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Dynamic Profit Inefficiency: A DEA Application to Belgian Dairy Farms

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Abstract

Using a nonparametric framework, we analyze dynamic profit inefficiency for a sample of Belgian, specialized dairy farms from 1996–2008. Profit inefficiency is decomposed into contributions of output, input, and investment. Moreover, we identify the contributions of technical and allocative inefficiency in each input and output. The results suggest substantial profit inefficiency under the current dairy-quota system, mainly driven by an average underproduction of approximately 50 percent and an average underuse of variable inputs of approximately 60 percent, due to allocative inefficiency. Consequently, abolishing the dairy-quota system in 2015 may considerably increase demand for variable inputs and supply of output.

Keywords: distance function, dynamic efficiency, dairy sector

JEL codes: D22, D24, D92, Q12

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The milk-quota system will be abolished in 2015, which is expected to trigger a substantial structural change in the European dairy sector. The milk-quota system has been in place since 1984. It was incorporated in the European Common Agricultural Policy (CAP) to curb overproduction of milk and reduce budgetary deficits (Naylor 1987). The price support for milk producers, aiming to protect dairy farmers' income, was the largest driver of these two problems. The milk-quota system holds for all member states of the European Union. It constrains milk production to farm-level quota by levying surplus production (Boots, Oude Lansink and Peerlings 1997).

The dairy-quota system's inherent weakness is that it protects inefficient producers and harms more efficient producers (who are obliged to buy/rent quota if they want to increase their output). Numerous studies analyzed technical inefficiency under a milk milk-quota regime, using either output- or input-oriented approaches. Areal, Tiffin and Balcombe (2012) and Latruffe, Fogarasi and Desjeux (2012) are examples of the output approach, and Sauer (2010) and Steeneveld et al. (2012) are examples of the input approach. As the dairy-quota system constrains milk production, the input approach seems to be exclusively used by those not only interested in the technical inefficiency, but also in dairy farmers' allocative and economic inefficiency.

The vast majority of studies analyzing the economic efficiency of the dairy sector use a static approach, in which firms are assumed to instantaneously adjust inputs and outputs to their long-run optimal levels. However, firms often incur costs when adjusting the quantity of quasi-fixed inputs. Such adjustments may negatively affect production in the short run, but are necessary to enhance productivity in the long run. Silva and Stefanou (2003; 2007) implement the adjustment-cost technology in an inter-temporal cost-minimization problem. They assess the economic, technical, and allocative inefficiency through a nonparametric dynamic approach. This approach is also applied by parametric reduced-form estimations (Ahn and Sickles 2000; Emvalomatis, Stefanou and Oude Lansink 2010; Tsionas 2006) and parametric structural estimations (Rungsuriyawiboon and Stefanou 2007; Serra, Oude Lansink and Stefanou 2011).

Furthermore, the radial input-oriented approach to measuring inefficiency that currently dominates the literature has limitations. Although there is a constraint on the output production under a quota regime, firms can still expand/limit production by acquiring/selling quotas. The output level is also a choice variable, even in a quota context. We were surprised that, to our knowledge, no study assumes profit-maximizing behavior and investigates the profit inefficiency, and its allocative and technical inefficiency components.[1] Such an analysis would assess the effect of the current quota system on output supply and input demand. The current milk-quota system is expected to drive a wedge between profit-maximizing allocation of inputs and outputs on the one hand, and technically optimal input and output allocation on the other hand (Lovell and Sickles 1983).

Given the drawbacks of a static approach, and the possibilities of assuming profit-maximizing behavior, our research objective was to analyze the dynamic profit inefficiency of the Belgian dairy farms under the current milk-quota system and decompose dynamic profit inefficiency in two novel ways. First, we determined the contributions of outputs, variable inputs and dynamic factor inputs to dynamic profit inefficiency. Second, we calculated the contributions of technical and allocative inefficiency in each output and input inefficiency. Doing so allowed us to identify the degree of underproduction of output and under- or overuse of inputs.

The empirical application focuses on Belgian specialized dairy farms from 1996–2008. The dynamic profit inefficiency measure Silva, Stefanou and Oude Lansink (2014) developed compares the firm's actual long-run profit to the maximally possible (benchmarked) long-run profit. It is calculated by a nonparametric Data Envelopment Analysis (DEA) framework. In summary, this study contributes to the literature by being the first study to apply the dynamic profit inefficiency framework and analyzing the distorting effects of the current milk-quota system in a framework that separately disentangles technical and allocative inefficiency in the production of outputs and use of inputs.

The remainder of the paper is structured as follows. In the next section, we describe the theoretical background of the dynamic profit inefficiency measure and translate this theory to a DEA model. The third section describes our data. The fourth section shows the results. We discuss these results in the fifth section. Finally, the sixth section concludes this paper.

Dynamic Profit Inefficiency

We start from a dynamic, inter-temporal, profit-maximization problem to assess allocative inefficiency and technical inefficiency of outputs and variable, dynamic factor inputs. The

[1] Breustedt, Latacz-Lohmann and Tiedemann (2011) compared the short-run profit efficiency of organic dairy farms to conventional dairy farms, but do not analyze the corresponding technical and allocative contributions.

inter-temporal profit-maximization problem assumes that the firm maximizes the discounted flow of profits over time at any base period $t \in [0, +\infty[$, while being restricted by the adjustment-cost directional technology distance function. The firm faces competitive variable input, output, and capital markets in that all corresponding prices cannot be affected by the firm. It updates its expectations regarding these prices as the base period changes. In addition, all firms have identical, static expectations on the discount and depreciation rates. The inter-temporal profit maximization problem is defined as follows:

$$J(p, K_t, w, c) = \max_{\{y,x,I\}} e^{-rs} \int_t^{+\infty} [p_s{}' y_s - w_s{}' x_s - c_s{}' K_s] \, ds \quad (1)$$

s.t.

$\dot{K}_s = I_s - \delta' K_s$ with $K_t = K_{t_0}$

$\vec{D}_T(x_s, I_s, y_s, K_s;\ g_x, g_I, g_y) \geq 0$ with $s \in [0, +\infty[$

where $J(.)$ is the present value form of dynamic profit maximization, $y \in \mathbb{R}_+^M$ is the output vector, $x \in \mathbb{R}_+^N$ is the input vector, $K_t \in \mathbb{R}_+^F$ is the initial capital vector, $I \in \mathbb{R}_+^F$ is the investment vector, $p \in \mathbb{R}_+^M$ is the vector of output prices, $w \in \mathbb{R}_+^N$ is the vector of input prices, $c \in \mathbb{R}_+^F$ is the vector of capital prices, $\vec{D}_T(.)$ is the adjustment-cost directional technology distance function, (g_x, g_I, g_y) is the corresponding directional vector in terms of inputs, investment and outputs, $r \geq 0$ is the rental rate, and $\delta \in \mathbb{R}_+^F$ is the depreciation rate. The directional distance function $\vec{D}_T(.)$ provides a measure of the distance of y, x and I to the frontier in the direction defined by the directional vectors g_y, g_x and g_I, respectively. The characterization of the directional distance function follows Silva, Stefanou and Oude Lansink (2014), who developed the directional input distance function.

In what follows, it is convenient to use the current value formulation of (1), or the Hamilton-Jacobi-Bellman (H-J-B) equation (Caputo 2005: 528):

$$rJ(p, K, w, c) = \max_{\{y,x,I\}} \{p'y - w'x - c'K + J_K(p, K, w, c)'(I - \delta' K)\} \quad (2)$$

s.t. $\qquad \vec{D}_T(x, I, y, K;\ g_x, g_I, g_y) \geq 0,$

where K is a vector of quasi-fixed factors in the base period.

The H-J-B equation in (2) is represented by the following DEA problem:

$$rJ(p, w, K, c, L) = \max_{\{y,x,I,\gamma\}} \{p'y - w'x - c'K + J_K(.)'(I - \delta K)\} \quad (3)$$

s.t.

$$y_m \leq \sum_{j=1}^{J} \gamma^j y^j, m = 1, \ldots, M$$

$$\sum_{j=1}^{J} \gamma^j x^j \leq x_n, n = 1, \dots, N$$

$$(I_f - \delta_f K_f) \leq \sum_{j=1}^{J} \gamma^j (I_f^j - \delta_f K_f^j), f = 1, \dots, F$$

$$\sum_{j=1}^{J} \gamma L^j \leq L_z^j, z = 1, \dots, Z$$

$$\sum_{j=1}^{J} \gamma^j = 1$$

$$\gamma^j \geq 0, j = 1, \dots, J$$

$$y_m \geq 0, m = 1, \dots, M$$

$$x_n \geq 0, n = 1, \dots, N$$

$$I_f \geq 0, f = 1, \dots, F$$

The first four constraints respectively impose restrictions on the outputs, inputs, investments, and fixed factors. The fifth constraint allows for a variable returns to scale technology. The last four constraints ensure non-negativity of the optimal choice variables.

Following Silva, Stefanou and Oude Lansink (2014), we define the dynamic profit inefficiency (PI) as:

$$PI = \frac{rJ(.) - [p'y - w'x - c'K + J_K(.)'(I - \delta'K)]}{p'g_y + w'g_x + J_K(.)'g_I} \quad (4)$$

PI is a normalized deviation between the maximum shadow profit and the shadow profit of the actual choices. The normalizing factor is the shadow value of the direction vector. Consequently, PI is a dimensionless measure.

The dynamic directional distance function measures dynamic technical inefficiency (TI) for each firm.[2] The overall TI for each observation i is calculated by the following linear programming problem:

$$\vec{D}_T(x, I, y, K, L;\ g_x, g_I, g_y) = \max_{\beta,\gamma} \beta \quad (5)$$

s.t.

[2] We assume that the directional vectors of variable inputs, investment and outputs are respectively equal to $g_{x_n} = x_n$, $g_{I_f} = I_f$, and $g_{y_m} = y_m$. This means that $\vec{D}_T(.)$ can be interpreted as the maximum proportional contraction of variable inputs and simultaneously is the maximum proportional expansion of dynamic factors and outputs.

$$y_m + \beta g_{y_m} \leq \sum_{j=1}^{J} \gamma^j y^j, m = 1, \ldots, M$$

$$\sum_{j=1}^{J} \gamma^j x^j \leq x_n - \beta g_{x_n}, n = 1, \ldots, N$$

$$(I_f - \delta_f K_f) + \beta g_{I_f} \leq \sum_{j=1}^{J} \gamma^j (I_f^j - \delta_f K_f^j), f = 1, \ldots, F$$

$$\sum_{j=1}^{J} \gamma L^j \leq L_z^j, z = 1, \ldots, Z$$

$$\sum_{j=1}^{J} \gamma^j = 1$$

$$\gamma^j \geq 0, j = 1, \ldots, J$$

This maximization problem solves for each firm's dynamic technical inefficiency β and the vector of firm weights γ. The first, second, and third constraints respectively imply strong disposability of outputs, inputs, and investments. The fourth constraint defines the fixed factors of production. The assumption of variable returns to scale is reflected by the fifth constraint. The sixth constraint guarantees non-negativity of γ.

This paper decomposes overall profit inefficiency to identify the contributions of outputs, inputs, and investments. (4) can be rewritten to identify the contributions of output (PI_{py}) variable input (PI_{wx}) and investments ($PI_{J_K I}$) to profit inefficiency:

$$PI = PI_{py} + PI_{wx} + PI_{J_K I} \qquad (6)$$

where $PI_{py} = \frac{p'(y^* - y)}{p' g_y + w' g_x + J_K(.)' g_I}$, $PI_{wx} = \frac{w'(x - x^*)}{p' g_y + w' g_x + J_K(.)' g_I}$, $PI_{J_K I} = \frac{J_K(.)'(I^* - I)}{p' g_y + w' g_x + J_K(.)' g_I}$.

PI_{py}, PI_{wx} and $PI_{J_K I}$ are the normalized deviations of actual from optimal output y^*, input x^* and investments I^*, respectively.

Following Chambers et al. (1996) for the proof in the static case, profit inefficiency can also be decomposed into the contributions of allocative inefficiency (AI) and technical inefficiency (TI):

$$PI = AI + TI \qquad (7)$$

with $TI = \vec{D}_T(.)$

Analogous to the decomposition of profit inefficiency in (7), PI_{py}, PI_{wx}, and $PI_{J_K I}$ are further decomposed into the contributions of allocative and technical inefficiency in each output, variable input, and quasi-fixed factor of production. Respectively denoting allocative inefficiency of outputs, inputs and investments as AI_{py}, AI_{wx} and $AI_{J_K I}$, and corresponding technical inefficiency components as TI_{py}, TI_{wx} and $TI_{J_K I}$, we have:

$$PI_{py} = AI_{py} + TI_{py} \quad (8a)$$

with $TI_{py} = \frac{p' g_y}{p' g_y + w' g_x + J_K(.)' g_I} TI$

$$PI_{wx} = AI_{wx} + TI_{wx} \quad (8b)$$

with $TI_{wx} = \frac{w' g_x}{p' g_y + w' g_x + J_K(.)' g_I} TI$

$$PI_{J_K I} = AI_{J_K I} + TI_{J_K I} \quad (8c)$$

with $TI_{J_K I} = \frac{J_K(.)' g_I}{p' g_y + w' g_x + J_K(.)' g_I} TI$

The sum of the partial technical inefficiencies is equal to the total technical inefficiency:

$$TI_{py} + TI_{wx} + TI_{J_K I} = TI \quad (9)$$

Likewise, the sum of the partial allocative inefficiencies is equal to the total allocative inefficiency:

$$AI_{py} + AI_{wx} + AI_{J_K I} = AI \quad (10)$$

The shadow value of capital $J_K(.)$ is implicit and endogenous. We find values for $J_K(.)$ by estimating a normalized quadratic functional approximation of $J(.)$ with the price of the variable inputs w as the *numéraire*, eventually enabling a calculation of $J_K(.)$.[3]

Data and Descriptive Statistics

This study uses data from Belgian specialized dairy farms from 1996–2008. Data on quantities of outputs, variable inputs, quasi-fixed capital inputs, investments, and fixed factors are obtained from the Farm Accountancy Data Network (FADN). We only select specialized dairy farms that obtained an average 80 percent of their total output from milk production, in order to achieve a homogenous sample of farms. We consider two outputs (milk and meat), four variable inputs (seed, fertilizer, feed, and energy), two quasi-fixed capital inputs with

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[3] $$J(p,K,w,c,L) = A_0 + [A_p \quad A_K \quad A_w \quad A_c \quad A_L]\begin{bmatrix} \frac{p}{w} \\ K \\ 1 \\ \frac{c}{w} \\ L \end{bmatrix} + \frac{1}{2}\left[\frac{p}{w} \quad K \quad 1 \quad \frac{c}{w} \quad L\right]\begin{bmatrix} A_{pp} & A_{pK} & A_{pw} & A_{pc} & A_{pL} \\ A_{Kp} & A_{KK} & A_{Kw} & A_{Kc} & A_{KL} \\ A_{wp} & A_{wK} & A_{ww} & A_{wc} & A_{wL} \\ A_{cp} & A_{cK} & A_{cw} & A_{cc} & A_{cL} \\ A_{Lp} & A_{LK} & A_{Lw} & A_{Lc} & A_{LL} \end{bmatrix}\begin{bmatrix} \frac{p}{w} \\ K \\ 1 \\ \frac{c}{w} \\ L \end{bmatrix}$$

To ensure symmetry of the matrix with the quadratic coefficients, we assume that $A_{pK} = A_{Kp}$, $A_{pw} = A_{wp}$, $A_{pc} = A_{cp}$, $A_{pL} = A_{Lp}$, $A_{Kw} = A_{wK}$, $A_{Kc} = A_{cK}$, $A_{KL} = A_{LK}$, $A_{wc} = A_{cw}$, $A_{wL} = A_{Lw}$, and $A_{cL} = A_{Lc}$.

their corresponding investments (buildings and machinery), and two fixed factors (agricultural land and total labor).

Labor is assumed to be a fixed factor because the procedure of hiring additional workers is sluggish and since a large proportion of labor comes from family members. The expenditures of outputs, variable inputs and capital and investment in dynamic factors are expressed in constant 1996 price. Agricultural land and total labor are respectively expressed in hectares and annual working hours. Price indexes of outputs, variable inputs and capital are obtained from the EUROSTAT (2013) database and aggregated to Törnqvist price indexes. These price indexes vary over years, but not over farms. This implies that differences in the composition of outputs, variable inputs and capital or quality differences are revealed by the quantity (Cox and Wohlgenant 1986). The implicit aggregated quantity indexes of outputs, variable inputs, and capital, which are implemented in the DEA models, are generated as the ratio of the value to the price index. Following Serra, Oude Lansink and Stefanou (2011), the rental cost price of capital is defined as $c_i = (r + \delta_i)z_i$, where r is the interest rate, δ_i is the depreciation rate and z_i is the Törnqvist price index for capital. The interest rate r is the average, annual interest-rate for 10-year government bonds from 1996–2008, and is equal to 4.69 percent (EUROSTAT 2013). The depreciation rate of buildings and machinery is assumed to be 15 percent in both cases. The final dataset contains 1,295 observations for 254 dairy farms. Table 1 presents the descriptive statistics of the dataset.

INSERT TABLE 1 HERE

Results

Table 2 shows the average, dynamic profit inefficiency scores and its components of outputs, variable inputs, and dynamic factor inputs from 1996–2008. The dynamic profit inefficiency is an average 0.405. The decomposition of profit inefficiency into the contributions of outputs, inputs, and investments in dynamic factor inputs shows that dynamic inefficiency is mainly caused by underproduction of outputs (0.482) and underuse of variable inputs (-0.081). The contribution of the investment in dynamic factors only plays a very minor role (0.005), implying that Belgian dairy farmers' actual investments in dynamic factor inputs are close to optimal investments. For this reason, we only decompose the inefficiency of output production and variable input use. The average dynamic profit inefficiency varies between 0.311 and 0.478 (standard deviation = 0.049).

INSERT TABLE 2 HERE

Table 3 presents the decomposition of output inefficiency in output technical inefficiency and output allocative inefficiency. On average, allocative inefficiency (0.370) made a larger contribution to dynamic profit inefficiency (0.482) than did technical inefficiency (0.112). Furthermore, Table 3 shows that output would, on average, have expanded by €46,014 (in constant 1996 €) if all firms were allocatively efficient in terms of their output production. In relative terms, this means an average potential increase of output of 46.46 percent.

INSERT TABLE 3 HERE

Table 4 presents variable input inefficiency and its decomposition into input technical inefficiency and input allocative inefficiency. This table shows the relative allocative input expansion and absolute allocative input expansion if firms were allocatively efficient in terms of their variable input use. The overuse of variable inputs due to technical inefficiency (0.031) is cancelled out by the underuse due to allocative inefficiency (-0.112), resulting in an input inefficiency of an average -0.081. Variable input use would, on average, have expanded by €13,659 (in constant 1996 €) if all firms were allocatively efficient in terms of their variable input use. This corresponds to a relative expansion of the use of variable inputs by 62.47 percent.

INSERT TABLE 4 HERE

Table 5 shows the technical and allocative inefficiency scores for groups of small, medium and large farms. We follow the FADN guidelines for the size classification of our dataset. Small farms are 16–40 Economic Size Units (ESUs), medium farms are 40–100 ESUs, and large farms are > 100 ESUs. Dynamic profit inefficiency of small, medium, and large farms is, respectively, an average 0.473, 0.452 and 0.208. The output allocative inefficiency of small, medium, and large farms is, respectively, 0.490, 0.421 and 0.153. If the farms were producing allocatively efficiently in terms of their output, then output would respectively expand by €34,279 (60.43 percent), €52,196 (52.56 percent) and €25,567 (19.72 percent) expressed in constant 1996 €. The output technical inefficiency is, respectively, 0.091, 0.123

and 0.070 for small, medium, and large farms. The variable input allocative inefficiency of small, medium, and large farms is, respectively, -0.132, -0.129 and -0.044. The underuse of variable inputs thus decreases with farm size. If the farms were producing in an allocatively efficient way with respect to variable inputs, then variable input use would respectively expand by €9,790 (75.10 percent), €15,907 (71.82 percent) and €6,161 (25.83 percent), expressed in constant 1996 €. The variable input technical inefficiency respectively changes from 0.025, to 0.033, and back to 0.020 for small, medium, and large farms.

INSERT TABLE 5 HERE

Discussion

The results of this study suggest that there is high dynamic profit inefficiency under the current dairy-quota system. The inefficiency is mainly caused by allocative inefficiency in producing outputs and using variable inputs. Assuming cost-minimizing behavior, many studies also decompose economic inefficiency of dairy farms into technical and allocative inefficiency. Several studies established that allocative inefficiency is the main driver of economic inefficiency, in line with our results. Kelly et al. (2012) applied nonparametric techniques and obtained a technical inefficiency of 0.23 and an allocative inefficiency of 0.26 for a sample of Irish dairy farms. Sauer (2010) used a Bayesian distance approach and found a technical inefficiency of 0.01–0.08, and an allocative inefficiency of 0.64–0.70, for a sample of Danish dairy farms.

Our results contrast with results found from a number of other studies. For a sample of Italian dairy farms, Maietta (2000) obtained a technical inefficiency of 0.45 and an allocative inefficiency of 0.17, using the stochastic frontier approach. Reinhard and Thijssen (2000) also used the stochastic frontier approach and found a technical inefficiency of 0.15 and an allocative inefficiency of 0.05 for a sample of Dutch dairy farms. Serra, Oude Lansink and Stefanou (2011) parametrically estimated a directional distance function for a sample of Dutch dairy farms. They found a technical inefficiency of 0.10 and an allocative inefficiency of 0.02. The ambiguity regarding the importance of allocative inefficiency may not only be explained by differences in policy but also by the fact that the radial input-orientation of the cost-minimizing behavioral assumption does not take into account the considerable allocative inefficiency in production of outputs due to the distortion effects of the milk-quota system. Therefore, our results are not directly comparable with the results of the studies mentioned.

Several studies solely concentrated on the technical inefficiency of dairy farms. Reinhard, Lovell and Thijssen (2000) calculated an output-oriented technical inefficiency of 0.11 (when stochastic frontier analysis was used) and 0.22 (when DEA was used) for a sample of Dutch dairy farms. Another study of Dutch dairy farms used nonparametric techniques and derived an input-oriented technical inefficiency of 0.22–0.24 (Steeneveld et al. 2012).

For a milk-quota market that is free of restrictions, economic theory argues that efficient firms will be net purchasers of milk quota and inefficient firms will be net sellers of milk quota (Alvarez et al. 2006). However, the Belgian milk-quota system has mixed-market regulations. The administration sets the price of, and regulates, transfers (prioritizing younger farmers) of forty percent of the total milk quota. Sixty percent of the total market quota can be traded between the producers within the distinct trading regions of Flanders and Wallonia. Moreover, there are strict regulations within each trading region. In Flanders, dairy farmers can only trade within a radius of 30 km (with the exception of family members). Walloon dairy farmers are constrained geographically by cadre. Although there is a market for milk quota, as opposed to in France, there are strict regulations that make the Belgian milk-quota system less competitive than in the Netherlands and the United Kingdom (DG Agriculture 2008). Sauer (2010) showed that the Danish deregulatory measure of setting up a bi-annual milk-quota exchange in 1997 decreased the allocative inefficiency of dairy farms, while the effect on technical inefficiency was insignificant. The lack of competition in the Belgian milk-quota market may exacerbate the allocative inefficiency problem, so that removing the milk-quota system could result in a larger expansion of dairy output and use of variable inputs.

Our results also showed that dynamic profit inefficiency decreases as farm size increases. This is driven by allocative, rather than technical, inefficiency. The relationship between technical inefficiency and farm size is unclear. Maietta (2000) also found that there was a negative relationship between allocative inefficiency and farm size, and an uncertain relationship between technical inefficiency and farm size. As a consequence, in combination with the compounding problems of efficiency losses associated with the highly regulated dairy-quota system, abolishing the dairy-quota system would likely be coupled with a substantial decrease of allocative inefficiency. This would result in a considerable expansion of variable inputs use and output production. Relatively smaller farms are particularly susceptible to these changes.

This paper complements other recent research on the potential impact of abolishing the milk-quota system. An applied general equilibrium analysis by Lips and Rieder (2005) predicted a modest output growth of 3 percent, and a decline of the milk price of 22 percent in the EU-15 as a whole. In Belgium, output would decline by 0.2 percent, and the milk price would decrease by 19.5 percent. By means of the Dutch Regional Agricultural Model, Jongeneel et al. (2010) forecasted a 10 percent increase of Dutch milk output. Estimating the marginal cost curve for a panel of Belgian dairy farms, de Frahan et al. (2011) put forward that quota removal would increase aggregate milk supply if milk prices remain the same. In accordance with our results, the predicted output expansion decreases for increasing farm size. Using the same size classifications, their simulation indicates a respective expansion of output production of 58 percent and 22 percent for small and medium farms, and a decline of 19 percent for large farms.

Conclusions

Using a DEA framework, we analyze the dynamic profit inefficiency for a sample of Belgian specialized dairy farms for 1996–2008. In contrast to the static efficiency measures that dominate in the literature, the dynamic perspective starts from an inter-temporal optimization framework, in which long-run decisions about investment are taken into account. The results point out that many Belgian dairy farmers are inefficient in dynamically maximizing their inter-temporal profit. A more detailed analysis indicates that the allocative inefficiency of variable input use and output production is the biggest driver of this dynamic profit inefficiency. Over- and under-investment in dynamic factors, such as buildings and machinery, are unimportant. We estimate an average underproduction of approximately 50 percent and an average underuse of variable inputs of approximately 60 percent due to allocative inefficiency. However, this effect is much more pronounced for small and medium farms than for large farms.

These results should be seen in light of the current milk-quota system. Abolishing the milk-quota system in 2015 will have a significant effect on the Belgian dairy sector. This study shows that allocative, rather than technical, inefficiency is the source of dynamic profit inefficiency. For small farms, removing the milk-quota system may result in a drastic expansion of variable input use and output production.

This research could be extended in several ways. First, it would be interesting to calculate the dynamic profit inefficiencies for other countries. The milk-quota system holds for all member countries of the European Union. Nevertheless, as each country individually decides about concrete implementation, there is a substantial heterogeneity in the organization of the milk quota. A comparison of Belgium's mixed-market system to a competitive market system (for example, the Netherlands) and a system in which quotas are distributed top-down from the administration to the farmers (for example, France) would shed additional light on the relationship between competitiveness and efficiency. Second, a more elaborate analysis of the drivers of dynamic profit inefficiency could provide more guidance to policy makers. Finally, this research could be used to conduct a simulation exercise for various future scenarios. Because we essentially study the past behavior of farmers, a focus on future scenarios taking into account plausible future developments (such as price dynamics) could be worthwhile.

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Table 1. Descriptive Statistics of the Dataset (1,295 Observations for 254 Dairy Farms).

Variables	Unit	Mean	Minimum	Maximum	Std. dev.
Output quantities	Constant 1996 €	123,267	17,185	310,620	45,344
Variable input quantities	Constant 1996 €	29,680	6,933	92,896	13,157
Capital	Constant 1996 €	114,243	4,032	623,049	84,040
Investment	Constant 1996 €	16,680	0	531,643	40,305
Total labor	Hours	4,564	1,560	12,743	1,255
Agricultural land	Hectares	42	12	111	18
Price index of output	Dimensionless	0.949	0.842	1.032	0.059
Price index of variable inputs	Dimensionless	0.967	0.898	1.201	0.072
Price index of capital	Dimensionless	1.042	1.000	1.166	0.056

Table 2. Profit Inefficiency Disentangled in Output Inefficiency, Input Inefficiency and Investment Inefficiency.

Year	Profit Inefficiency	Output Inefficiency	Input Inefficiency	Investment Inefficiency
Average	0.405 (0.049)	0.482 (0.048)	-0.081 (0.024)	0.005 (0.009)
1996	0.333	0.414	-0.083	0.003
1997	0.363	0.453	-0.089	-0.001
1998	0.425	0.498	-0.069	-0.004
1999	0.464	0.503	-0.052	0.013
2000	0.478	0.578	-0.105	0.005
2001	0.390	0.532	-0.143	0.000
2002	0.311	0.393	-0.085	0.003
2003	0.403	0.478	-0.071	-0.004
2004	0.392	0.483	-0.091	0.000
2005	0.408	0.473	-0.087	0.021
2006	0.427	0.456	-0.048	0.019
2007	0.460	0.518	-0.069	0.012
2008	0.416	0.487	-0.067	-0.003

Note: Standard deviations of average inefficiencies between parentheses

Table 3. Output Inefficiency Disentangled in Output Technical Inefficiency and Output Allocative Inefficiency, and Relative Allocative Output Expansion and Absolute Allocative Output Expansion if Firms Were Allocatively Efficient in Output Production.

Year	Output Inefficiency	Output Technical Inefficiency	Output Allocative Inefficiency	Relative Allocative Output Expansion (in %)	Absolute Allocative Output Expansion (in constant 1996 €)
Average	0.482 (0.048)	0.112 (0.014)	0.370 (0.049)	46.46 (5.95)	46,014 (8,109)
1996	0.414	0.118	0.295	37.46	31,732
1997	0.453	0.107	0.347	42.88	37,586
1998	0.498	0.115	0.383	46.99	41,142
1999	0.503	0.137	0.366	45.02	43,929
2000	0.578	0.119	0.459	56.35	57,426
2001	0.532	0.093	0.439	53.63	59,140
2002	0.393	0.102	0.291	35.94	38,343
2003	0.478	0.114	0.363	45.08	53,087
2004	0.483	0.086	0.397	49.81	50,131
2005	0.473	0.108	0.365	46.08	47,614
2006	0.456	0.129	0.327	42.75	39,986
2007	0.518	0.122	0.396	50.25	48,529
2008	0.487	0.102	0.385	51.71	49,535

Note: Standard deviations of average inefficiencies between parentheses

Table 4. Input Inefficiency Disentangled in Input Technical Inefficiency and Input Allocative Inefficiency, and Relative Allocative Input Expansion and Absolute Allocative Input Expansion if Firms Were Allocatively Efficient in Variable Input Use.

Year	Input Inefficiency	Input Technical Inefficiency	Input Allocative Inefficiency	Relative Allocative Input Expansion (in %)	Absolute Allocative Input Expansion (in constant 1996 €)
Average	-0.081 (0.024)	0.031 (0.005)	-0.112 (0.021)	62.47 (13.53)	13,659 (3,647)
1996	-0.083	0.037	-0.121	61.92	13,454
1997	-0.089	0.030	-0.120	67.33	13,258
1998	-0.069	0.030	-0.098	60.75	11,488
1999	-0.052	0.033	-0.085	51.09	9,988
2000	-0.105	0.030	-0.135	77.36	17,387
2001	-0.143	0.024	-0.166	96.27	22,994
2002	-0.085	0.027	-0.112	64.31	13,839
2003	-0.071	0.031	-0.102	58.65	14,390
2004	-0.091	0.024	-0.115	63.51	15,069
2005	-0.087	0.028	-0.114	64.50	14,387
2006	-0.048	0.037	-0.085	42.92	9,504
2007	-0.069	0.034	-0.103	56.24	12,415
2008	-0.067	0.036	-0.103	47.23	9,389

Note: Standard deviations of average inefficiencies between parentheses

Table 5. Inefficiency Characteristics Classified by Size.

Inefficiency Characteristics	Small Size (16 – 40 ESU)	Medium Size (40 – 100 ESU)	Large Size (> 100 ESU)	Full Sample
Total Profit Inefficiency	0.473	0.452	0.208	0.408
	(0.467)	(0.294)	(0.271)	(0.313)
Output Allocative Inefficiency	0.490	0.421	0.153	0.374
	(0.562)	(0.327)	(0.302)	(0.350)
Relative Allocative Output Expansion (in %)	60.43	52.56	19.72	46.74
	(67.67)	(40.91)	(43.32)	(44.54)
Absolute Allocative Output Expansion (in constant 1996 €)	34,279	52,196	25,567	46,576
	(35,111)	(35,296)	(36,947)	(37,120)
Output Technical Inefficiency	0.091	0.123	0.070	0.112
	(0.104)	(0.088)	(0.072)	(0.088)
Input Allocative Inefficiency	-0.132	-0.129	-0.044	-0.113
	(0.157)	(0.100)	(0.103)	(0.108)
Relative Allocative Input Expansion (in %)	75.10	71.82	25.83	63.34
	(97.71)	(60.06)	(51.50)	(62.96)
Absolute Allocative Input Expansion (in constant 1996 €)	9,790	15,907	6,161	13,867
	(10,810)	(11,437)	(15,638)	(12,888)
Input Technical Inefficiency	0.025	0.033	0.020	0.031
	(0.031)	(0.029)	(0.026)	(0.029)
Observations	48	1,006	241	1,295

Note: The size is expressed in terms of Economic Size Units (ESUs). The standard deviations are between parentheses.