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Modelling the Impact of Sugar Reform on Belgian Agriculture

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Abstract

In the European Union, the policy debate has seriously started to reform the sugar Common Market Organization. Due to complex quota regulations and high quota rents, the supply of sugar beets cannot be simulated in the same way as the other crops. Therefore, an adapted version of Positive Mathematical Programming allowing simultaneous modelling of individual sugar beet farms is developed and applied to a sample of 108 Belgian sugar beet farms of the Farm Accountancy Data Network. A quadratic cost function that includes the observed quota rent, is estimated and integrated into a profit function with several technical and economic constraints. The model is calibrated at farm level to account for the large variability among sugar beet farms. In addition, a quota exchange among sugar beet farms is modelled to account for quota exchanges. This model allows the simulation of the effects of different policy scenarios on quota rents and farm supply. The results show that sugar beet supply responses more to quota than price cuts and that quota exchanges can play a key role in letting the sugar beet growers to adjust to the new economic environment.

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Introduction

The mid term review of the Common Agricultural Policy (CAP) decided in June 2003 did not reform the sugar regime. Instead, the European Commission opened the discussion to propose different reform options in September 2003 (European Commission, 2003a). Reform proposals are based on quota or price decreases, or both, and on alternative compensation mechanisms, whether or not decoupled. Meanwhile, many studies analysing the impact of different possible reforms became available (European Commission, 2003; Frandsen *et al.*, (2003). Complex quota regulations and implicit quota rents make it difficult to model the sugar beet growers' response to reform options in a coherent way.

Among these studies, Frandsen *et al.* (2003) use a general equilibrium model to compare the effects of price and quota cuts in all member states of the European Union (EU). Their approach relies on the calculation of a single production cost per member state. To avoid aggregation errors, the present paper develops a mathematical programming model based on the calibration method of Positive Mathematical Programming (PMP) (Howitt, 1995) but allowing simultaneous modelling of individual farms. More details and other applications of this model can be found in Buysse *et al.* (2003) and Henry de Frahan *et al*. (2004).

The model uses data from the EU Farm Accountancy Data Network (FADN). As a result, such model could be used for other applications of interest in all member states of the EU. Our application deals with a sample of 108 Belgian farms from the FADN.

The second section of this paper describes the model and the method to calibrate crop activities without quota restriction. The third section extends the model to include sugar quota and their eventual transfer among beet farms. In the fourth section, the model is used to simulate different changes in quota and sugar beet prices on a selected sample of 108 Belgian sugar beet farms. The fifth section discusses results from a sensitivity analysis. The last section concludes.

Basic model description

The mathematical programming model used in the current paper relies on a modified version of the standard PMP calibration method. As originally described in Howitt (1995), the first step of the standard three step procedure provides duals of calibration constraints that are then used in the second step to derive marginal costs for the different activities. Because, by construction of this first step, one dual of the calibration constraint of at least one activity is zero, the resulting shadow costs of the limiting resources are as high as possible which, in turn, affects the duals of the calibration constraints. The resulting derived marginal costs of the different activities are, therefore, likely to be biased because of the overestimation of the shadow costs of the limiting resources. This is the reason why this model skips this first step and, instead, these costs are included in the following farm level profit function expressed with a quadratic cost functional form in matrix notation:

$$\Pi = P^T * X - ½ X^T * Q * X - H^T * X + A^T * Subs * X$$

with
P: a j x 1 vector of output prices,
X: a j x 1 vector of production quantities,
Q: a j x j diagonal matrix of quadratic cost function parameters,
H: a j x 1 vector of linear cost function parameters,
A: a j x 1 vector of technical coefficients determining how much land is needed for a production X,
Subs: a j x j diagonal matrix of subsidies per ha,
T: transpose matrix,
j: index for crops.

Output prices and subsidies are externally determined in the model. The parameters of the matrix Q and the vector H are calibrated referring to the basic assumption made in PMP, i.e., farmers have made their optimal choice in the base year considering their production constraints and market opportunities they face. Parameters of matrix Q and vector H are determined in such a way that the observed production quantities X_o maximise profit given the observed output prices P_o and subsidies $Subs_o$ Therefore, the first derivative to X of the above profit function is set to zero to have the following equation:

$$P_o + Subs_o * A = Q * X_o + H$$

The intuition behind this derived equation is that marginal revenue should be equal to marginal costs. To calibrate every parameter of the cost function, the observed average variable cost is used as following:

$$C_o = ½ Q * X_o + H$$

with C_o the vector of observed average variable costs per activity.

From these two equations, the diagonal matrix Q and the vector H can be calibrated for every farm in the sample as following:

$$Q = 2 * (P_o * X_o^T + Subs * A * X_o^T - C * X_o^T) * (X_o * X_o^T)^{-1}$$

$$H = P_o + A * Subs - 2 * (P_o * X_o^T + Subs * A * X_o^T - C * X_o^T) * (X_o * X_o^T)^{-1} * X_o$$

In the last step of PMP, the calibrated profit function is, in turn, optimised for the different simulation scenarios as following:

$$\Pi = P^T * X - ½ X^T * Q * X - H^T * X + A^T * Subs * X$$

with land constraint over all n farms: $\Sigma A_n^T * X_n$ = total available land in the region.

Because the land constraint is defined over all the n farms in the sample, the model allows for competition and exchange of land among farms. The model also includes a constraint avoiding farms to start a new activity. As a result, each farm can re-allocate land among base year activities and trade land to farms included in the sample.

Sugar Beet Supply Representation

Under the sugar Common Market Organisation (CMO), the EU enforces a quota system for sugar beet deliveries to refineries and, consequently, sugar supplies to the EU market. The quota system distinguishes an "A" quota receiving full price support through the intervention price which is, however, discounted by a 2% producer levy, and a "B" quota receiving substantially lower price support due to a maximum of 39.5% producer levy being charged on the intervention price. Any sugar beet and sugar quantities sold beyond the combined A and B quotas and called "C" sugar have to be exported at international prices without refund (see details in Commission of the European Communities, 2003b).

While refineries in most Member States apply the classical A, B, C discriminatory quota system, refineries in Belgium offer a pooled A and B prices for all quota beets to beet growers. Subsequently in the paper, index A applied to sugar beet quantities and prices refers to this pooled price or quantity. To model sugar beet supply, two supply variables are introduced into the initial model: Xa for sugar beet supply within the A and B sugar beet quotas and Xc for sugar beet supply beyond the A and B sugar beet quotas. The two decision supply variables Xa and Xc are, however, introduced with one single cost function into the sugar beet profit function to simulate sugar beet supply as a single activity. The A and B sugar beet supply is, in addition, restricted by the volume of the A and B sugar beet quotas. The dual λ of that quota restriction represents the quota rent.

This gives the following profit function for the sugar beet supply in algebraic notation:

$$\Pi = Pa\ Xa + Pc\ Xc - Q/2\ (Xa + Xc)^2 - H\ (Xa + Xc)$$

$$\text{subject to: } Xa \leq Quota \qquad [\lambda]$$

with

Pa: the price of A sugar beet,

Pc: the price of C sugar beet,

Xa: the supply of A and B sugar beets,

Xc: the supply of C sugar beets,

Q: the quadratic cost function parameter,

H: the linear cost function parameter,

Quota: the A and B sugar beet quota,

λ: the dual of sugar beet quota restriction.

The model does not treat the whole observed C sugar beet supply as a supply respecting the profit maximisation first order condition. Part of the observed C sugar beet supply is likely to result from a precautionary behaviour as opposed to the apparent profit maximisation behaviour of the sugar beet grower. Indeed, the sugar beet grower wants to avoid the situation where his sugar beet supply is lower than his A and B sugar beet quota delivery right neither in one particular year, nor during many subsequent years. Although the sugar beet grower has the possibility to report his under delivery from one year to the next one, he faces some additional transactions costs in doing so. If he consistently fails to supply up to his A and B sugar beet quota delivery right, he may loose part of his delivery right from the refinery. In either case, he looses a profitable quota rent.

To represent this precautionary behaviour, it is assumed that only sugar beet supply above 110% of the A and B sugar beet quotas of sugar beet farms showing a positive margin in the FADN statistics is treated as being actually induced by the described profit maximisation behaviour. Sugar beet supply between 100% and 110% of their A and B sugar beet quotas is treated as an A and B sugar beet supply. Figure 1 and Figure 2 illustrate the discontinuity in the marginal cost (MC) curves derived from the proposed profit function for an A and B sugar beet quota supplier and a C sugar beet supplier. The red arrows on the figures illustrate possible changes during simulation. Changes on the marginal cost function and changes of the quota rent result from the optimization of the constrained profit function. The changes of Xquota result from a quota exchange mechanism that is introduced (cfr. infra) besides the profit maximisation.

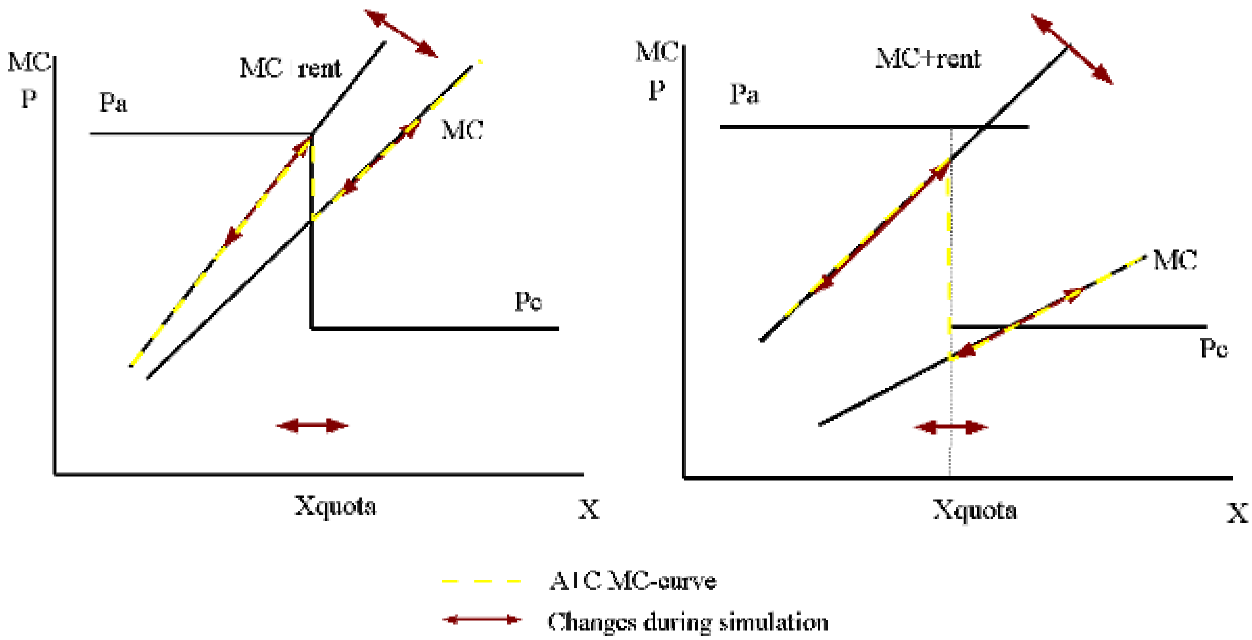

Figure 1. MC-curve for an A and B sugar beet farm

Figure 2. MC-curve for a C sugar beet farm

The model is again calibrated following the original idea of PMP by considering the observed supply of sugar beets as the result of a maximisation profit process. Because the model now includes a restriction for the A and B sugar beet quotas, the optimum is derived using the Kuhn Tucker conditions. The Lagrangean L is as follows:

$$L = Pa\ Xa + Pc\ Xc - Q/2\ (Xa + Xc)^2 - H\ (Xa + Xc) - \lambda\ (Xa - Quota)$$

The optimum is reached according to the following first order conditions:

$\partial L/\partial Xa = 0 \quad \Rightarrow Pa - Q\ Xa - Q\ Xc - H - \lambda = 0$

$\partial L/\partial Xc = 0 \quad \Rightarrow Pc - Q\, Xc - Q\, Xa - H = 0$

$\partial L/\partial \lambda = 0 \quad \Rightarrow Xa = Quota$

From these conditions, it is derived that:

for sugar beet farms that do not supply C sugar beet, the marginal cost of sugar production is: $Q\,(Xa + Xc) + H = Pa - \lambda$ and for sugar beet farms that supply C sugar beet, the marginal cost of sugar production is:

$$Q\,(Xa + Xc) + H = Pc$$

For sugar beet farms that do not supply C sugar beets, the quota rent cannot be directly observed. Therefore, the quota rent is calculated as the difference between the observed gross margins of sugar beet and the second best crop. The average of the calculated quota rents over five years preceding the base year is used in the simulation phase.

Figure 3 shows a broad distribution of these average quota rents over the sugar beet farm sample. Such a broad distribution in quota rents over the sample probably results from strong rigidities or transaction costs in the quota market as shown in Bureau *et al.* (1996). The rigidities in the quota market hamper structural adjustment in the sugar sub-sector and lead to welfare loss (Mahler, 1993).

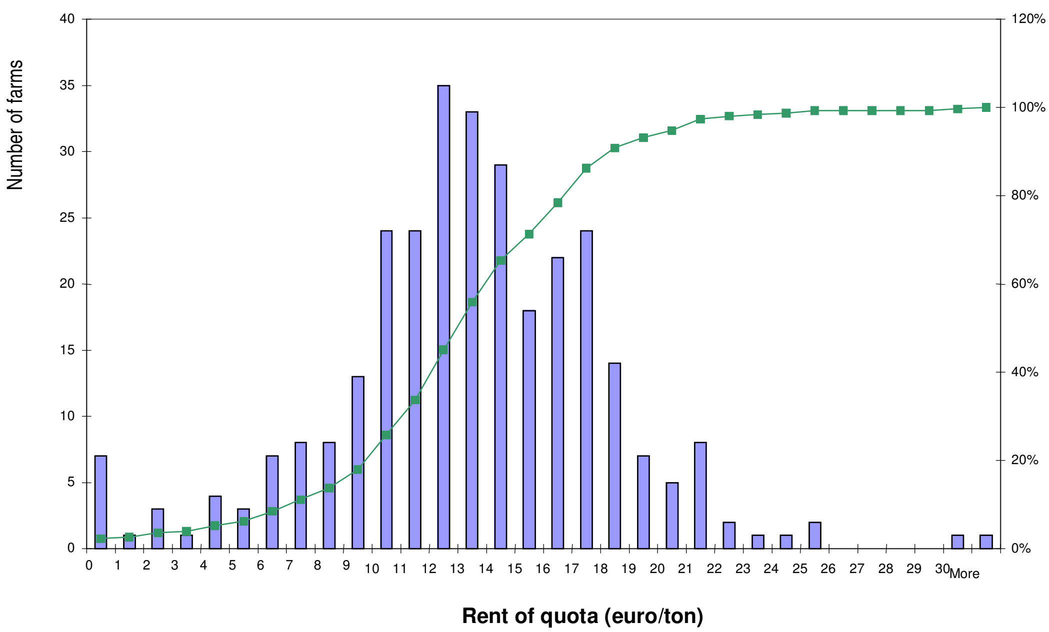

Figure 3. Overview of the estimated quota rent for sugar beet producer in the Belgian FADN.

The parameters Q and H of sugar beet are calibrated as for the other crops. The calibrated profit functions are used during simulation. For each crop, the production levels X are chosen to optimize profit.

In addition to the profit function with a quadratic cost function as described in the preceding section, a quota exchange mechanism is formulated in the model to allow for the complete use of the sugar beet quota available for the sample. The quota exchange mechanism works in such a way that when a sugar beet quota is not fulfilled at the level of a particular beet farm of the sample, then the unfilled quota is distributed to the beet farms of the sample that still have a rent on their own quota. This redistribution process is performed through a loop in the model and ends when the supply of A and B sugar beets equals the A and B sugar beet quotas available for the sugar beet farms of the sample. During the exchange, sugar beet quota goes from beet farms with a lower margin on sugar beet to beet farms with a higher margin on sugar beet.

Simulation Results

Simulations are performed on a FADN sample of 108 sugar beet farms specialised in arable crops or in a mix of arable crops and dairy production. Only crops that account for more than 0.5 % of the total farm gross margin are simulated. The base year is 2000 and the reference scenario is the mid-term review as applied in 2009. In this application of the mid-term review, direct subsidies are 75% partially decoupled for cereal, oilseed and protein (COP) crops and 60% partially decoupled for bovine slaughters. Subsidies for suckler cows remain completely coupled. Table 1 summarises the observed levels of supply in the base year and the simulated levels of supply in the reference scenario. The results of the reference scenario show that decoupling partially the direct subsidies results in a decrease in the supply of subsidized crops such as cereals and fodder maize but an increase in the supply of almost all the other crops. Supply of sugar beets increases by 2 percent in the mid-term review reference scenario. Milk supply and A and B sugar beet supply are limited by quota and, therefore, do not increase.

Table 1. Changes in sugar beet supply as a result of the mid-term review

	Fodder beets	Cereals	Grassland	Industrial crops	Fodder maize	Milk	Potatoes	A & B sugar beets	C sugar beets	Total sugar beets
Base year supply (ton)	1518	14628	14415	10301	8829	2542	23340	58525	1466	59991
Reference supply (ton)	1503	14130	14647	11326	8602	2542	23963	58525	2787	61312
%difference	-1	-3	2	10	-3	0	3	0	90	2

To analyse possible impacts of the reform of the sugar CMO, four types of scenarios are applied through the simulations. First, a price decrease from 10 to 60 % of the pooled A and B sugar beet is simulated. Second, a sugar beet quota decrease from 5 to 30% is simulated. Third, the price and quota decreases are combined. And finally, the third type of scenarios is run again but with a fully decoupled subsidy to compensate 50% of the price decrease. The changes in supply are indicated with respect to the reference scenario in the following summary tables.

Simulation results in Table 2 show that a pooled A and B price decrease induces a moderate negative effect on sugar beet supply. We need to have a decrease in pooled price of 60% to observe a decrease of 12% in A and B sugar beet supply and 16% in total beet supply. In contrast, the quota rent decreases more rapidly. For a 50% pooled price decrease, the quota rent becomes zero and, then, sugar beet supply decreases strongly. The decline in the pooled price induces a transfer of sugar beet quota from beet growers not supplying at C sugar beet price to beet growers able to supply at C sugar beet price in the base year. Because these more efficient beet growers acquire additional quota, their C sugar beet supply declines. When the quota rent of these beet growers supplying at C sugar beet price reaches zero, the A sugar beet supply starts to decline. This is observed for a 50% drop in the pooled price.

Table 2. Changes in sugar beet supply as a result of a change in A and B pooled price

A & B pooled price change (%)	A & B sugar beets (%)	C sugar beets (%)	Total sugar beets (%)	Quota rent (euro/ton)
-10	0,00	-0,40	-0,02	19,31
-20	0,00	-2,12	-0,10	14,50
-30	0,00	-11,30	-0,51	9,88
-40	0,00	-75,90	-3,45	6,53
-50	-0,07	-100,00	-4,61	0,00
-60	-11,86	-100,00	-15,87	0,00

Table 3 shows that a sugar beet quota reduction induces a much larger effect on sugar beet supply than an A and B pooled price cut. Only the sugar beet growers supplying at C price in the base year can compensate the quota cut by supplying more C sugar beets. In this case, the quota rent increases and no transfer of quota is observed. That a quota reduction has so much more influence on sugar beet supply than a A and B pooled price cut can also be understood by observing the change in marginal revenue for both types of scenarios. For sugar beet farms that do not supply C sugar beets, a price cut of 1% results in a decrease in marginal revenue of 1% while a quota reduction of 1% results in a decrease in marginal revenue of more than 60%. In case of the price cut the price of the last produced unit decreases from 50 euro to 49,5 euro. For the quota decrease on the other hand the price of the last produced unit decreases from 50 euro to less then 20 euro.

Table 3. Changes in sugar beet supply as a result of a change in sugar beet quota

Quota change (%)	A & B sugar beets (%)	C sugar beets (%)	Total sugar beets (%)	Quota rent (euro/ton)
-5	-5,00	44,62	-2,74	25,19
-10	-10,00	89,23	-5,49	26,22
-15	-15,00	133,85	-8,23	27,24
-20	-20,00	178,46	-10,98	28,26
-25	-25,00	223,08	-13,72	29,29
-30	-30,00	267,69	-16,47	30,31

Table 4 shows that the effect of a combined pooled price and quota decrease on sugar beet supply is paradoxically much lower than the sum of the separated effects of the pooled price decrease and the quota decrease. As observed in Table 2, a price cut has most of its influence on sugar beet supply when the quota rent becomes zero. Because the quota rent increases when the quota is reduced, the price cut has not as much influence on sugar beet supply. In contrast to sugar beet supply, the quota rent is much lower when a price cut is added to the quota reduction.

Table 4. Changes in sugar beet supply as a result of a combined change in pooled price and quota

A & B pooled price change (%)	Quota change (%)	A & B sugar beets (%)	C sugar beets (%)	Total sugar beets (%)	Quota rent (euro/ton)
-10	-5	-5,00	44,62	-2,75	20,32
-20	-10	-10,00	88,41	-5,53	16,50
-30	-15	-15,00	131,65	-8,33	12,69
-40	-20	-20,00	172,57	-11,25	8,89
-50	-25	-25,00	206,76	-14,47	5,17
-60	-30	-30,00	188,73	-20,06	2,45

Table 5 presents results from the same pooled price and quota decreases than in Table 4 but, in this case, with a decoupled subsidy to compensate 50% of the price decrease. This pooled price cut subsidy is integrated in total subsidies, the sum being divided over all the eligible land of the beet farm, i.e., land not planted with potatoes and vegetables. Therefore, sugar beet growers have a greater incentive to supply C sugar beets instead of potatoes or vegetables in this last type of scenarios than in the previous types of scenarios. This incentive explains why total sugar beet supply becomes even higher with the half compensated price cut subsidy combined with pooled price and quota reductions than with a decrease in quota only.

Table 5. Changes in sugar beet supply as a result of a pooled price and quota decreases with a decoupled subsidy for 50% compensation of the price decrease

A & B pooled price change (%)	Quota change (%)	A & B sugar beets (%)	C sugar beets (%)	Total sugar beets (%)	Quota rent (euro/ton)
-10	-5	-5,00	59,40	-2,07	22,34
-20	-10	-10,00	117,70	-4,20	20,50
-30	-15	-15,01	171,73	-6,52	18,72
-40	-20	-20,00	215,31	-9,30	17,18
-50	-25	-25,00	250,77	-12,47	15,86
-60	-30	-30,00	287,16	-15,58	14,34

Table 6 clearly indicates that the supply of the other crops is strongly affected by this decoupled subsidy. In the first three scenarios reported in Table 6, there is a small increase in the supply of the other arable crops such as cereals, industrial crops and potatoes. In the last reported scenario, the decoupled subsidy induces a large shift in agricultural land from non eligible crops (i.e., potatoes) to eligible crops (i.e., sugar beets, industrial crops and cereals).

Table 6. Changes in supply for other crops (%)

A & B pooled price change	Quota change	Fodder beets	Cereals	Grassland	Industrial crops	Fodder maize	Milk	Potatoes	A & B sugar beets	C sugar beets	Total sugar beets
-30	0	0	0	0	0	0	0	0	0	-11	-1
0	-15	0	3	0	2	0	0	2	-15	134	-8
-30	-15	0	3	0	2	0	0	2	-15	132	-8
-30 and 50 % compensation	-15	4	14	-2	10	-3	0	-29	-15	172	-7

Sensitivity Analysis

During the previous scenarios, it is always assumed that sugar beet farmers that produce less than 10% C sugar in the base year do that as precaution. The sensitivity of the results on this arbitrary chosen coefficient is here tested by increasing it to 15%. The simulation results of the last scenario with this adjusted coefficient are shown in Table 7. If a higher precaution coefficient is assumed, more of the observed C production is assigned to precaution behaviour and less to actual C production. There are also fewer farms assumed to be able to produce at the C price. The actual C sugar beet production reported in Table 7 is therefore lower than in Table 5.

With a higher precaution coefficient, the initial quota rent is lower. A lower quota rent results in a higher exchange of quota. For a price cut of 60% and a quota reduction of 30% there is 3778 ton sugar beet quota exchanged with the precaution coefficient of 10% and 4309 ton with the precaution coefficient of 15%. Because the calculated quota rent is a weighted average, the rent in Table 7 decreases less than in Table 5 as price decreases.

Table 7. Sensitivity analysis: scenarios of Table 5 but with a precaution coefficient of 15% instead of 10%

A & B pooled price change (%)	Quota change (%)	A and B sugar beets (%)	C sugar beets (%)	Total sugar beets (%)	Quota rent (euro/ton)
-10	-5	-5,00	44,23	-2,76	18,96
-20	-10	-10,00	88,73	-5,51	17,94
-30	-15	-15,01	128,27	-8,50	16,98
-40	-20	-20,00	157,73	-11,92	16,14
-50	-25	-25,00	177,25	-15,82	15,56
-60	-30	-30,00	191,56	-19,93	15,07

Conclusions

The present model uses discontinuous marginal cost and revenue functions of sugar beets to represent the sugar beet grower optimising behaviour. This approach allows to deal with quota rents and their changes during simulations. To deal with the sugar beet grower's precautionary behaviour, it is assumed that a fixed proportion of C sugar beets in total sugar beet supply is supplied by the sugar beet grower for precaution against quota underfilling or eventual delivery right cut. A sensitivity analysis shows that the magnitude of this assumed proportion influences the simulation results.

Simulation results show that, because of the high quota rents, sugar beet supply responds very inelastically to A and B pooled price decreases but elastically to quota reductions. These results depend on two key assumptions. The model does not integrate any feed back market effect of supply decline and does allow for exchanges of sugar beet quotas among sugar beet farms.

The supply of C sugar as precaution probably depends on the level of the quota rent as well as on the speed of enforcing a penalty in quota delivery rights. To deal with this precaution behaviour that is subject to the quota rent, other approaches can be introduced. One possibility is to calibrate the initial profit function on an expected revenue with a stochastic supply variable. Another approach consists in describing the precautionary C sugar beet supply as a function of the quota rent. Both approaches will be tested with this model in the near future whose results may eventually be presented during the conference.

The present paper shows that the initial idea of PMP serves as a flexible calibration tool for policy analysis. PMP is not only suitable for regional of sector level models, but is also suitable for aggregate farm level models.

In the case of sugar beet supply, the introduction of two production decision variables in one cost function proofs to be a key feature to duplicate sugar beet grower's behaviour. It also allows dealing with variable quota rents during simulation. Another key feature of the model is the exchange of quota among sugar beet farms.

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