



**AgEcon** SEARCH

RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

*No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.*

**Analysis of Technical and Policy Changes for Belgian Dairy Farms  
Using an Estimated Augmented SGM Cost Function**

**Rembert De Blander and Bruno Henry de Frahan**

Economie rurale, Earth and Life Institute, Université catholique de Louvain, 1348  
Louvain-la-Neuve, Belgium. E-mail: [bruno.henrydefrahan@uclouvain.be](mailto:bruno.henrydefrahan@uclouvain.be)



**Paper prepared for presentation at the EAAE 2011 Congress  
Change and Uncertainty  
Challenges for Agriculture,  
Food and Natural Resources**

August 30 to September 2, 2011  
ETH Zurich, Zurich, Switzerland

*Copyright 2011 by Rembert De Blander and Bruno Henry de Frahan. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.*

# Analysis of Technical and Policy Changes for Belgian Dairy Farms Using an Estimated Augmented SGM Cost Function\*

Rembert De Blander and Bruno Henry de Frahan

February 2011

**Abstract:** This paper provides some evidence on the evolution of marginal and average costs of dairy farms in Belgium between 1990 and 2007. It investigates the effect of the 2003 Mid-Term Review by adding time trends and linear splines to an augmented multi-input multi-output symmetric generalized McFadden cost function and estimating it using a panel of Belgian dairy farms. Existence of size, scale and scope economies in the dairy sub-sector is also examined. This exercise increases our understanding of dairy farm responses to reforms and helps envision the possible effects of ending the milk quota system as it is now planned for 2015.

## 1 Introduction

This paper focuses on providing some evidence on the evolution of marginal and average costs of dairy farms in Belgium since 1990 until 2007 by underlining the effect of the 2003 Mid-Term Review (MTR) of the Agenda 2000 taking into account technical changes<sup>1</sup>. This empirical study is based on the estimation of an augmented multi-input multi-output symmetric generalized McFadden (SGM) cost function (see Henry de Frahan et al., 2011) using an unbalanced panel data set of Belgian dairy farms from the European Farm Accountancy Data Network (FADN). Time trends and linear splines are added to this flexible cost function to account for changes in technology and policy. Existence of size, scale and scope economies in the dairy sub-sector is also examined. This *ex post* evaluation of the 2003 MTR is useful to understand better the responses from dairy farms to such reform and to envision the possible effects of ending the milk quota system as it is now planned for 2015 (of the European Union, 2008).

It is anticipated that the decline in the intervention price of dairy products under the 2003 MTR should have reduced marginal and average costs of supplying dairy products. Dairy farms facing a lower milk price are forced to better control production expenses or to cease production (Gardner, 1987, p. 148). Preliminary econometric results of this study do not, however, confirm this trend. They actually reveal that the marginal cost of milk output averaged over the whole farm sample increases at an annual rate of one per cent over the whole 1990-2007 period with

---

\*The research leading to these results has received funding from the European Community's Seventh Framework Program (FP7/2007-2013) under grant agreement no 212292.

<sup>1</sup>The 2003 Fischler reform or Mid-Term Review of Agenda 2000 brought a 25 per cent decline in the intervention price of butter and a 15 per cent decline in the intervention price of skimmed milk powder by 2006 as well as an increase in dairy quota spread from 2006 to 2013 (0.5 per cent annual increase from 2006 to 2008, a 2 per cent annual increase in 2009 and a 1 per cent annual increase from 2009 and 2013). The intervention price decline has been compensated at 60 per cent of the decline by direct payments linked to the quota then included in the Single Payment Scheme.

an acceleration in this increase at an annual rate of 1.6 per cent after the implementation of the 2003 MTR reform. Somehow, dairy farms in Belgium are facing increasing marginal costs. It is also anticipated that the decline in the intervention milk price and the progressive expansion of the dairy quota should have reduced quota rents<sup>2</sup>. Preliminary results confirm this anticipation. They show that the value of the quota rent relative to the milk output price decreases from 25 per cent in 1990 to 7 per cent in 2007 with an acceleration in this drop after the MTR reform. The recent increase in the marginal costs of milk output also contributes to this trend.

This paper is organized as the following. The next section specifies the augmented SGM cost function with the added time trends and splines. The third section derives the key results that will be commented. The fourth section explains the estimation procedure and shows the data preparation. The fifth section provides and comments the estimation results. The last section concludes.

## 2 Specification

The cost function  $TC$  used here is based upon the standard Symmetric Generalized McFadden (SGM) cost function used, for example, by Wieck and Heckelei (2007) and Henry de Frahan et al. (2011). Its properties are thoroughly described in Diewert and Wales (1987). The SGM functional form is particularly ideal for applied work. Contrary to other quadratic forms, the SGM form is invariant to normalization and its flexibility property is maintained when theoretical curvature properties need to be imposed. Compared to the popular translog form, imposing global concavity in input prices on the SGM form is easier to implement without imposing unrealistic restrictions on input demand elasticities.

Using a notation similar to Henry de Frahan et al. (2011), we represent the total cost function to produce  $M$  goods, using  $I$  variable inputs and  $K$  quasi-fixed inputs, which is subject to  $P$  policy changes, as

$$\begin{aligned}
TC = & (\theta'W) a'Y \left[ \sum_{p=0}^P aa_p (t - t_p) \cdot I_{t \geq t_p} \right] + (\phi'Y) b'W \left[ \sum_{p=0}^P bb_p (t - t_p) \cdot I_{t \geq t_p} \right] \\
& + Y'CW + Z'DW (\phi'Y) + \frac{1}{2} (\theta'W)^{-1} W'EW (\phi'Y) \\
& + (\theta'W) \left\{ Z'FZ (\phi'Y) + Y'GY \left[ 1 + \sum_{p=0}^P gg_p (t - t_p) \cdot I_{t \geq t_p} \right] \right. \\
& \left. + Z'HY + \sum_m^M y_m (Y'Q_m Y) \right\}, \tag{1}
\end{aligned}$$

with output quantities  $Y = (y_1, \dots, y_M)'$ , input prices  $W = (w_1, \dots, w_I)'$  and fixed inputs  $Z = (z_1, \dots, z_K)'$ , where the time index  $t = 1, \dots, T$  and farm index  $f = 1, \dots, F$  are suppressed for readability, and where  $t_1, \dots, t_P$  represent the periods at which a policy change occurred. The initial period is denoted by  $t_0$  and the indicator function  $I_{condition}$  is defined as

$$I_{condition} = \begin{cases} 1 & \text{if } condition \\ 0 & \text{if } \neg(condition). \end{cases}$$

The product  $(\theta'W)$  can be interpreted as a fixed-weight input price index, with

$$\theta_i = T^{-1} \sum_{t=1}^T \frac{\sum_f x_{ift}}{\sum_i \sum_f x_{ift}},$$

---

<sup>2</sup>Quota rents are defined as the differences between producer prices and marginal costs evaluated at the quota level.

where  $X = (x_1, \dots, x_I)'$  denotes the vector of input quantities. Similarly, the product  $(\phi'Y)$  can be interpreted as a fixed-weight output quantity index, with

$$\phi_m = T^{-1} \sum_{t=1}^T \frac{\sum_f p_{mft}}{\sum_n \sum_f p_{nft}},$$

where  $P = (p_1, \dots, p_M)'$  denotes the vector of output prices. The input price index is inserted to ensure first-order homogeneity in input prices, the output quantity index is inserted to ensure regularity condition  $TC(Y=0, W, Z) = 0$  (Chambers, 1988, p.52, property 2B-6). The variable  $TC$  is constructed as  $\sum_{i=1}^I x_i \cdot w_i$ .

Compared to the standard SGM, we add all third-order terms in outputs to the cost function. This addition allows us to estimate cost functions for which the marginal costs are downward sloping at some of the observations, a not unlikely situation under the dairy quota system and an observation made before (Henry de Frahan et al., 2011). We do not include third-order terms in input prices to avoid the curse of dimensionality. In addition, the markets for agricultural inputs are assumed not to exhibit features inhibiting profit maximization. Analogously to Peeters and Surry (2000), we add linear spline functions to the cost function, with break points at the incidence of well-known policy changes.<sup>3</sup>

Shephard's (1970) lemma yields a set of input demand equations

$$\begin{aligned} x_i &= \frac{\partial TC}{\partial w_i} \\ &= \theta_i a'Y \left[ \sum_{p=0}^P aa_p (t - t_p) \cdot I_{t \geq t_p} \right] + (\phi'Y) b_i \left[ \sum_{p=0}^P bb_p (t - t_p) \cdot I_{t \geq t_p} \right] + Y' C_i \\ &\quad + Z' D_i (\phi'Y) + (\theta'W)^{-1} \left\{ W' E_i - \frac{1}{2} \theta_i (\theta'W)^{-1} W' EW \right\} (\phi'Y) \\ &\quad + \theta_i \left\{ Y' GY \left[ 1 + \sum_{p=0}^P gg_p (t - t_p) \cdot I_{t \geq t_p} \right] + (\phi'Y) Z' FZ + Z' HY + \sum_m^M y_m (Y' Q_m Y) \right\} \end{aligned} \quad \{2\}$$

where the observed input quantities  $x_i$  are equated with the optimal input quantities, i.e. those that minimize total costs. Note that a sub-scripted matrix denotes its corresponding column.

### 3 Derivation of key results

The absolute marginal cost of output  $m$  is given by expression

$$\begin{aligned} MC_m &= (\theta'W) a_m \left[ \sum_{p=0}^P aa_p (t - t_p) \cdot I_{t \geq t_p} \right] + b'W \phi_m \left[ \sum_{p=0}^P bb_p (t - t_p) \cdot I_{t \geq t_p} \right] + C'_m W \\ &\quad + Z' DW \phi_m + \frac{1}{2} (\theta'W)^{-1} W' EW \phi_m + (\theta'W) \{ Z' FZ \phi_m \} \\ &\quad + (\theta'W) \left\{ 2Y' G_m \left[ 1 + \sum_{p=0}^P gg_p (t - t_p) \cdot I_{t \geq t_p} \right] + Z' H_m + 3Y' Q_m Y \right\}, \end{aligned} \quad (3)$$

while the average variable cost can be obtained by

$$AVC_m = \frac{\int_0^{y_m} MC_m dy_m}{y_m}.$$

---

<sup>3</sup>Unlike Peeters and Surry (2000), we only include linear splines in the cost function. A similar approach can be found in Diewert and Wales (1992), who add quadratic splines to a production function.

Following Kumbhakar (1994), we define the following quantities.

- Overall returns to scale

$$\begin{aligned} ORTS &= \left\{ \sum_{m=1}^M \frac{\partial \ln TC}{\partial \ln y_m} \right\}^{-1} \\ &= TC / \sum_{m=1}^M y_m MC_m. \end{aligned}$$

$ORTS > 1$  implies that there are economies of scale.

- Product-specific returns to scale

$$PSRT_m = \frac{TC(y_1, \dots, y_{m-1}, y_m, y_{m+1}, \dots, y_M) - TC(y_1, \dots, y_{m-1}, 0, y_{m+1}, \dots, y_M)}{y_m MC_m}.$$

Economies of scale in output  $m$  ( $PSRT_m > 1$ ), means that total incremental costs will rise less than proportionately as  $y_m$  increases.

- Economies of scope

$$ESCP = \frac{\sum_{m=1}^M TC(0, \dots, 0, y_m, 0, \dots, 0)}{TC(y_1, \dots, y_M)}.$$

If economies of scope are present ( $ESCP > 1$ ), for a given output mix, a farm producing all the outputs will have lower costs than costs of firms producing only one output.

In addition, the presence of time-dependent terms in the cost function allows us to compute some indicators of change.

- Rate of marginal cost diminution

$$\begin{aligned} -\frac{\partial MC_m}{\partial t} MC_m^{-1} &= - \left\{ (\theta'W) a_m \left[ \sum_{p=0}^P aa_p \cdot I_{t \geq t_p} \right] + b'W \phi_m \left[ \sum_{p=0}^P bb_p \cdot I_{t \geq t_p} \right] \right. \\ &\quad \left. + (\theta'W) 2Y'G_m \left[ \sum_{p=0}^P gg_p \cdot I_{t \geq t_p} \right] \right\} MC_m^{-1}. \end{aligned}$$

If this rate is positive, the marginal costs diminish over time.

- Rate of cost diminution (Chambers, 1988, p.214) is defined as<sup>4</sup>

$$\begin{aligned} \theta(w_1, \dots, w_I, y_1, \dots, y_M, t) &= -\frac{\partial TC}{\partial t} TC^{-1} \\ &= - \left\{ (\theta'W) a'Y \left[ \sum_{p=0}^P aa_p \cdot I_{t \geq t_p} \right] + (\phi'Y) b'W \left[ \sum_{p=0}^P bb_p \cdot I_{t \geq t_p} \right] \right. \\ &\quad \left. + (\theta'W) Y'GY \left[ \sum_{p=0}^P gg_p \cdot I_{t \geq t_p} \right] \right\} TC^{-1} \end{aligned}$$

If  $\theta > 0$ , the change is progressive, i.e. costs diminish over time.

---

<sup>4</sup>Remark that the rate of cost diminution has a sign opposite to Chambers's definition, but consistent with Kumbhakar (1994, p.354).

- Rate of technical change (Chambers, 1988, p.205) is defined as

$$\mathcal{T}(x_1, \dots, x_I, t) = \frac{\partial \ln f(x_1, \dots, x_I, t)}{\partial t},$$

where  $f(x_1, \dots, x_I, t)$  denotes the time-varying single-output production function. It can be shown that (Chambers, 1988, p.214)

$$\mathcal{T}(x_1, \dots, x_I, t) = \varepsilon^*(w, y, t) \cdot \theta(w, y, t),$$

where  $\varepsilon^*(w_1, \dots, w_I, y, t)$  denotes the elasticity of size of the cost function associated with  $f(x_1, \dots, x_I, t)$ . This elasticity of size is the reciprocal of the cost flexibility  $\eta = \frac{\partial TC}{\partial y} \frac{y}{TC}$  (Chambers, 1988, p.69). Now, for a multi-output firm, we derive that

$$\begin{aligned} \eta &= \frac{\partial TC}{\partial y} \frac{y}{TC} \\ &= \frac{y}{TC} \sum_{m=1}^M \frac{\partial TC}{\partial y} \frac{\partial y}{\partial y_m} \\ &= \frac{y}{TC} \sum_{m=1}^M \frac{\partial TC}{\partial y_m} \\ &= \frac{y}{TC} \sum_{m=1}^M MC_m \end{aligned}$$

using the identity  $y = y_1 + \dots + y_M$ , which holds if all outputs are expressed in values. The elasticity of size is thus given by

$$\varepsilon^*(w_1, \dots, w_I, y_1, \dots, y_M, t) = TC \left( y \sum_{m=1}^M MC_m \right)^{-1},$$

for a multi-output firm.

If  $\mathcal{T} > 0$ , production increases over time, while holding inputs constant.

- Factor-biased technical change (Chambers, 1988, p.219) is defined as

$$\begin{aligned} &= \frac{\partial \ln x_i(w_1, \dots, w_I, y_1, \dots, y_M, t)}{\partial t} \\ &= x_i^{-1} \left\{ \theta_i a' Y \left[ \sum_{p=0}^P aa_p \cdot I_{t \geq t_p} \right] + (\phi' Y) b_i \left[ \sum_{p=0}^P bb_p \cdot I_{t \geq t_p} \right] \right. \\ &\quad \left. + \theta_i Y' G Y \left[ \sum_{p=0}^P gg_p \cdot I_{t \geq t_p} \right] \right\}. \end{aligned}$$

If  $\frac{\partial \ln x_i}{\partial t} < 0$ , the technical change is input  $i$  saving.

## 4 Estimation procedure

We estimate the system of equations (2) by the method of (nonlinear) seemingly unrelated regressions on the within transformed variables and the within transformed cross-products of variables. More specifically, to each of the  $i$  input equations we add an error vector  $\varepsilon_{i,ft}$ , which

consists of a farm-specific component  $\mu_{i,f}$  (possibly correlated with some of the regressors), a period-specific component  $\tau_{i,t}$  and an idiosyncratic component  $u_{i,ft}$ . While the within transformation removes the farm-specific component, the period-specific error component is accounted for by using cluster-corrected standard errors.

On the system of equations (2) a number of canonical restrictions are imposed. Matrices  $E$ ,  $F$  and  $G$  are re-parametrized such that they are guaranteed to be symmetric. In addition, the columns of  $E$  are linearly dependent, which ensures the adding up constraint (Diewert and Wales, 1987, p.54). Finally, *convexity* of the cost function in fixed inputs (Chambers, 1988, p.109) requires the matrix  $F$  to be positive semi-definite, which is ensured by writing it as the product of its Cholesky factors, and *concavity* of the cost function in input prices (Chambers, 1988, p.52, property 2B-3) (together with the adding-up constraint) is imposed by the Lau (1986) decomposition.

For the augmented SGM to increase monotonically in  $Y$  we have the following requirements (Chiang, 1984, p.250-2):

1. convexity of every  $MC_m$  in all the output quantities  $Y$ ,
2. non-negativity of every  $MC_m$ ,

for all possible vectors  $(y_1, \dots, y_M) \in [0, \infty)^P$  and  $(w_1, \dots, w_I) \in [0, \infty)^I$ . Consequently, we re-parametrize every  $Q_m$  (appearing in (3)) using the Cholesky decomposition. In addition, we impose that the minimum of the marginal cost curve on  $Y \in [0, \infty)^P$  is positive. Following recommendations in Wolff et al. (2004), we do not impose *both* monotonicity and curvature of input prices.

We follow Henry de Frahan et al. (2011) in defining the aggregate input and output variables, notwithstanding small modifications due to the use of the FADN dataset from the European Commission instead of the FADN provided by the agricultural administration of the Region of Wallonia, Belgium. Accordingly, we define dairy farms as those farms that have the 4-digit type of farming ( $TF$ ) variable ( $a30$ ) equal to 4110, 4120 or 4310. We obtain an unbalanced panel of 6456 dairy farms with the lowest number of 296 farms in 1990 and the highest number of 411 farms in 1999 (see Table 1 in Appendix A).

We define aggregate inputs to be

- $X_1$ : animal-specific inputs
- $X_{2l}$ : crop-specific inputs (including land)
- $X_3$ : cow inputs
- $X_4$ : intermediate inputs
- $X_5$ : purchased feeds.

Supposing all inputs  $h = 1, \dots, \sum_{i=1}^I N_i$  are grouped into  $i = 1, \dots, I$  categories, the Törnqvist index  $w_{ift}$  is defined for each input aggregate  $i$ , each farm  $f$  and each period  $t$  as

$$w_{ift} = \prod_{j=1}^{N_i} \left( \frac{w_{jft}}{w_{jft_0}} \right)^{\frac{g_{jft} + g_{jft_0}}{2}}$$

$$g_{jft} = \frac{V_{jft}}{\sum_{k=1}^{N_i} V_{kft}},$$

where  $N_i$  denotes the number of inputs encompassed by the aggregate  $i$ ,  $w_{jft}$  represents the farm-gate price of input  $j$  in period  $t$  for farm  $j$ , and  $V_{jft}$  represents the total value spent on input  $j$  by farm  $f$  in period  $t$ .

We aggregate outputs into two categories

- $Y_a$ : dairy output (both milk and milk products)
- $Y_b$ : all other outputs (other animal and crop outputs).

Index construction for output aggregates parallels the index construction for input aggregates. For descriptive statistics, see Table 2 in Appendix A.

## 5 Results

The system of equations 2 is estimated quite decently, with uncentered  $R^2$  lying between 21% and 48% and 66% of the coefficients being significant at the 5% level (see Table 3 in Appendix B). In addition, three out of the four free cubic coefficients and one out of the three free quadratic coefficients are significant. The splines indicate a statistically significant break in 2005, for all three parameter matrices  $a$ ,  $b$  and  $G$ . Inspection of the signs of the estimated input demands reveals that monotonicity of total cost in input prices is respected.

### 5.1 Marginal and average costs

The mean observed absolute marginal cost for  $Y_a$  (milk output) amounts to 222.60 €/ton (79% of the observed farm-gate milk price). It declines from 1990 to 1995, but increases steadily from then up to 264 €/ton in 2007. The temporal evolution of the marginal cost curve is depicted in Figure 1. That the mean observed relative marginal cost for  $Y_a$  is at 79% of the observed farm-gate price is realistic given the quota constraint and compares favorably with results from the literature (see for example Wieck and Heckeley, 2007). The mean observed relative marginal cost for  $Y_a$  (milk output) declines from 1991 to 1995, but increases steadily from then up to 93% in 2007. This steady decline of the relative quota rent expressed as the value of the quota rent over the farm-gate milk price is nicely illustrated in Figure 2.

The mean observed average variable cost for  $Y_a$  (milk output) amounts to 232.01 €/ton (82% of the observed farm-gate price). It has the same pattern as the marginal cost for  $Y_a$  (milk output).

### 5.2 Economies of size, scale and scope

Cost flexibility of  $Y_a$  (milk output) is statistically indistinguishable from one and slightly decreases with time from 0.98 in 1990 to 0.94 in 2007. There is no economy of size in milk output.

The overall returns to scale (ORTS) are slightly higher than one but not statistically significant from it. The product-specific returns to scale (PSRTS) for  $Y_a$  (milk output) fluctuates around 1, but not statistically different from 1.

The economies of scope (ESCP) steadily increases from 1 in 1990 to 5.56 in 2007, but is on average not statistically different from 1.

### 5.3 Indicators of change

All indicators of change exhibit a clear break in 2005.

The rate of marginal cost diminution for milk output is statistically significantly different from zero. On average marginal costs for milk increase with 1% per year. This rate slightly worsens with time from 0.9% per year in 1990 to 1.5% per year in 2007. In addition, it exhibits a cost increasing shock in 2005 at the year preceding the full implementation of the 2003 MTR reform.

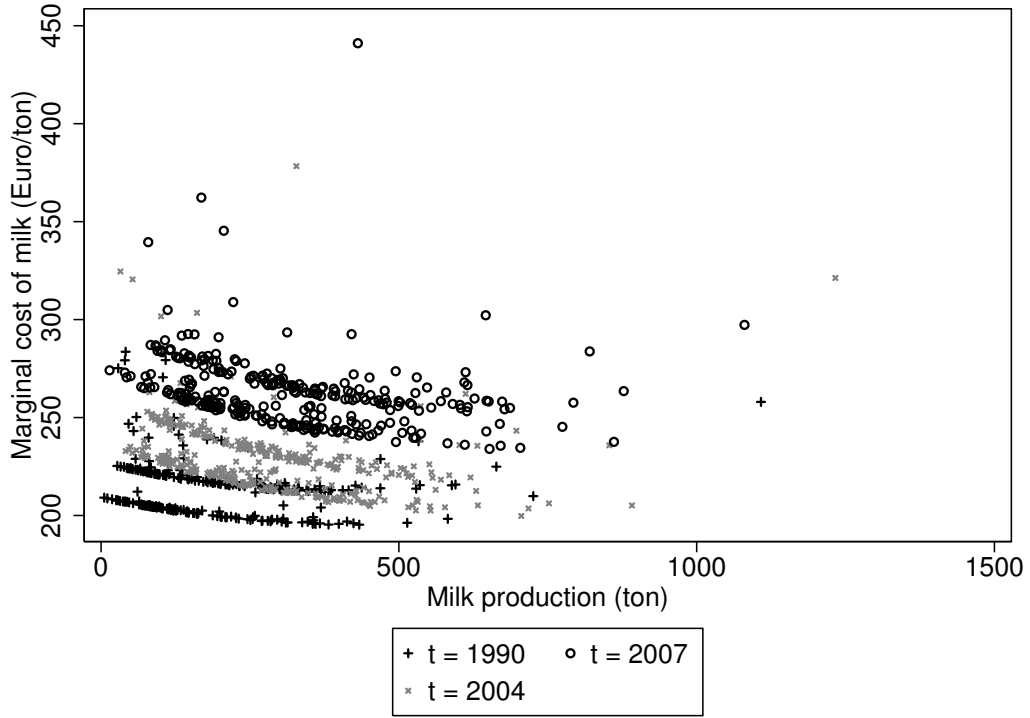


Figure 1: Shift of the marginal cost curve over time

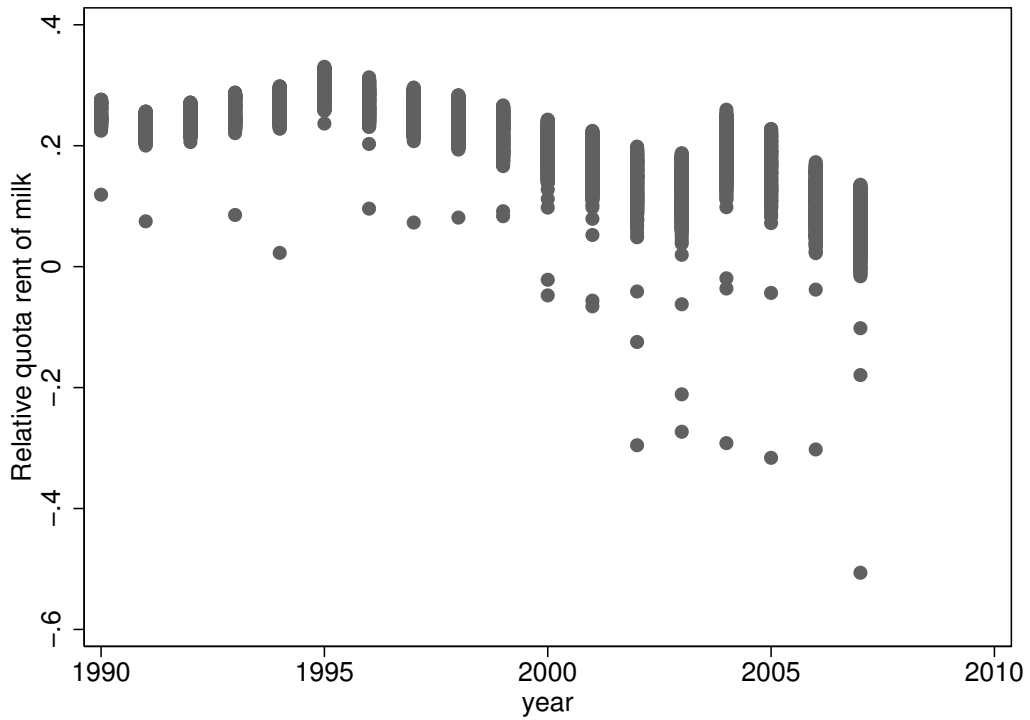


Figure 2: Temporal evolution of the quota rent of milk relative to its price

The rate of cost diminution is statistically significantly different from zero. On average costs increase with 1.6% per year. This rate slightly deteriorates over time from 1.5% per year in 1990 to 3.2% per year in 2007 and exhibits a cost increasing shock in 2005.

On average there is a statistically significant technological regression of 1% each year. The rate of technical change is rate slightly deteriorates over time from 1% per year in 1990 to 2% per year in 2007. In addition, it exhibits a regressive shock in 2005.

Technological change increases the use of X1 (animal-specific inputs) by 5.9% per year and X2 (crop-specific inputs) by 2.5% per year statistically significant. For all inputs there is an input-increasing shock in 2005.

## 6 Concluding remarks

Applied to a panel of Belgian dairy farms from the European FADN, the estimation of an augmented SGM cost function with time trends and linear splines provides satisfying results with 66% of parameters estimated significantly. Theoretical symmetry, adding-up and curvature restrictions as well as monotonicity in outputs are imposed. Monotonicity in input prices is not imposed but respected.

The average estimated marginal cost for milk output steadily increases from 200 in 1996 to 264 in 2007 in nominal €/ton. The average estimated real rate of increase in the marginal cost of milk output goes from 1% during the 1990-2004 period preceding the 2003 MTR reform to 1.6% since 2005. Contrary to expectations, the decline in the intervention price of dairy products as a result of the 2003 MTR reform does not induce a parallel decline in marginal costs of milk output. However, the value of the quota rent relative to the farmgate milk price declines from 19% in 2004 to 7% in 2007. Several reasons may explain these unexpected results. First, methodologically, it would be more appropriate to add linear splines that are specific to aggregate outputs so that effects of policy change in the mid-2005 can be differentiated according to the type of outputs. Second, as adjustment takes time, it would be wiser to estimate this cost function on more recent farm data. Third, price statistics actually show that the price of standardized milk that also includes dairy premium and compensation payments fluctuates around 30 €/100l between 1992 and 2004, then slightly declines to 28 €/100l in 2006 and climbs up to 36 €/100l in 2007 (CBL, 2010). The 2003 MTR reform does not seem to have depressed the farmgate price of milk.

Not only there are hardly any economies of size, scale and scope among the Belgian dairy farms but, surprisingly, there is a technological regression of 1% each year since 1990 with a further regressive shock since 2005. The technological change is slightly biased towards a greater use of animal and crop-specific inputs. These technological changes need further investigation.

## References

- CBL (2010). *Rapport annuel 2010. Année d'activités 2009*. Leuven: Confédération belge de l'Industrie laitière.
- Chambers, R. G. (1988). *Applied Production Analysis: A Dual Approach*. Cambridge, UK: Cambridge University Press.
- Chiang, A. C. (1984). *Fundamental Methods of Mathematical Economics*. McGraw-Hill, 3rd ed.
- Diewert, W. E. and Wales, T. J. (1987). Flexible functional forms and global curvature conditions. *Econometrica* 55: 43–68.

- Diewert, W. E. and Wales, T. J. (1992). Quadratic spline models for producer’s supply and demand functions. *International Economic Review* 33: 705–722.
- European Union, C. of the (2008). Press release. 2904th meeting of the council of agriculture and fisheries, 15940/08 (presse 335), brussels, November 18 - 20, 2008.
- Henry de Frahan, B., Baudry, A., De Blander, R., Polomé, P. and Howitt, R. (2011). Dairy farms without quotas in Belgium: Estimations and simulations with a flexible cost function. *European Review of Agricultural Economics* 38: accepted.
- Kumbhakar, S. C. (1994). A multiproduct symmetric generalized McFadden cost function. *Journal of Productivity Analysis* 5: 349–357.
- Lau, L. J. (1986). Functional forms in econometric model building. In Griliches, Z. and Intriligator, M. (eds), *Handbook of Econometrics*. Elsevier Science Publishers, *III*, chap. 26.
- Peeters, L. and Surry, Y. (2000). Incorporating price-induced innovation in a symmetric generalised McFadden cost function with several outputs. *Journal of Productivity Analysis* 14: 53–70.
- Shephard, R. W. (1970). *Theory of Cost and Production Functions*, Princeton Studies in Mathematical Economics 4. Princeton University Press.
- 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* 36: 203–220.
- Wolff, H., Heckelei, T. and Mittelhammer, R. C. (2004). Imposing monotonicity and curvature on flexible functional forms, paper presented at the American Agricultural Economics Association Annual Meeting, Denver, Colorado, August 1-4.

## A Sample description

Year	Freq.	Percent	Year	Freq.	Percent
1990	296	4.58	1999	411	6.37
1991	331	5.13	2000	399	6.18
1992	324	5.02	2001	409	6.34
1993	346	5.36	2002	397	6.15
1994	355	5.5	2003	382	5.92
1995	333	5.16	2004	360	5.58
1996	361	5.59	2005	334	5.17
1997	400	6.2	2006	327	5.07
1998	395	6.12	2007	296	4.58
Total	6456	100			

Table 1: Number of farms per year

Variable	Obs	Mean	Std.Dev	Min	Max
year	209083	1997.4	5.12	1990	2007
Cost	209083	90859.37	59948.63	12001.21	871826.8
ya	209083	6.12	4.43	0.12	43.9
yb	209083	2.97	4.7	0	95.11
px1	209083	1	0.04	0.92	1.1
px2l	209083	0.91	0.05	0.81	1
px3	209083	1	0.07	0.84	1.18
px4	209083	0.98	0.04	0.87	1.07
px5	209083	1.02	0.04	0.95	1.19
pya	209083	1.01	0.07	0.66	1.26
pyb	209083	1.04	0.17	0	1.88
x1	209083	6027.62	5276.9	58.71	56392.47
x2l	209083	16097.78	10531.06	1246.75	128895
x3	209083	10454.94	6739.56	1366.16	68792.27
x4	209083	40001.51	26167.41	5673.8	315941.6
x5	209083	18277.53	25270.27	0	602154

Table 2: Descriptive statistics of model variables

## B Estimation results

	Coef.	Robust Std. Err.	z	P> z	[95%	Conf. Interval]
/a1	0.03	0.03	1.04	0.3	-0.02	0.08
/a2	-11.61	5.12	-2.27	0.02	-21.64	-1.57
/b1	42.58	4.12	10.34	0	34.51	50.65
/b2	38.7	7.43	5.21	0	24.15	53.26
/b3	14.14	2.77	5.11	0	8.72	19.56
/b4	100.96	20.3	4.97	0	61.16	140.75
/b5	1.03	2.23	0.46	0.65	-3.34	5.39
/c1_1	75	36.25	2.07	0.04	3.96	146.05
/c1_2	966.69	809.77	1.19	0.23	-620.44	2553.81
/c1_3	722.88	441.47	1.64	0.1	-142.4	1588.15
/c1_4	4192.84	1858.46	2.26	0.02	550.34	7835.34
/c1_5	1406.71	1194.04	1.18	0.24	-933.55	3746.98
/c2_1	-31.04	4.2	-7.39	0	-39.28	-22.8
/c2_2	34.01	43.83	0.78	0.44	-51.89	119.91
/c2_3	167.44	27.45	6.1	0	113.65	221.24
/c2_4	-111.93	31.05	-3.6	0	-172.79	-51.08
/c2_5	867.59	418.66	2.07	0.04	47.03	1688.15
/e1_1	-3.36	1.14	-2.96	0	-5.59	-1.13
/e2_1	-0.5	0.17	-2.91	0	-0.84	-0.16
/e3_1	0.02	0.01	1.29	0.2	-0.01	0.04
/e4_1	0.38	0.13	2.93	0	0.13	0.64
/e2_2	-1.93	0.27	-7.21	0	-2.46	-1.41
/e3_2	-0.23	0.11	-2.05	0.04	-0.45	-0.01
/e4_2	1.48	0.56	2.64	0.01	0.38	2.58
/e3_3	-6.2	0.14	-44.45	0	-6.47	-5.92
/e4_3	-21.01	2.32	-9.06	0	-25.56	-16.46
/e4_4	0.04	.	.	.	.	.
/g1_1	-46.21	14.66	-3.15	0	-74.95	-17.47
/g2_1	-0.02	0.01	-1.53	0.13	-0.04	0.01
/g2_2	7.27	4.16	1.75	0.08	-0.89	15.42
/aa1	-33.45	10.23	-3.27	0	-53.49	-13.4
/bb1	0.35	0.18	1.94	0.05	0	0.71
/GG0	0.05	0.05	0.91	0.36	-0.05	0.15
/GG1	-0.05	0.02	-2.6	0.01	-0.09	-0.01
/Qfree1	1.06	0.29	3.66	0	0.49	1.63
/Qfree2	0.31	0.12	2.56	0.01	0.07	0.55
/Qfree3	0.79	0.05	15.2	0	0.69	0.89
/Qfree4	-0.02	.	.	.	.	.

Table 3: Stata estimation results