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New challenges for EU agricultural sector and rural areas.
Which role for public policy?

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The Cost Function Structure of Dutch Dairy Farms:

Effects of Quota Abolition and Price Volatility

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Abstract

This paper investigates potential impacts on milk production of Dutch dairy farms if feed prices increase, milk prices decrease and milk quotas are abolished. A quadratic cost function is estimated using panel data on individual dairy farms of the Dutch FADN. Marginal costs and revenues are evaluated to show the heterogeneous farm-level impact of changing prices on potential production developments. The main finding is that potential increases in milk production when quota are abolished, are offset by a decreasing marginal revenue due to lower milk prices, and increasing marginal costs due to higher feed prices.

Keywords: Milk quota, Milk price, Feed price, Dutch dairy sector

JEL classification: Q1, D2

1. INTRODUCTION

As part of the 2003 European Policy reforms, milk quotas are gradually increasing, and will be fully abolished in 2014. As of 2006/07 the milk quota were increased in three yearly steps with in total 1.5%. In 2008, an extra increase of 2% was applied. From 2009/10 to 2013/15, the quotas are increased with 1% per year. Finally, in 2015, there is complete abolishment of milk quota in the EU (European Commission, 2011). Until 2004/05 there was a net overrun of the total milk quota in the EU. However, as of 2005/06 this overrun changed into a net underuse of the milk quota, which increased rapidly over the years. In the year 2009/10 only Denmark and the Netherlands were producing more milk than their national quotas allowed (Jongeneel et al., 2011: 75).

The impact of abolishing the milk quota on the dairy sector as a whole and on the behaviour of dairy farmers is a highly discussed topic in European policy. Several studies focus at a more macro-level on possible impacts of the abolishment. Of these, Jongeneel (2009) provides a view on possible developments in the Dutch dairy sector when the milk quota system is abolished. He argues that after the abolishment two possible effects can be distinguished concerning the income for dairy farmers. The first effect is decreasing milk prices, the second effect increasing milk production.

Dairy markets are characterized by inelastic demand and supply, meaning that a relatively small change in the demand or supply of milk can have a large impact on milk prices. In their study, Jongeneel et al. (2010) show that, based on several recent (macro-level) studies of projections on developments in the EU dairy sector by FAO, FAPRI and EC, the demand for dairy products will increase in the coming years, which would lead to an increase in milk price. However, it is expected that discussions with the WTO on further trade liberalisations will influence the conditions in the agricultural commodity markets and as such will also have impact on the market for milk. The trend towards more trade liberalisation reduces the use of agricultural trade distorting measures. This will push down the EU prices for agricultural commodities, including milk, in the coming years. The overall effect, taking into account the expected increase in demand for milk as well, might even lead to an 8% decrease of the milk price (Jongeneel et al., 2010).

At the same time, also effects on the supply side of milk production are expected. In case of binding milk quota, as is the case in the Netherlands, the supply depends on the level of quota rents. The value of the quota rent is the difference between its shadow price of production, or also called their marginal costs, and the market price of milk, or also called their marginal revenues (Oskam and Speijers, 1992). Each farmer wants to produce against the lowest possible marginal costs, in order to obtain the highest possible quota rent. Although the milk production is fixed at the quota level, we can see that if production would increase, it will induce higher marginal costs for the farmer, leading to a lower quota rent. Also, until the abolishment of the milk quota, the rental value is expected to decline due to the combination of a decline in milk price and because they will lose value since they expire (Jongeneel et al., 2010). Still, whereas the total amount of quota is limited and the value of quotas is falling, a significant part of active Dutch dairy farmers generally follow an expansion strategy (exploiting economies of scale). When milk quotas are abolished and the effect of quota on the supply response is taken away, it is expected that the overall milk production in the Netherlands will increase. In general if the supply of milk production increases, milk prices will decline (Jongeneel, 2009).

If the effect on supply dominates the price effect, the income per unit of milk production will increase (Jongeneel, 2009). In their study, Jongeneel et al. (2010) predicted this expansion in milk production after abolishment to be about 11% in the Netherlands, even taken into account a milk price decline of 8%.

Studies at the micro- or farm level are relatively scarce in the current discussion on the impact of milk quota abolishment. An exception is the study by Frahan et al. (2011) in which they evaluate effects of abolishing milk quotas in combination with milk price reductions on milk supply and farm income of Belgian dairy farms. Their analysis was performed using data of the Belgian farm accountancy data network, and the main result showed that after abolishment of the milk quota and in case of a reduction in milk prices of 20 per cent, milk supply and farm income will be at the same level as in the initial year 2006 (base year) (Frahan et al., 2011).

As mentioned above, milk prices take an important position in the debate on impacts of quota abolishment. Until 2004 milk prices were relatively stable, but thereafter milk prices started to fluctuate. Remarkable in the years as of 2004 was a high price peak in 2006/07, which reduced quickly again in 2008/09. This price peak can be explained by several factors. Among other, at the world-level the dairy sector was facing high input costs and a reduction in milk production because of unfavourable weather conditions (Jongeneel et al., 2011: 30).

Also, at the European level, several decisions taken during the policy reforms in 2003, affected the milk prices. In the reform it was decided to reduce the intervention prices for skimmed milk powder and butter with respectively 25% and 15% in total in the period 2004/05 till 2007/08. Reducing the intervention prices gives space for more price volatility since bottom prices for milk are lowered. However, the dairy premium was granted as a direct payment to milk producers as a compensation for these reductions in intervention prices. This dairy premium consists of two parts: a dairy premium, and an additional payment, decided on per EU member state. The dairy premium is paid on an individual basis, according to the farmers reference quantity for milk (i.e. coupled payment, incl. leased-in/excl. leased-out)(Jongeneel et al., 2011: 76-78). In 2007 these payments were decoupled from production and instead Single Farm Payments were introduced in The Netherlands.

These changes in policy lead to fluctuating milk prices in the years 2004 to 2010. Previous studies on milk quota abolishment did not take into account this price volatility since they mainly used data of before 2004. For the estimation of our model however, we use recently collected data of Dutch dairy farms, and as such we will implicitly account for price volatility.

In this study we will investigate the effects of milk quota abolishment on potential milk production in the Dutch dairy sector. This study will contribute to the current debate by conducting research at the individual farm level of the Dutch dairy sector. The Dutch dairy sector is an interesting case because compared to other European countries, the farmers are producing at the maximum quota levels, so quotas are still binding. This influences the behaviour of dairy farmers since farmers cannot choose optimal production levels themselves. In fact they face a constraint on their output, so that optimizing behaviour amounts to minimizing costs (i.e. by choosing optimal levels of inputs, given their prices) rather than maximizing profit (by choosing optimal levels of output, besides input levels, as well, given in- and output prices). The microeconomic model used in this study therefore is a cost minimization model. Shadow prices and quota rents are derived for each individual farm. Microeconomic modelling specifically allows for heterogeneity in costs structures between individual farms. It therefore provides more information on the specific course of marginal costs of individual farmers compared to sector models for the whole Dutch dairy sector. Moreover, analysis at the farm level is able to show which farms specifically are more likely to expand production after quota abolition and which are not.

In particular this study focuses on the sensitivity of the milk supply with respect to feed prices (since a significant part of marginal costs of farmers contain costs on feed) and the effect of potential changes in the milk price on the milk supply. The research question we answer in this explorative paper is 'What are the effects of changes in milk prices and prices for animal feed on the supply of milk by Dutch dairy farmers, and what does this mean if milk quota are abolished?' In the end, this assessment will be useful in defining suitable future agricultural policies in the European Union, and in particular in The Netherlands.

2. THEORETICAL MODEL

In this section we develop a theoretical micro-economic model for the dairy farming sector in the Netherlands. The behavioural assumption is that farmers minimize costs in the short run at a given level of outputs and input prices. This means that we assume that the supply of output is fixed at the quota level. Farmers produce multiple outputs using quasi-fixed inputs and variable inputs. The theoretically well-behaved short run cost function is:

$$C(\mathbf{w};\mathbf{y},\mathbf{z}) = \mathbf{w} \cdot x(\mathbf{w};\mathbf{y},\mathbf{z}) \quad s.t. \ \mathbf{w} > 0, f(\mathbf{x}) = \mathbf{y} \tag{1}$$

Where $C(\mathbf{w};\mathbf{y},\mathbf{z})$ are the restricted short run costs, **w**, **y** and **z** are respectively the vector of variable input prices, vector of outputs and the vector of fixed factor inputs. $x(\mathbf{w};\mathbf{y},\mathbf{z})$ is the vector of variable inputs and $f(\mathbf{x})$ represents the production function.

The first order derivatives of the well-behaved cost function with respect to variable input prices give the conditional input demand functions for variable inputs (Shepard's Lemma). These demand functions are conditional on output levels. The input demand functions are given by:

$$\frac{dC(\mathbf{w};\mathbf{y},\mathbf{z})}{dw_i} = x_i(\mathbf{w};\mathbf{y},\mathbf{z}) \qquad i = 1,2 \tag{2}$$

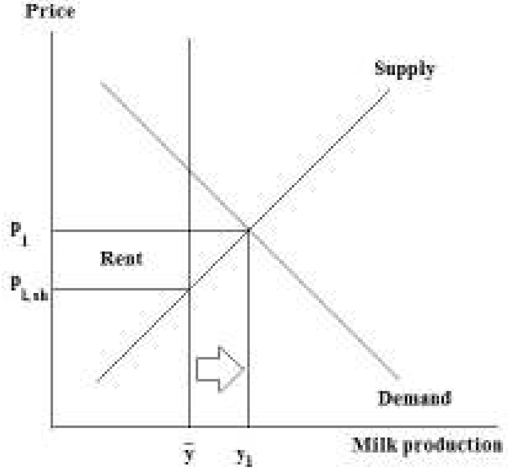
An additional assumption we make on the model is that the cost function is homogeneous of degree one in input prices. If output levels change, but all prices remain the same, the input shares in total costs should not change (Chambers, 1988: 52).

The marginal costs function is derived from the short run cost function by taking the first derivative to output. Setting the marginal costs equal to its price gives the condition for optimal output in case of profit maximization. However, since farmers are producing under a quota constraint, the derived marginal costs equal the shadow prices of production:

$$\frac{dC(\mathbf{w};\mathbf{y},\mathbf{z})}{dy_l} = p_{l,sh}(\mathbf{y},\mathbf{z}) \qquad l = 1,2 \tag{3}$$

Figure 1 shows that the difference between the market price of output 1 (P_l), and the shadow price of output 1 ($P_{l,sh}$), which is implied by the introduction of the milk quota($\bar{y}$), determine the quota rent. Each farmer faces different shadow prices, which are the marginal costs of the farmer. If the shadow price of production lies under the market price (marginal revenue), the farmer is making profit, which equals the quota rent.

Figure 1: Supply quota



Source: own elaboration

Figure 1 shows that in case of a quota constraint, farmers are not producing at the optimal point where marginal costs equal the market price. When quotas are abolished, it is expected that farmers will increase production (to y_l) in order to end up in the point where marginal costs equal marginal revenues, as indicted by the arrow in the figure. Farmers with lower shadow prices of production have more potential to increase production compared to farmers with higher shadow prices of production.

3. EMPIRICAL MODEL

In this section we develop the empirical specifications of the theoretical model. We consider a cost minimizing dairy farmer producing two outputs. The first output is milk production (y_1), which is currently in the Netherlands subject to a supply constraint, the milk quota. The second output is livestock (y_2); in order for dairy cows to have an optimal production of milk they should deliver calves every year. The outputs are produced using variable inputs feed (x_1) and energy (x_2) and quasi-fixed inputs labour (z_1), capital (z_2), land (z_3) and cows (z_4). Farm-specific fixed effects (α_{0h}) are added in the model to capture the unobserved heterogeneity among farms, e.g. relating to management quality and soil differences.

Following earlier research on the Dutch dairy sector (Ooms and Peerlings, 2005) we estimate the model using a quadratic functional form because of its flexibility. The theoretically well-behaved cost function then becomes:

$$
\begin{aligned}
C_{ht}(w_{it};y_{lht},z_{kht}) &= \alpha_{0h} + \sum_{i=1}^{2}\beta_i w_{it} + \sum_{l=1}^{2}\gamma_l y_{lht} + \sum_{k=1}^{4}\xi_k z_{kht} \\
&+ \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2}\beta_{ij} w_{it} w_{jt} + \frac{1}{2}\sum_{l=1}^{2}\sum_{d=1}^{2}\gamma_{ld} y_{lht} y_{dht} + \frac{1}{2}\sum_{k=1}^{4}\sum_{m=1}^{4}\xi_{km} z_{kht} z_{mht} \\
&+ \sum_{i=1}^{2}\sum_{l=1}^{2}\mu_{il} w_{it} y_{lht} + \sum_{i=1}^{2}\sum_{k=1}^{4}\rho_{ik} w_{it} z_{kht} + \sum_{k=1}^{4}\sum_{l=1}^{2}\sigma_{kl} z_{kht} y_{lht} + \sum_{d=1}^{9}\delta d_{dht}
\end{aligned}
\tag{4}
$$

In the equation above subscripts *h* and *t* refer to the farm and the year of the observation respectively. Symmetry is maintained requiring $\beta_{ij} = \beta_{ji}, \gamma_{ld} = \gamma_{dl}, \xi_{km} = \xi_{mk}$. Homogeneity of degree one in input prices is maintained requiring $\sum_{i=1}^{2}\beta_i = 1$. The assumptions we set on non-changing input shares if output increases are maintained through the restrictions $\sum_{i=1}^{2}\mu_{il} = 0$ for variable inputs and $\sum_{k=1}^{4}\sigma_{kl} = 0$ for fixed inputs. From the cost function the following input demand functions $x_{iht}(w_{it};y_{lht},z_{kht})$ are derived:

$$
\frac{dC_{ht}(w_{it};y_{lht},z_{kht})}{dw_{it}} = \beta_i + \sum_{j=1}^{2}\beta_{ij} w_{jt} + \sum_{l=1}^{2}\mu_{il} y_{lht} + \sum_{k=1}^{4}\rho_{ik} z_{kht}
\tag{5}
$$

The marginal costs function is derived from the short run cost function by taking the first derivative to output and equals the shadow price of production.

$$
\frac{dC_{ht}(w_{it};y_{lht},z_{kht})}{dy_{lht}} = \gamma_l + \sum_{d=1}^{2}\gamma_{ld} y_{dht} + \sum_{l=1}^{2}\mu_{il} w_{it} + \sum_{k=1}^{4}\sigma_{kl} z_{kht}
\tag{6}
$$

4. DATA AND ESTIMATION METHOD

The data for estimating this model was obtained from the Dutch Farm Accountancy Network Data (FADN) and includes 2513 observations on 295 Dutch dairy farms. The data covers the period 2000 to 2010. Since farms usually remain in the panel for about five years, the data set forms an unbalanced panel.

Of the sample, 156 farms are in the panel the whole sample period (10 years). 28 farms are in the panel from year 2004-2010, and 21 farms are in the panel from year 2002-2010. Together these farms include 62% of the total observations in the panel.

One of the outputs in the model is livestock (y_2) which represents the yearly turnover and growth of livestock and is calculated by dividing the value of livestock taken directly from the FADN (in euros) by the price for slaughter cows taken from the Agricultural and horticultural prices (2011) (in euros). In this study however we are mainly interested in the effects on milk production (y_1). In order to obtain an amount of milk production (in kilos), we gathered data on the value of milk production (in euros) from FADN and divided this value by the amount of milk production (in kilos) of farmers as reported in the FADN as well. This way we obtained the actual milk price farmers received on average for their production each year. This price differs per farm per year, as all farmers receive different prices for their milk based on different quality of their milk (i.e. fat- and protein content). In order to get the same price for each farm per year, we take the means per year of these prices. As a last step we divide the value of milk production (in euros) obtained from FADN by this average milk price to calculate the amount of milk production (in kilos). Calculation of milk production in this way is recommendable since it turns differences in quality of milk as reflected in different milk prices, into differences of quality as reflected in quantities of production.

The model contains two variable inputs which are feed (x_1) and energy (x_2). Feed is a compound variable of concentrates, roughage, and milk products feed to livestock. It is measured as an implicit quantity by dividing the total value of expenditures on feed obtained from FADN by the Tornqvist price index for feed. This Tornqvist price index, in the model introduced as w_1, is calculated based on prices for concentrates (*'standaard brok A'*), roughage ('*snijmais*') and milk products ('*melkpoeder*') obtained from Agricultural and horticultural figures (2011). Energy is calculated in the same way. It is a compound variable of natural gas, gasoline and electricity used for production. It is measured (in implicit quantities) as the total value of expenditures on energy as reported in FADN divided by a Tornqvist price index for energy, in the model represented as w_2. The Tornqvist price index is calculated based on prices obtained from the Agricultural and horticultural figures (2011) on natural gas, gasoline and electricity. The Tornqvist price indices vary over years but not over farms, implying that differences in the quality of the inputs are reflected in the quantities. The base year for the indices is 2010.

The fixed inputs in the model are labour (z_1), capital (z_2), land (z_3) and cows (z_4). Labour is taken directly from the FADN and measured as the time (in hours) worked on the farm by the farmer only. In the Dutch dairy farm sector it is mostly the farmer self that does all work on the farm. Sometimes farms are so big that they need extra help of employees, however only a few of these farms are present in the Netherlands, and were not well presented in the FADN. Also, often dairy farmers hire workers to do the heavy machine-work in case they do not own the machines needed for the work themselves. Data on this type of work was not reliably reported in the FADN, and so it was decided to not include these hours either. The replacement values on different types of capital are reported directly in the FADN and are measured in this study as a compound replacement value (in euros) for machinery, tools and buildings. For land we take the agricultural land area as reported in the FADN (in ha). Also the amount of cows is taken directly from the FADN and measured as the average amount of cows per year per farm.

Table 1: Descriptive statistics of variables in dataset

Variable	Sample mean	Dimension	Standard deviation
Milk production (y_1)	6.633	Kilograms * 100.000	4.421
Livestock production (y_2)	0.699	Kilograms * 10.000	0.735
Feed (x_1)	4.690	Implicit quantity *10.000	3.319
Energy (x_2)	7.353	Implicit quantity *1.000	7.673
Tornqvist price index feed (w_1)	0.934		0.139
Tornqvist price index energy (w_2)	0.861		0.149
Labour (z_1)	3.605	Hours*1.000	1.549
Capital (z_2)	8.149	Euros*100.000	5.603
Land (z_3)	5.352	Hectares*10	3.165
Cows (z_4)	8.520	Pieces*10	5.203

Source: own elaboration

The shares of feed and energy in the short run costs are 87% and 13% respectively. This means that in our model the variable input feed is more important in the total short run costs than the variable input energy, as was expected and indicated in the introduction already.

Because of the farm-specific effects, we estimate the model using a fixed effects estimator. For this we transform the data using a within transformation. This transformation, which takes for each variable the deviation for each observation per year that a farm is present in the panel from the calculated mean of the variable per farm per year present in the panel, can also be applied to an unbalanced panel.

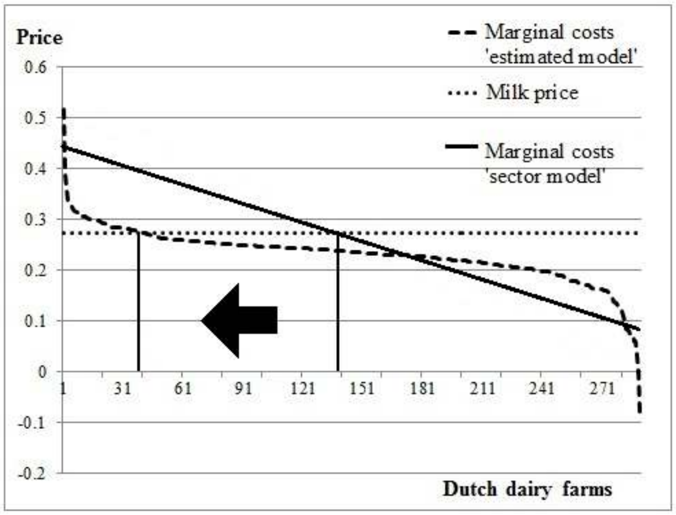
We estimate the cost function and the input demand equations together as a system in order to impose parameter restrictions over equations and obtain efficiency gains in estimating. The input demand for the second input can be obtained from the estimates of the model.

5. RESULTS

In this section we present the main findings of our model. The estimation results of the model are shown in appendix 1.

The main advantage of using farm level data in microeconomic modelling is the richness of information which allows to explore the behaviour of individual farmers, rather than it provides only information on the marginal farmer, such as in the case in macro studies using data aggregated at the sector level. Using farm level data provides more information on the true structure of the marginal cost curve. A key finding in this study, is the course of marginal costs of individual Dutch dairy farms, which play a significant role in evaluating the possible effects of milk quota abolishment on milk production.

Figure 2: Marginal costs 'estimated model' and 'sector model'

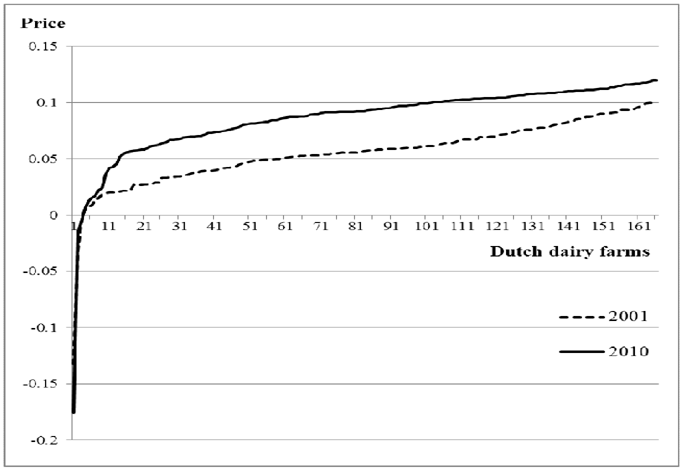


Source: own elaboration

Figure 2 shows the course of the marginal cost curve as it usually is estimated in a standard sector model, and the marginal costs curve as we have estimated in our model. The differences between the marginal costs and marginal revenues determine the profit of the farms, or also called the quota rents in case of production under a quota regime. Farms will produce up to the point where marginal costs equal marginal revenues. As can be seen in figure 2, the sector model would underestimate the amount of farms making profit. Compared to the results of our model, which estimates the true marginal costs curve, the amount of farms making profit is smaller. If marginal costs are lower than marginal revenues, farms will expand production. The figure shows that the amount of farms that will potentially expand their production is estimated to be larger in the estimated model than in the sector model.

Figure 3 shows the quota rents of the farms in the sample for the first and last year included in our study. As can be seen, the pattern is the same in both years, although the quota rents in 2010 are higher than in 2001. This is observed due to technological change during the years and farms currently producing more efficient and more profitable than before.

Figure 3: Quota rent of Dutch dairy farms



Source: own elaboration

Farms having a negative quota rent might still continue farming in the short run if their loss is compensated with Single Farm Payments (SFPs). However, the European Common Agricultural Policy is going to be changed as of 2014, and so will also the direct payment system. It is also relevant to evaluate the share in milk production of these farms with negative quota rents, because if they exit production, the impact on total milk production when quotas are abolished, will be lower. Table 2 shows that there are only a few farms in the sample which have negative rents. In almost every year they account for less than 5% of total milk production. This implies that the potential exit of these farms will not have major effects on total milk production. An exceptional year is 2009. In this year milk prices were relatively low and feed prices, which determine a great part of marginal costs, were relatively high. This is reflected in lower and more negative quota rents for farms.

Table 2: Shares in milk production of farms with negative quota rents

Year	Number of farms	Total milk production (in 100.000 kg)	Total milk production of all farms in sample (in 100.000 kg)	Shares
2001	3	14.35	1100.57	1.3%
2002	4	23.95	1211.71	2.0%
2003	6	58.95	1321.82	4.5%
2004	16	120.07	1405.17	8.5%
2005	1	30.70	1452.43	2.1%
2006	2	42.93	1640.51	2.6%
2007	1	7.30	1794.17	0.4%
2008	6	89.95	2008.22	4.5%
2009	40	375.52	2274.20	16.5%
2010	3	39.23	2460.07	1.6%

Source: own calculation

Feed costs determine for a large part the marginal costs of farms. Feed costs are expected to increase in the future due to increasing price volatility in the commodity market for agricultural products (Jongeneel et al., 2010). The effect on quota rents of increasing marginal costs due to increasing feed costs, is presented in table 3. The milk price is not changing.

Table 3: Increasing feed prices and the effect on milk production

		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Base situation	No.[1]	3	4	6	16	1	2	1	6	40	3	8
	Percentage[2]	1.3	2.0	4.5	8.5	2.1	2.6	0.4	4.5	16.5	1.6	4.4
5% increase	No.[1]	6	14	25	30	3	3	4	8	55	5	15
	Percentage[2]	2.7	7.0	13.3	14.3	3.0	3.0	3.2	5.5	21.9	2.4	7.6
10% increase	No.[1]	16	31	42	54	3	4	5	15	95	9	27
	Percentage[2]	8.2	14.7	21.3	24.2	3.0	3.5	3.3	9.0	33.0	3.8	12.4
15% increase	No.[1]	28	49	68	95	8	6	6	28	148	10	45
	Percentage[2]	13.4	22.0	29.8	37.2	4.7	4.3	3.7	13.9	49.1	4.3	18.2
20% increase	No.[1]	49	86	110	127	18	10	15	67	192	15	69
	Percentage[2]	23.2	36.3	44.2	48.8	8.5	5.3	7.2	26.6	60.6	6.0	26.7
25% increase	No.[1]	79	117	135	162	32	20	32	128	222	31	96
	Percentage[2]	36.4	48.1	55.8	63.7	14.4	9.3	12.2	45.5	68.7	13.5	36.7

[1]refers to the number of Dutch dairy farms with negative returns of farming in each year

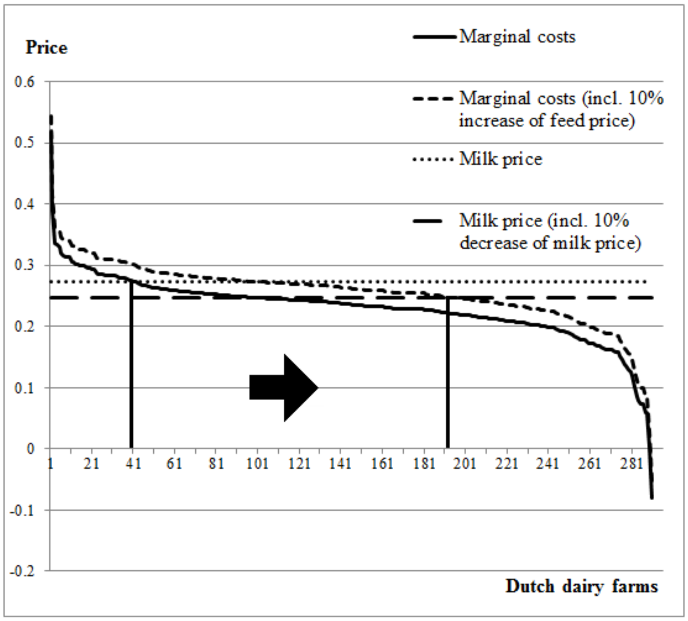
[2]refers to the percentage of total loss in milk production in each year

Source: own calculation

Compared to the base situation, where there is no increase of feed prices, the number of farms with negative quota rents, and therefore the potential loss in milk production, increase if feed prices increase. In case of an increase of 25% of the feed price might even lead to a potential loss of on average 37%. This implies that the number of farms which are potentially increasing production if milk quotas are abolished, reduces significantly if marginal costs increase due to increasing feed prices.

Not only feed prices are expected to be affected by price volatility in the agricultural commodity market, also milk prices are. Milk prices and feed prices tend to develop parallel to each other (Jongeneel et al., 2010), and are believed to decrease in the future. Figure 4 graphically shows the impact of increasing feed prices and decreasing milk prices for the farms in the sample. Compared to the base situation, an increase in marginal costs, together with a decrease in marginal revenue, lead to a significant reduction in the number of farms which will potentially increase production when quotas are abolished.

Figure 4 Influence of increasing feed prices and decreasing milk prices



Source: own elaboration

6. CONCLUSION

This paper investigated the question 'What are the effects of changes in milk prices and prices for animal feed on the supply of milk by Dutch dairy farmers, and what does this mean if milk quota are abolished?'

In the coming years, prices for feed and milk are expected to become more volatile. At the same time milk quota will be abolished in 2014/15. This affects the Dutch milk production in different ways. Currently Dutch dairy farms face binding quota levels, which implies that they cannot produce at their optimal output levels. Because most farms are making positive profits, reflected in positive quota rents, the potential increase in milk production when milk quotas are abolished is large. However, these potential effects are offset by a decreasing marginal revenue due to lower milk prices, and increasing marginal costs due to higher feed prices. This reduces the quota rents of farmers, and consequently reduces the potential increase in milk production when milk quotas are abolished.

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APPENDIX 1

1. Estimation results of the model

Equation	Main variables	Coefficient[1]	Standard error
Restricted short run costs	Milk production(y_1)	0.241***	0.0330
	Livestock production (y_2)	0.0615	0.0519
	Tornqvist price index feed (w_1)	-0.00103	0.0207
	Tornqvist price index energy (w_2)	1.001***	0.0207
	Labour (z_1)	0.143**	0.0531
	Capital (z_2)	-0.148***	0.0269
	Land (z_3)	-0.0943*	0.0483
	Cows (z_4)	-0.0111	0.0440
	Milk production, squared (y_{11})	0.00353	0.00235
	Livestock production, squared (y_{22})	0.00374	0.00702
	Tornqvist price index feed, squared (w_{11})	-0.147*	0.0816
	Tornqvist price index energy, squared (w_{22})	-0.147*	0.0816
	Labour, squared (z_{11})	0.00244	0.00438
	Capital, squared (z_{22})	-0.00130**	0.000655
	Land, squared (z_{33})	0.00461**	0.00208
	Cows, squared (z_{44})	0.00253	0.00260
	Constant term	-0.000830	0.0183
Input demand for feed	Milk production (y_1)	0.274***	0.0336
	Livestock production (y_2)	0.00183	0.0472
	Tornqvist price index feed (w_1)	-0.293*	0.163
	Tornqvist price index energy (w_2)	0.293*	0.163
	Labour (z_1)	0.0506*	0.0300
	Capital (z_2)	0.0344**	0.0120
	Land (z_3)	-0.292***	0.0259
	Cows (z_4)	0.420***	0.0299
	Constant term	-0.00103	0.0207
Input demand for energy	Milk production (y_1)	-0.274***	0.0336
	Livestock production (y_2)	-0.00183	0.0472
	Tornqvist price index feed (w_1)	0.293*	0.163
	Tornqvist price index energy (w_2)	-0.293*	0.163
	Labour (z_1)	-0.180***	0.0482
	Capital (z_2)	0.134***	0.0261
	Land (z_3)	0.0545	0.0445
	Cows (z_4)	0.141***	0.0407
	Constant term	1.001***	0.0207

[1] The significance level is indicated between brackets, where *** is 0.001, ** is 0.05 and * is 0.10.

Source: Own elaboration

2. Elasticities of input demand functions

Variable	Elasticity of feed	Elasticity of energy
Milk production (y_1)	0.388	-0.247
Livestock production (y_2)	0.000273	-0.000170
Labour (z_1)	0.0389	-0.0883
Capital (z_2)	0.0598	0.148
Land (z_3)	-0.334	0.0397
Cows (z_4)	0.763	0.163
Tornqvist price index feed (w_1)	-0.058	0.0372
Tornqvist price index energy (w_2)	0.0537	-0.0343

Source: own calculation

3. SUR estimation

The Breusch-Pagan test showed a significant (chi2: 2104.9 and P=0.000) correlation over the residuals of the two equations. The correlation between the residuals of the restricted short costs function and the demand function for feed is fairly strong (around 92%). For this we have efficiency gains through SUR estimation.