Flexible quota constraints in positive mathematical programming models

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Paper prepared for presentation at the 107th EAAE Seminar *"Modelling of Agricultural and Rural Development Policies"*. Sevilla, Spain, January 29th -February 1st, 2008

Abstract

To explain over- and underuse of available quota, Buysse et al. (2007) have integrated the shadow cost of the quota constraint in a quota flexibility function in a positive mathematical programming model. This method and central hypothesis, formulated and tested for the case of Belgian sugar beet farms, is in current paper extended and confirmed for the cases of Flemish dairy quota and manure emission rights. Despite the different organisation, objectives and implementations of the diverse quota systems, the results are similar. A higher utilisation of quota is significantly driven by the quota rent, but farm characteristics are also important and the effect declines with increasing quota rent. Regardless the quota, the dairy quota flexibility behaviour of the sample of Flemish farms results in an output price elasticity of 0.6%. The quota flexibility functions can be used for policy analysis, model sophistication and farm advisory instrument.

Key words: Quota, flexibility, Positive Mathematical Programming, farm model, Common Agricultural Policy.

1. Introduction

Quota are widely considered as an effective and efficient policy tool to control emission, production or a budget at national or international level. Effectiveness and efficiency are not accomplished as such, but are subject to various aspect of the quota implementation. For instance, quite a broad number of studies (Colman, 2000) stresses that economic efficiency of quota strongly depends on the possibility of transfers of quota to the most efficient producers. Another aspect, which we want to elaborate in current study, is the fact that efficiency and effectiveness of a quota policy also depends on the ability and the cost for the producer to control the production and supply within the quota limits.

A constraint can never be exactly binding, because in practice the production can not be precisely monitored due to stochastic production processes. This is in particular true for agricultural production. Moreover, some stochastic flexibility around constraints themselves may exist. For instance, the penalty for a farm that oversupplies milk beyond its dairy quota depends on the national milk supply and is, therefore, not known to the farmer in advance.

This problem of flexible constraints is widely addressed in operation research literature. Fuzzy and stochastic mathematical programming can optimize firm management with the existence of flexible constraints (Rommelfanger, 1996; Luhandjula, 2006). Conversely, in policy analysis only few researches are devoted to the issue of over- or underuse of flexible binding quota constraints. One of the reasons is that the approach of a firm management optimisation model and a policy model is fundamentally different: the firm management model simulates and proposes the actions needed to maximise profit while the policy model explains observed over- or underuse behaviour and simulates changes in this behaviour as a function of policy.

There are three reasons why an assessment of this quota flexibility in policy research is nevertheless important.

First, scientist and policy makers are interested in the underlying mechanism and behaviour of farms because of the influence of quota flexibility on the effectiveness and efficiency of the quota policy. For sugar, the system of A, B and C quota and the possibility to carry over sugar to the next year provided a lot of flexibility for sugar farms. The WTO panel ruling and Gohin and Bureau (2006) have shown that this quota flexibility explains the large quota oversupply in some EU regions. The applied system of quota in the sugar CMO was thus certainly not very effective to keep supply within quota limits, supposing that this was one of the objectives.

Secondly, correct policy analysis models require also a correct description of the behaviour, including the quota flexibility behaviour. Recently, Gohin and Bureau (2006) have integrated sugar beet oversupply in a CGE policy model. Adenauer *et al.* (2004) have also developed a model that explicitly considers yield uncertainty to model C sugar beet supply. The approach of Adenauer *et al.* (2004) illustrates the logic and profitability of quota oversupply for sugar beet even if the marginal costs are higher than the C sugar beet price. It shows the economic mechanism behind some of the elements of the precautionary oversupply behaviour and indicates some driving factors of it, however Adenauer and Heckelei (2005) have shown that it can not fully justify the observed C sugar beet supply. Buysse *et al.* (2007) have also proposed an approach to simulate explicitly changes in oversupply behaviour of sugar beet farms by means of an additional quota flexibility function in a positive mathematical programming policy model.

All these studies point to the importance of the sugar quota flexibility to simulate the reactions of farms to policy changes. It is yet to be investigated if quota flexibility is also relevant and important for other types of quota.

Thirdly, the quota under- or overuse might gives us also information about the value of the quota or quota rent. Quota rent information can be useful in the case of malfunctioning of quota trade markets and limited information on the correct quota price. It would, therefore, be interesting to develop a farm advice tool based on parameters that are easily observed such as the under- or overuse of quota.

The objective of this paper is therefore to extend the approach of Buysse *et al.* (2007) and to test and apply it to the case of Flemish manure and dairy quota policies. A comparison of the different cases and the types of quota can indicate whether the approach and theory is more generally applicable.

The paper is organised as follows. The next chapter gives an overview of the applied theory followed by an estimation of a quota flexibility function of the dairy quota and Flemish manure emission rights. Section 4 describes how the results of estimated functions can be used for policy advice and in programming models. Both applications provide elements for the final discussion and conclusions.

2. Theory and base model

In the case of sugar beet in Belgium sugar beet farms risk to loose their delivery right and profits if the quota is not completely filled. The deal with the stochastic yield, farms take a precautionary margin and tend to overshoot their quota. Buysse *et al.* (2007) have shown that this oversupply behaviour is a function of farm characteristics but also of the shadow cost of the quota constraint.

Sugar beet growers tend to overshoot their quota more when the profit on quota sugar beet is higher. A lower quota rent leads to lower out-of-quota supply of sugar beets. Buysse *et al.* (2007) have integrated the oversupply behaviour in the model with an additional quota flexibility function, specified as an extra constraint, that simulates the oversupply as a function of the quota, shadow cost of quota and firms' characteristics. The proposed approach is actually very simple but can easily simulate changes in the quota, quota rent and supply as a function of changes in all other model parameters.

At farm level, the model can be represented as follows:

Maximise profit $z = f(x,y)$ (1)

subject to:

$x \leq q$ [ρ] (2)

$f(x,\rho,s) \leq y$ [σ] (3)

where:

x is the activity level within quota limits and y is the precautionary activity,
q is the farm level quota,
s is a vector of farm characteristic that influence the precautionary activity,
ρ is the dual variable (shadow cost) of the quota constraint (2)
and σ is the dual variable from the flexible quota constraints (3)

For the case of sugar beet of Buysse et al. (2007) holds: $x \geq 0$; $y \geq 0$; $\rho \geq 0$; $\sigma \geq 0$.

ρ (quota rent) represents the shadow cost of quota and σ the cost of precautionary supply and as duals of inequality constraints they are always zero or positive.

Before applying the approach of Buysse *et al.* (2007) to other cases, the question to be answered is that for other types of quota the flexibility behaviour is (or is not) also a function of the quota rent.

Intuitively it can be expected that overuse of manure emission rights is indeed stimulated by a higher cost of disposing the manure within the quota limits, which is the shadow cost of the manure constraint. Underuse of the manure disposability space is likely to diminish with increasing shadow cost of the manure constraint. The same also applies to the dairy quota case. The sections 3 and 4 of current paper provide estimations to test the hypothesis of the influence of the quota rent on the quota flexibility behaviour.

After confirmation of the basic question and the estimation of the quota flexibility behaviour, the programming model can be adapted with the new quota flexibility function. In the case of the manure and dairy policy, the quota flexibility function (3) could then be extended to over- and underuse and supplement it with other explaining factors relevant to the manure and the dairy policy. The model has also to take into account that overuse of quota is penalised for both the manure emission rights as for the dairy quota. The basic model, therefore, should be adapted with a new objective function that takes penalties into account and a quota flexibility function in which the arguments are switched compared to (3):

$y \leq f(x,\rho,s)$ [σ] (4)

y is not strictly positive in the case of the manure and the dairy policy because both over- and underuse of the quota is observed. The actual application of manure or the supply of milk, similar to the sugar beet case, can be calculated as: x + y. A negative y, in the case of manure constraints, means that the firm takes a precautionary margin resulting in unfilled quota. In that case, x can be equal to the quota level q and the quota constraint (2) is binding, while the variable y simulates the flexibility of the constraint that is related with the risk attitude of overuse of manure, transaction costs of accepting other manure. The model can thus reflect the actual situation of a farm that perceives the quota constraint as binding while the actual use of the quota is still lower than the quota constraint. Such a model can therefore also explain why a farm is willing to pay for additional quota, because of the positive shadow cost ρ, even though the own actual quota limit is not reached yet.

The use of the dual variable of the quota constraint in the primal specification of the model in the quota flexibility function (3) and (4) creates two challenges that need to be overcome.

The first problem is the optimisation itself of the model. Model (1)-(4) can not be simply programmed in optimisation software, such as GAMS, because it is not possible to maintain the equality between ρ in the primal specification in constraint (4) and ρ as dual variable of constraint (2) during optimisation. Buysse *et al*. (2007) have overcome the optimisation problem by rewriting the model in complementary slackness constraints in which both the primal as dual variables are used. The model specified as complementary slackness constraints can be optimised with the MCP (Mixed Complementary Problem) solver Path in the GAMS (General Algebraic Modelling System) software.

The second problem is the specification and estimation of the quota flexibility function. One of the issues is that shadow costs ρ of quota constraint (2), also in the case of the Flemish manure policy and dairy quota, are often not directly observed. Therefore, we have to use indirect estimation procedures or proxy variables for the shadow cost ρ. The estimation of the parameters also suffers from endogeneity because the flexibility of a quota constraint is simulated as a function of the quota rent, but the quota rent is actually also partially influenced by the quota flexibility. The endogeneity problem increases with increasing quota flexibility.

The estimation of the parameter of the quota flexibility function is therefore only completely correct if it is simultaneously estimated with all equations that determine the shadow cost of the quota constraint. One has to rely therefore on the estimation of constrained optimisation models as proposed by Heckelei and Wolff (2003).

The following sections of the paper are mainly devoted to the estimation of the quota flexibility functions for the case of manure emission rights and dairy quota in Flanders. The next section starts with the application of the theory to the flexibility of the dairy quota.

3. Application Dairy quota

The dairy quota system exists in the EU since 1984. Unlike the sugar quota, dairy quota do not allow for oversupply at world market prices and each EU member state is responsible to maintain its supply within the quota limits. Oversupply is penalized with a levy higher than the market price for milk if the national quota is exceeded.

The levy limits the flexibility and each farm tries to avoid penalties. However, the amount of oversupply that is subject to the levy is a function of the national supply leading to a speculative behaviour of small amounts of oversupply. The milk production process is also difficult to manage precisely and, therefore, also the amount of undersupply is related to risk of penalty on oversupply and possible foregone profits caused by undersupply.

The fundamental question is whether this over- or undersupply is indeed driven by the milk quota rent, as suggested in the theoretical chapter of this paper. This hypothesis is tested for the case of Flemish dairy quota[1].

A sample with farm accountancy data of the largest farmers' organisation in Flanders contains data of 1466 Flemish dairy farms over a period of 12 years (1995 – 2006) with a total of 7922 unbalanced panel observations. Farms are spread over the entire Flemish region, however they are not representative with respect to farm size as the smallest category of farms are underrepresented in the accounting system. Farms are also not randomly selected causing a possible sample bias. Therefore, results should be interpreted with caution.

The quota rent is approximated by the variable cost of milk production (expressed in euro / litre) because the data have no direct milk quota rent information. Based on panel data of oversupply (both positive and negative) and the variable cost, the following model is estimated with OLS:

$$Oversupply_{it} = C + f_i + t_t + \beta1\ variable\_cost_{it} + \beta2\ variable\_cost_{it}^2 + \varepsilon_{it}$$

i and t are respectively the farm and year indices. f_i and t_t are respectively the fixed farm and year effects and ε_{it} is the error term. C is the constant[2] and β1 and β2 are the estimated parameters.

The fixed effect panel specification is preferred to a random effect because of the probable correlation between variable cost and farm, which is confirmed by a Hausman test ($p=0.000$). The fixed effect panel specification is also preferred to the pooled regression because the farm effect can absorb possible missing regressors. In addition, the Breusch Pagan's Lagrange multiplier statistic confirmed that effects are not redundant.

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[1] In Belgium, the last 20 years the quota regime has undergone several changes and the dairy quota implementation is now under control of the Flemish and Walloon regional governments. Our case only considers the Flemish situation.

[2] EViews automatically adds a constant to the common coefficients portion of the specification if necessary, to ensure that the effects sum to zero.

Table 1 reports the resulting values of the estimated parameters of the quadratic dairy quota flexibility function and their respective significance. The estimation results indicate that farms with a higher quota rent indeed tend to supply closer to or over the quota limits compared to farms with a lower quota rent (p=0.000). Hence, the hypothesis that over- or undersupply is driven by the milk quota rent, is confirmed. However, the negative sign of the quadratic term indicate that the positive effect of quota rent on oversupply only holds within a limited range. The low R^2 of the estimation results of a pooled regression (without fixed farm effect) also indicate that, besides the quota rent, farm characteristics play an essential role.

Table 1. Estimation results of the fixed panel OLS estimation of the dairy quota flexibility behaviour

	Coëfficiënt	Std. Error	t-Statistic	Prob.
C	55650.96	4914.849	11.32302	0.0000
β1	**-651922.3**	**74341.99**	**-8.769234**	**0.0000**
β2	**1341179.**	**279244.1**	**4.802892**	**0.0000**
R-squared	0.651044	Mean dependent var		2343.529
Adjusted R-squared	0.570995	S.D. dependent var		38911.37
S.E. of regression	25486.35	Akaike info criterion		23.29642
Sum squared resid	4.19E+12	Schwarz criterion		24.59906
Log likelihood	-90798.10	Hannan-Quinn criter.		23.74251
F-statistic	8.133052	Durbin-Watson stat		2.022085
Prob(F-statistic)	0.000000			

The estimated fixed year effects (Table 2) indicate that yearly variations also play a role in over- or undersupply. Weather conditions can partly explain a yearly lower production because dairy cows can suffer from hot weather leading to lower production. A wet harvest season for forage crops can also reduce forage quality and total milk production. The undersupply of 2005 and 2006 can be explained by the change of the rules of quota transfers that have induced an important restructuring in the Flemish dairy sector.

Several subsequent years of oversupply followed by a number of years with undersupply indicate that further research is required in order to describe the apparent cyclical behaviour in quota over- or undersupply.

Table 2. Fixed year effects of the dairy quota flexibility estimation

1995	4892	2001	4656
1996	-2496	2002	588
1997	-3772	2003	2076
1998	-1936	2004	120
1999	-4144	2005	-3908
2000	-1064	2006	-6500

The next chapter tests if the hypothesis of over- or undersupply is driven by the quota rent also applies to the case of manure emission rights in Flanders.

4. Application manure emission rights

As a consequence of the nitrate directive, the Flemish region has introduced a manure decree in 1991, which describes how manure should be disposed. A limited amount of manure can be spread on the land according to the type of manure and land. At the start, the manure decree has actually created a system of tradable emission rights because the land, which entails a right to spread manure, and also the manure itself are tradable between farms. In the system of tradable emission rights, manure is labelled as the emission whereas the right to spread manure on land is labelled as the emission right[3].

A Flemish farm can react to the manure legislation as follows:

- the farm can adapt its animal production to produce less manure;
- the farm can choose for abatement or end-of-pipe solutions such as manure processing;
- the farm can try to obtain sufficient emission rights to dispose the produced manure, which is the most customary option.

During the last fifteen years, manure disposal limits have been restricted further, which created a serious problem for the Flemish animal production sector. The demand for emission rights has increased and experts indicate that also the prices of the emission rights have gone up. Due to the increased pressure, a part of the farms have also chosen to emit above the limits, which we label as overuse of available emission rights. Despite the increased price for emission rights, there are also still farms that do not yet use all their land to dispose manure, leaving a great amount of manure emission rights unused.

At farm level, the manure legislation poses a lot of problems, while at aggregate regional level, the total supply of manure is still lower than the total available space. For that reason, the apparent contradiction of binding manure constraints coexisting next to unused manure emission rights has attracted the attention of policy makers.. The flexibility of constraints and the precautionary behaviour result thus in both an ineffective and inefficient Flemish manure policy.

Several reasons, which can mainly be categorized as 'transaction costs', exist for this apparent non-optimal behaviour of underuse of available emission rights. The qualification and quantification of these costs are subject of a subsequent study. Current study tries to analyse if the over- or underuse of emission rights is also driven by the price of the manure emission rights. It can be expected that in regions with intensive animal production most of the emission rights are used due to a great manure pressure and high manure emission prices.

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[3] The Flemish government has never called this a system of tradable emission permits as such, even though the legislation has actually created it. On top of the described actual system of tradable emission permits, later changes of the manure policy have introduced a system of tradable production permits linked to manure. The farms need to have now both the tradable production permits for animal activities and they have to dispose the manure according to the legislative limits that we call manure emission rights.

This hypothesis is tested on an administrative anonymous database, including a population of 48138 farms with 194597 unbalanced panel observations (from 2002 until 2006). The dataset is very comprehensive with detailed information about land use, number of animals, manure storage, transport and disposal. Unfortunately, there is no information on prices paid for the manure emission rights or the manure quota rents.

The manure quota rents are therefore approximated by the manure disposal cost calculation from a linear programming manure transport model. Given the observed manure production and the available land, the model minimises the manure disposal cost for each farm. It simulates therefore simultaneously the transactions between all farms in the population and calculates their cheapest way of disposing manure. The distance between farms is approximated by the distances between communes because the exact location of the farms is not known.

Subsequently, the manure quota rent right price can be derived from the shadow price of the animal manure disposal constraint. This shadow price is calculated for all observations by running the model for each observed year separately.

Based on the panel data of the overuse of manure emission rights (both positive and negative) and the approximated manure quota rents, the following model is estimated with OLS:

$$Overuse_{it} = C + f_i + t_t + \beta 1\ quota\_rent_{it} + \beta 2\ quota\_rent_{it}^2 + \varepsilon_{it}$$

f_i and t_t are respectively the fixed farm and year effects and ε_{it} is the error term. C is the constant and $\beta 1$ and $\beta 2$ are the estimated parameters.

Likewise to the previous case of milk quota rent, the fixed effect panel specification is preferred to a random effect because of the probable correlation between manure pressure and farm location, which is confirmed by a Hausman test (p=0.000). The fixed effect panel specification is also preferred to the pooled regression because the farm effect can absorb possible missing regressors. In addition, the Breusch Pagan's Lagrange multiplier statistic confirmed that the effects are not redundant.

Table 3 reports the resulting values of the estimated parameters of the quadratic overuse flexibility function and their respective significance. The estimation results show that with increasing manure disposal cost there is a higher utilisation of the available manure emission rights (p=0.000). Consequently, the results are completely in line with the quota flexibility function for dairy quota and confirm the hypothesis that over- or underuse is driven by the shadow cost of the constraint. Also similar to dairy quota is the negative sign of the quadratic term which indicates that the positive effect of the shadow cost on oversupply only holds within a limited range. The comparison of the low R^2 of the pooled regression (without fixed farm effect) with the R^2 of the panel estimation show that, analogous as for the dairy quota, farm characteristics play a crucial role.

Table 3. Estimation results of the fixed panel OLS estimation of the emission right flexibility behaviour

	Coefficient	Std. Error	t-Statistic	Prob.
C	-891.8587	15.06792	-59.18923	0.0000
β1	**4.643605**	**0.212080**	**21.89555**	**0.0000**
β2	**-0.000248**	**1.19E-05**	**-20.75399**	**0.0000**
R-squared	0.824486	Mean dependent var		-582.3851
Adjusted R-squared	0.766790	S.D. dependent var		4827.152
S.E. of regression	2331.120	Akaike info criterion		18.55667
Sum squared resid	7.96E+11	Schwarz criterion		21.07491
Log likelihood	-1757392.	Hannan-Quinn criter.		19.29872
F-statistic	14.29015	Durbin-Watson stat		2.181213
Prob(F-statistic)	0.000000			

The estimated fixed year effects (Table 4), indicate that transaction costs, which hamper the exchange of manure or manure emission rights tend to decrease. The latter can be explained by the initiatives of the government to stimulate exchange by, for example, developing better structures to exchange manure. It is likely that after the implementation of a new policy, the farm sector needs a certain period to adjust and adapt optimally to the new situation. This can explain the rather upgoing trend in utilisation of manure emission rights in contrast with the cyclical behaviour in dairy quota. The latter policy is implemented many years earlier.

Table 4. Fixed year effects of the manure emission right flexibility estimation

2002	-201.51
2003	44.33
2004	35.83
2005	-9.89
2006	66.90

We are aware of the possible endogeneity problem in the model. The manure transport model, used to approximate the manure quota rent, does not yet contain the quota flexibility function, which is estimated in a following step. In the correctly specified manure transport model, including the quota flexibility function, the shadow price of the animal manure disposal constraint will be higher or lower for respectively the under- or overuse of the available emission rights.

As stated earlier, also in this case, the estimation of the parameters of the quota flexibility function would only be completely correct with a simultaneous estimation of the constrained optimisation manure transport model as proposed by Heckelei and Wolff (2003). Due to sample size and the complexity of the manure transport model, this challenge is very complicated. In fact, the manure transport model, whichis now running for each year separately, should function simultaneously for all years and more than 40000 farms. A possible solution would be a three step or an iterative approach which uses the estimated quota flexibility function of the second step in a new optimisation of the manure transport model in the first step.

5. Use of quota flexibility functions

In the introduction, we already indicated that the results of the estimated quota flexibility functions can be used in several ways. The following subsections discuss these applications for the quota flexibility functions of milk and manure in Flanders.

5.1 Quota flexibility information

Scientist and policy makers sometimes struggle to understand the observed behaviour of farms and seek for explanations and models which can elucidate apparent contradictions.

For example in France, the milk quota remained unfilled in 2006, although there are clear indications of positive dairy quota rents. According to Binfield *et al.* (2007), the milk production in France decreased during 2006 for a number of reasons. Weather conditions were poor, input prices increased and the manner in which milk quota is administered in France probably also prevented producers from filling the unused quota. As a result, the quota rent for France may have been positive in 2006, even though quota was unfilled. A programming model with quota constraint and a quota flexibility function can perfectly represent and describe a positive quota rent with unfilled quota.

Furthermore, the estimated quota flexibility function applied in a programming model, can also explain why certain farms are interested in buying additional quota even when the own quota are not entirely filled. The farms do not fill the quota completely because they fear oversupply penalties although they have a positive quota rent. Depending on the farms' risk behaviour, it is possible to have a higher quota rent with a lower utilisation of the available quota. As a result, the presented model can explain unexpected differences in quota rents between farms. In addition, the same principle can clarify differences between EU member states as well.

The estimated quota flexibility function gives also a quantitative indication of the possible reaction on price or cost shifts. Often supply elasticities are assumed to be zero when the supply is limited by quota with a positive quota rent. However, the quota flexibility function proves supply reactions even with quota limitations. The dairy quota flexibility function for the sample of Flemish farms indicate that the average Flemish farm would decrease its production with 1.89% in case of a cost increase of 0.01. The latter corresponds with an output price elasticity of 0.6%. This supply elasticity holds of course only for a limited range. The results confirm that quota certainly reduce the flexibility in farm production but that the supply elasticity is nevertheless still higher than zero.

The estimation results of the manure quota flexibility function are also interesting for policy makers as they indicate that the use of the available emission rights is changing during time. On the one hand, this might originate from the fact that transactions costs are reduced leading to a better interaction between farms and a better application of the manure. It is, on the other hand, also possible that more farms overuse their emission rights, which would imply that penalties are too low.

5.2 Policy model

Too much policy models rely on average quota rents in order to simulate supply behaviour of commodities subject to quota constrictions (for instance Lips and Rieder, 2005). Buysse *et al*. (2007) have already shown for the sugar beet supply that farm heterogeneity can have an impact on the aggregate outcome. Due to the differences in quota rent, it is possible that the quota rent of an individual farm has become zero even when the average quota rent is still positive. The relevance of farm heterogeneity is further illustrated by the decision of Adenauer *et al.* (2003). They integrate different producer types in the regional agricultural model CAPRI in order to simulate reliably the supply shifts of sugar in the EU.

The relevance of integrating quota flexibility in policy models has already been illustrated for sugar beet by Adenauer *et al*. (2003), Gohin and Bureau (2006) and Buysse *et al*. (2007). The estimated quota flexibility functions for the case of Flemish dairy quota en the Flemish manure emission right illustrate that also for other types of quota it should be considered. Both quota flexibility functions have shown that proxies for the quota rent have a positive and significant effect on the utilisation of the available quota. Furthermore, the order of magnitude of the reaction of farms is not negligible.

The most correct integration of the quota flexibility function in a policy model can be done with the representation of the individual farm behaviour as shown in theoretical section of the current paper. A model at farm-level, that simulates the interactions between the farms, can asses both the effect of heterogeneity of quota rents as the differences in quota flexibility behaviour.

It is, however, also possible to extend existing aggregate models with quota flexibility functions which is already done by Gohin and Bureau (2006) or, for programming models, by an extrapolation of the presented approach in the current paper.

5.3 Quota valuation

An additional application of the quota flexibility functions is to use them as farm advisory instrument. Currently, the markets of quota are often not transparent and correct price information is difficult to obtain. In the case of manure emission rights in Flanders, the lack of market information is a problem, which is further complicated by the great differences in space and time of the emission right prices. During further research, we will investigate if it would be possible to advice farms on quota prices based on the regional or national utilisation level of the quota.

6. Conclusion

The paper presents an approach for dealing with the observed over- and underuse of the available quota. This basic idea is to integrate the shadow cost of the quota constraint in a quota flexibility function that describes the over- or underuse of the quota constraint. The quota flexibility function can then be integrated in the programming model in which also all other constraints at farm level are present.

The specification of the quota flexibility function starts from the basic assumption that complete utilisation or overuse is stimulated by a higher shadow cost of the quota. This hypothesis, formulated and tested by Buysse *et al*. (2007) for the case of Belgian sugar beet farms, is confirmed in current paper for the cases of Flemish dairy quota and manure emission rights. Despite the very different organisation, goal and implementation, the two cases lead to very similar conclusions. A higher utilisation of quota is significantly driven by the quota rent. For both cases, the effect declines with increasing utilisation and the farm effect is also very important.

There is, however, a different evolution of the quota flexibility during time. The quota flexibility of dairy quota is cyclical while the manure emission rights show a trend of a higher utilisation. The difference can be explained by the fact that dairy quota exist longer and trade in manure and manure emission rights is still in development. It is likely that the transactions cost for manure emission rights exchange have diminished during the last five years. An extrapolation of these farm level results to the aggregate level leads to a total lower absolute variation in utilisation for dairy quota due to the structural development and the resulting declining number of farms.

The quota flexibility functions have three possible applications. From theoretical point of view, the approach provides an explanation for the apparent contradiction that depending on their risk attitude some farms are willing to pay for additional quota even if they are not completely filling their own current quota. In addition, some farms have a lower or zero willingness to pay for additional quota while their current use is beyond the quota limits. The estimated quota flexibility functions can also serve as elements to refine and improve current existing policy models that deal with quota. Finally, a topic for further research is to see whether these quota flexibility functions can be used as price indicators for quotas when there is not enough information on quota rent.

During the interpretation of the results, it is also important to remember the limitations of the applications. For both the dairy quota and the manure emission rights, proxies for the quota rent are used in the estimation procedure instead of the actual quota rent. Both estimations also ignore the existing endogeneity problem, which may be solved by a simultaneous estimation of the constrained optimisation problem or with a three step approach or iterative estimation process. The sample for the estimation of the dairy quota flexibility function is also not representative.

A final remark on the estimated quota flexibility function is the lack of the quantification of the penalty effect on the over- or underuse of quota. It is likely that with a higher penalty for overuse the complete utilisation would decline and vice versa. Despite the interest of scientists and policy makers in the penalty effect on quota flexibility, the parameter is not estimated in the presented cases because of lack of variation in penalties. For both the dairy quota as for the manure emission rights the penalties have not changed during the period of observation, which made it impossible to include it in the estimated function.

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