm sector under study and providing disaggregated results at the farm level that can, in turn, be aggregated according to relevant farm characteristics, in particular size and location. This exercise also shows that it is feasible to estimate production cost functions with a flexible functional form from a limited sample of farms from the FADN. The main difficulty, however, consists in overcoming sources of endogeneity. In our case, the only instruments that are available are lagged outputs. We use a bootstrap procedure to test the curvature properties of the estimated flexible cost functions. Meanwhile, the econometric estimations result in long-run estimates, in particular cost flexibilities, that offer another perspective on milk supply responses that is worth considering in partial and general equilibrium analyses.

Micro-simulations have, however, the disadvantage of not giving us a broad picture of the evolution of the dairy sub-sector with an equilibrium market price resulting from the removal of the quota system. In this respect, past published studies based on a partial (Bouamra Mechemache *et al*., 2002a, b) or a general (Benjamin *et al*., 1999; Lips and Rieder, 2005) equilibrium approach are valuable in providing equilibrium market prices that can interact with a farm optimisation model. These equilibrium studies have come up with a market price decline of about 30 per cent for a level of EU milk supply that is close to the level of the quota that is removed. According to our estimate, a complete transmission of this market price decline to our sample would reduce aggregate milk supply by 18 per cent and aggregate farm gross margin by 29 per cent from their 2005 reference level. For that price decline, a compensation rate of 50 per cent would be needed to maintain the aggregate farm gross margin at its reference level. These studies, however, emphasise that their simulation results are contingent upon demand and supply elasticities as well as values taken for quota rents.

REFERENCES

1. Commission of the European Communities (2007). Communication from the Commission to the

European Parliament and the Council. Preparing for the "Health Check" of the CAP reform. COM (2007) 722 final, Brussels. 20.11.2007

2. Bouamra-Mechemache Z, Chavas J-P, Cox T and Réquillart V (2002a) EU Dairy Policy Reform and Future WTO Negotiations: A Spatial Equilibrium Analysis. Journal of Agricultural Economics 53(2):233–257
3. Bouamra-Mechemache Z, Chavas J-P, Cox T and Réquillart V (2002b). Partial Market Liberalization and the Efficiency of Policy Reform: the Case of the European Dairy Sector. American Journal of Agricultural Economics 84(4):1003-1020
4. Benjamin C, Gohin A, and Guyomard H (1999) The Future of European Union Dairy Policy. Canadian Journal of Agricultural Economics 47(5):91-101
5. Lips M and Rieder P (2005). Abolition of Raw Milk Quota in the European Union: A CGE Analysis at the Member Country Level. Journal of Agricultural Economics 56(1):1-17
6. Bouamra-Mechemache Z, Burrell H, Guyomard H, Jongeneel R, and Réquillart V (2002c). The INRA-Wageningen Simulation System for the EU Dairy Sector. 10th Congress of the European Association of Agricultural Economists, Zaragoza, Spain, 2002
7. Boots M, Lansink A O, and Peerlings J (1997) Efficiency loss due to distortions in Dutch milk quota trade. European Review of Agricultural Economics 24:31-46
8. Colman D, Burton M, Rigby D and Franks J (2002). Structural Change and Policy Reform in the UK Dairy Sector. Journal of Agricultural Economics 53(3):645-663
9. Colman D, Solomon A. and Gill L (2005). Supply Response of U.K. milk producers. Agricultural Economics 32(3):239-251
10. Pierani P and Rizzi P L (2003). Technology Efficiency in a Panel of Italian Dairy Farms: an SGM Restricted Cost Function Approach. Agricultural Economics 29:195-209
11. Wieck C and Heckelei T (2007) Determinants, Differentiation, and Development of Short-term Marginal Costs in Dairy Production: an Empirical Analysis for Selected Regions of the EU. Agricultural Economics vol. 36:201-218
12. Chambers R G (1988). Applied Production Analysis, a Dual Approach. Cambridge University Press, Cambridge
13. Diewert W E and Wales T J (1987). Flexible Functional Forms and Global Curvature Conditions. Econometrica 55(1):43-68
14. Kumbhakar S C (1989). Estimation of Technical Efficiency Using Flexible Functional Form and Panel Data. Journal of Business & Economic Statistics 7(2):253-258
15. Rask K (1995). The Structure of Technology in Brazilian Sugarcane Production, 1975-97: an Application of a Modified Symmetric Generalized McFadden Cost Function. Journal of Applied Econometrics 10:221-232
16. Kumbhakar S C (1994). A Multiproduct Symmetric Generalized McFadden Cost Function. Journal of Productivity Analysis 5:349-357

Table A.1. Variable definitions and summary statistics (Region of Wallonia, 1996-2005)

Category	Variable	Definition	Base/unit	Source	Mean	Std. Dev.	Minimum	Maximum
Variable inputs	Other animal specific inputs	Veterinary expenses, insurances, treatments against diseases, contract services, other expenses						
	- Regional price index	Tornqvist price index	2004	Eurostat	0.99	0.02	0.95	1.01
	- Quantity	Value / price index	1 000 €	FADN	7.35	5.14	0.06	42.68
	Crop inputs and land	Total land area, seed, fertiliser, pesticide, contract services, other expenses on all crops except grass land						
	- Regional price index	Tornqvist price index	2004	FADN/INS	1.07	0.27	0.60	1.67
	- Quantity	Value / price index	1 000 €	FADN	30.72	17.36	5.15	130.67
	Dairy cows	Yearly average milk cows cattle						
	- Regional price index	Tornqvist price index	2004	FADN	1.03	0.15	0.69	1.45
	- Quantity	Milk cows	10 LU	FADN	7.53	3.06	2.00	25.03
	Other intermediate inputs	Electricity, fuel, capital and maintenance of the capital, hired labour, other insurances						
	- Regional price index	Tornqvist price index	2004	FADN/INS	0.99	0.03	0.92	1.10
	- Quantity	Value /price index	1 000 €	FADN	20.17	10.22	4.94	174.61
	Purchased feeds	Concentrates, fodder and straw purchased						
	- Regional price index	Tornqvist price index	2004	FADN/INS	1.00	0.07	0.89	1.32
	- Quantity	Value / price index	1 000 €	FADN	16.63	11.53	0.08	101.03
Outputs	Milk output for sales	Milk output for sales						
	- Price	Farm gate price	Euro/1 000 l	FADN	306.72	26.71	184.08	452.37
	- Quantity	Standardised volume	1 000 000l	FADN	0.279	0.120	0.051	0.953
	Other animal output for sales	Other animal products for sales						
	- Regional price index	Tornqvist price index	2004	FADN	1.29	0.21	0.97	1.78
	- Quantity	Value / price index	1 000 000€	FADN	0.021	0.014	0.001	0.152
	Crop output for sales	Crop output for sales						
	- Regional price index	Tornqvist price index	2004	FADN	0.97	5.53	0.00	77.67
	- Quantity	Value / price index	1 000 000€	FADN	0.001	0.004	0.000	0.059

Source: FADN and INS