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Ex-ante evaluations of public policies using farm models based on econometrically estimated flexible cost functions

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Abstract

Agriculture in the EU is strongly influenced by public policies. Most of the existing economic models which provide ex-ante analyses are defined on a more or less aggregated level, which ignores the underlying heterogeneity among farms in Europe. This paper presents a model which fills this gap. Flexible cost functions for dairy, cattle and crop were econometrically estimated using the EU farm accountancy data network for the period 1995-2007. For ex-ante evaluation of public policies, these cost functions are integrated in the objective function of farm mathematical programming models. The model is used to analyse the impact of dairy and sugar market reforms on output, input use and income. Generally, the results highlight that changes in farm supplies, input demands and gross margins are heterogeneous across farms, thus underlining the need to perform simulations at the farm level.

1 Introduction

Agriculture in the EU is strongly influenced by public policies. Most of the existing economic models which provide ex-ante analyses are defined on a more or less aggregated level, which ignores the underlying heterogeneity among farms in Europe. This paper presents a model which fills this gap, using the unique EU farm accountancy data network, which includes detailed economic and physical information for up to 90,000 farms per year.

The paper is structured as follows. First, a short overview of the modelling approach is given, outlining the estimation of flexible cost functions and the subsequent formulation of a calibrated programming model for ex-ante analysis in section 2. Then the data and key estimation results are described in section 3. Section 4 provides and discusses the results of selected policy analysis. Specifically, the impact of dairy and sugar quota abolishment for different scenarios of accompanying price decreases on output and farm incomes in selected regions of Germany is analysed. The paper concludes with a discussion of implications and challenges for policy analysis based on farm level modelling.

2 Modelling approach and Methodology

2.1 Estimating flexible cost functions

We represent cost-minimizing behaviour of farmers using a total cost function

$$TC_{ft} = f(W_{irt}, Y_{mrt}; Z_{kft}, t)$$

where subscript f stands for farms, i for variable inputs, k for quasi-fixed inputs, m for outputs, r for regions, and t for time period. Variable TC_{ft} is the total cost for the farm f at year t, Y_{mft} is the vector of output quantities, Z is the vector of quasi-fixed input quantities, W_{irt} is the vector of regional Törnqvist price indices of the input categories, and t is a time trend capturing technical change. It is assumed that the underlying production technology is the same across farms of similar type, except that its set of production possibilities can vary depending on farm-specific features which are captured by the fixed effects in the econometric estimation procedure.

The specification of the cost function used in this paper is based upon the standard Symmetric Generalized McFadden (SGM) cost function used, for example, by Wieck and Heckelei (2007) and Henry de Frahan et al. (2011). Compared to the standard SGM, all third-order terms in outputs are added to the cost function. This addition allows us to estimate cost functions for which the marginal costs are downward sloping at some of the observations, a not unlikely situation under quota systems and an observation made before (Henry de Frahan et al., 2011). The specification of the cost function in matrix notation is the following.

$$\begin{aligned} TC = {} & (\theta' W)a'Yt + (\phi' Y)b'Wt + Y'CW + Z'DW(\phi' Y) + \frac{W'EW}{2(\theta' W)}(\phi' Y) \\ & + (\theta' W)\left[Z'FZ(\phi' Y) + Y'GY + Z'HY + \sum_{\mathbf{m}} \mathbf{y_m}(\mathbf{Y'Q_m Y}) \right] \end{aligned}$$

where $(\theta' W)$ and $(\phi' Y)$ are fixed-weight indices for first-order homogeneity in input prices and TC(Y=0, W, Z) = 0 and where the farm index f = 1,...F and the time index t = 1,...T are suppressed for readability.

The parameters of this specification are estimated using a non-linear seemingly unrelated regression of input demands using a farm fixed-effect panel estimation, imposing symmetry, adding up and curvature properties (De Blander et al., 2011). Separate estimations are performed for panels of dairy, livestock and crop farms since technology is different. Each panel contains aggregated input and output values, input and output prices, and input and output quantities. In general, value and price information for the component items allows the construction of a Törnqvist price index for the aggregate and the quotient of aggregate value and Törnqvist index gives the quantity measure “value at base-year prices”.

2.2 Specification of the farm-level programming model

The farm models (Brunke and Henry de Frahan, 2011) maximize a profit function that includes the estimated long-run cost function, subject to constraints, which include e.g. quotas, and regional grass land and crop land. Land can be exchanged only among farms within the same region.

$$\underset{Y}{\mathrm{Max}} \sum_{f \in r} \left(P_{fs}' Y_{fs} + S_{fs} - \hat{C}_f (Y_{fs}, W_{rs}; Z_{fs}, t) - u_{ft} - L_{ft}' Y^2_{fs} \right)$$

Subject to:

$$P_{fs} = \rho_s P_{ft}'$$

$$S_{fs} = S_{ft} + Y_{ft}' P_{ft} \left[\gamma_s (1 - \rho_s) \right]$$

$$\sum_{f \in r} \left[X_{afs} + X_{gfs} \right] \leq \sum_{f \in r} \left[X_{afs} + X_{gfs} \right] \quad \forall r$$

$$Y_{qfs} \leq Y_{qft} \quad \forall f : \text{to remove or not}$$

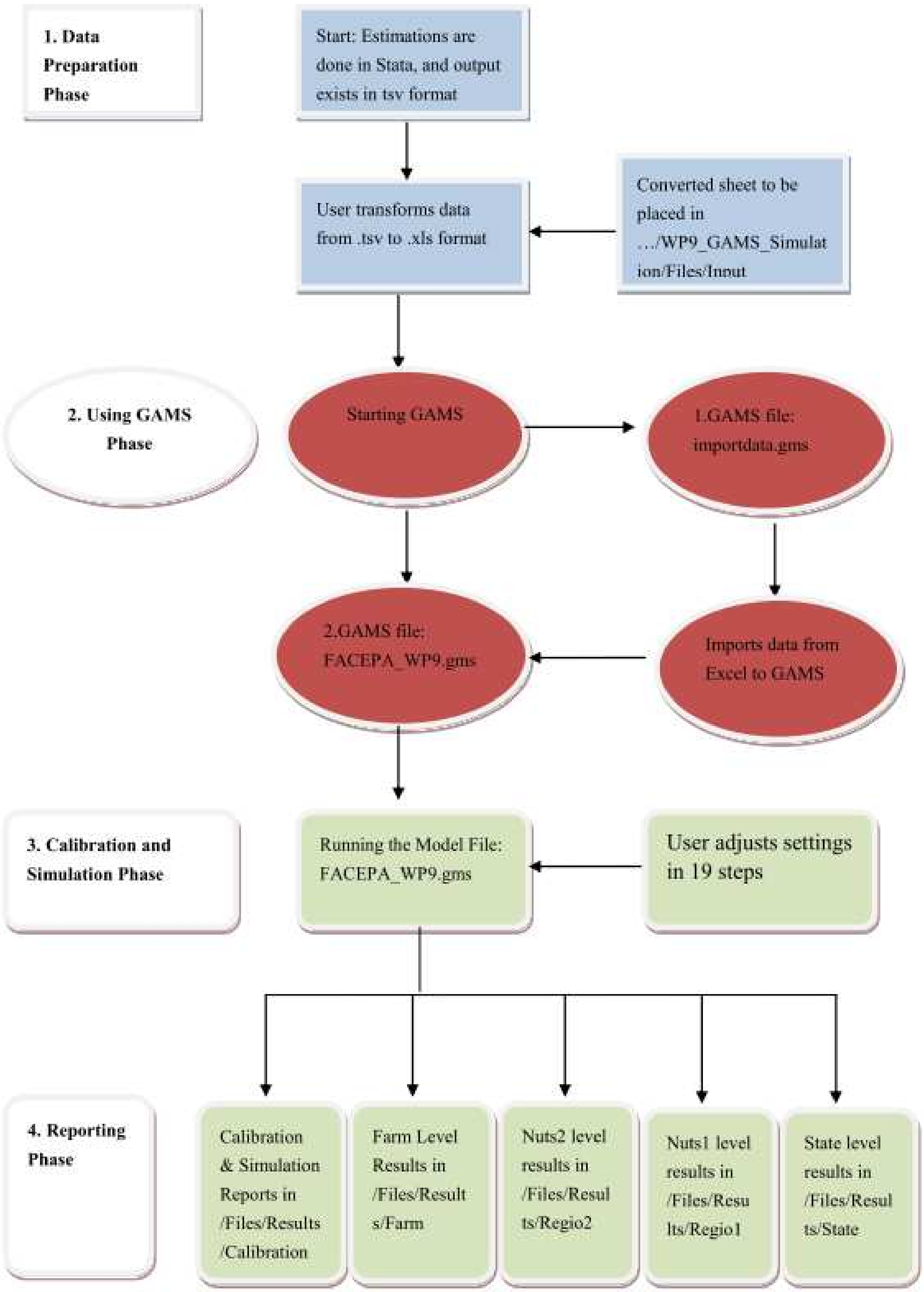
$$X_{fs} = (\hat{X}_{fs} (Y_{fs}, W_{rs}; Z_{fs}, t) + \varepsilon_{ft})$$

where subscript s stands for simulation results, a for arable land, g for grassland and q for the production activity under quota, The vector P is the vector of output prices, the scalar S the total decoupled subsidies, the scalar u the error term from the estimated cost function $\hat{C}$, ρ the diagonal matrix of the rates in price changes, $(1 - \rho)$ the diagonal matrix of one minus the rates in price changes, γ the diagonal matrix of the compensation rate of the price changes and $(\hat{X} + \varepsilon)$ the vector of the estimated input demand functions $\hat{X}$ plus their respective error term ε.

The programming models are systematically calibrated to exactly replicate the observed farm output levels in a given reference period *t*, using the neo-classical optimal condition that output prices should be equal to marginal costs for activities free of quota. Calibration can be established using either a parallel or a pivotal shift of the marginal cost curves. Indicators of changes in input demands, output supplies, farmland rental values, quota rents and farm profits are derived from the simulations according to farm type, farm size and European region.

The following flowchart shows the organisation of the four phases of the ex-ante evaluations of the agricultural and environmental policies consisting of (1) the preparation of the data and parameters, (2) the use of the GAMS simulation model, (3) the calibration and simulation, and (4) the report of the simulation results. It also shows the different programme files that are called and generated through the first three phases.

Figure 1: Flowchart of the four phases of the ex-ante evaluations



Source: Brunke and Henry de Frahan (2011).

3 Data

The EU FADN provides detailed accounting data of agricultural enterprises, including information on physical output quantities, products prices, expenditure for different inputs, and resource use, e.g. of land. For this study, data was available for the years 1990-2007. Separate estimations were established for panels of dairy, livestock and crop farms. Each panel contains aggregated input and output values, input and output prices, and input and output quantities. Table 1 provides an overview of input and output categories used.

Table 1: Input and output categories of farm models

	Dairy farms and other grazing livestock farms	**Crop farms**
Inputs	animal-specific inputs crop-specific inputs cow inputs intermediate inputs purchased feeds. arable land grassland	fertilizers pesticides seeds services capital inputs land
Outputs	milk livestock crop output	wheat other cereals oilseeds and pulses potatoes sugar beet

Cost functions are estimated for dairy farms (i.e. specialist dairy farms as well as dairy farms with rearing and fattening activities) in Lower Saxony and Bavaria, as these are the two most important regions for milk production in Germany. The cost function estimates are based on EU FADN data for 1990-2007 in Lower Saxony (5335 observations) and Bavaria (7460 observations). Mean marginal cost for milk output are estimated to be 268 €/ton (85% of the observed farm gate price) for Bavaria and 157 €/ton (52%) for Lower Saxony. The simulation model is applied for the year 2007 based on 233 dairy farms in Lower Saxony and 523 dairy farms in Bavaria. A parallel shift of marginal cost curves is used for calibration. Calibration was successfully established for all farm model.

Cost functions are also estimated for crop farms in Lower Saxony, some parts of which have very good soil and a high share of sugar beets in the crop rotation. Only specialist field crop farms were selected, in order to exclude crop farms with significant pig activities. Field vegetables farms were also excluded due to their very different structure. The cost function estimates are based on EU FADN data for 1990-2007 in Lower Saxony (4022 observations). Mean marginal cost for sugar beet are estimated to be 33 €/ton (70% of the observed farm gate price). The simulation model is applied on approximately 200 crop farms for the years 2005 and 2007. A parallel shift of marginal cost curves is used for calibration. Calibration success is almost 64% for 2005 and 100% for 2007.

Details on the estimation of flexible cost functions for Germany are given in Bahta and Offermann (2011) and Bahta et al. (2010).

4 Dairy market reform

For dairy farms, an abolishment of the milk quota is simulated. As milk prices are expected to fall (Institut d'économie industrielle, 2008), this simulation is performed for six different price levels on dairy products from 0 to 50% price decrease: P100, P90, P80, P70, P60 and P50.

In Lower Saxony, milk supply is set to increase by approximately 5%, if prices do not fall by more than 20% (Table 2). Milk supply is falling drastically if milk price decreases by more than 40%. Only few differences between sub-regions are observed.

Table 2: Change in milk output with quota abolishment in Lower Saxony

	Region			Total sample
	Hannover	Lüneburg	Weser-Ems	Lower Saxony
Milk price	% change to reference scenario (2007)			
no change	3.5	5.7	5.3	5.2
-10 %	3.4	5.5	5.1	5.1
-20 %	3.3	5.4	4.8	4.9
-30 %	3.1	5.2	4.4	4.6
-40 %	1.3	0.1	3.8	2.0
-50 %	-38.8	-43.6	-43.7	-43.0

In Bavaria, the increase in milk supply if milk price remains stable is higher (+8%) than in Lower Saxony (Table 3). However, response to a fall in prices is much more pronounced, and supply is projected to decrease strongly for a decrease in milk prices greater than 20%. Some differences between the sub-regions are observed, with the relative increase in milk supply ranging from 5.5% in Schwaben to 12.2% in Mittelfranken if the milk price remains stable.

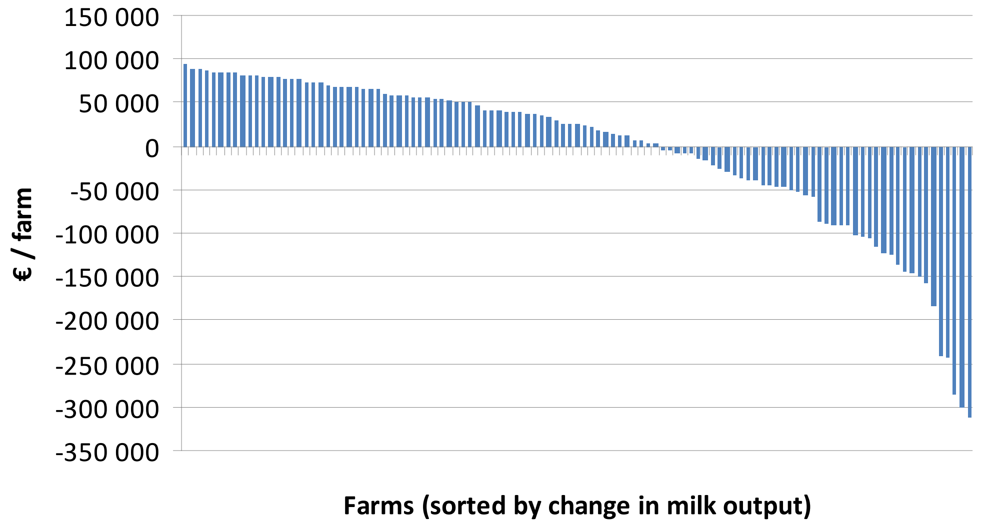
Table 3: Change in milk output with quota abolishment in Bavaria

	Region							Total sample
	Ober-bayern	Nieder-bayern	Ober-pfalz	Ober-franken	Mittel-franken	Unter-franken	Schwa-ben	Bavaria
Milk price	% change to reference scenario (2007)							
no change	6.2	9.5	10.6	10.2	12.2	12.0	5.5	8.4
-10 %	4.1	5.5	6.0	6.1	7.3	7.1	3.7	5.2
-20 %	-43.6	-53.6	-51.1	-49.2	-53.6	-49.6	-34.5	-45.6
-30 %	-51.2	-69.5	-63.4	-60.7	-66.0	-60.1	-39.6	-55.3
-40 %	-51.9	-72.9	-66.0	-63.8	-69.5	-63.4	-40.9	-57.4
-50 %	-51.9	-74.3	-67.3	-65.1	-70.9	-63.5	-41.4	-58.2

In Lower Saxony, significant input changes are observed only in the scenario with a milk price decrease of 50%, and a significant share of the land is not used anymore. However, in general the change in other input demands as a reaction to product price seems rather small. In Bavaria, changes in input demands match output changes, e.g., the increase in milk supply by 8.4% if milk price remains stable comprises a change in input demand for cows (+10%), purchased feeds (+8,4%) and other animal specific inputs (+5,8%).

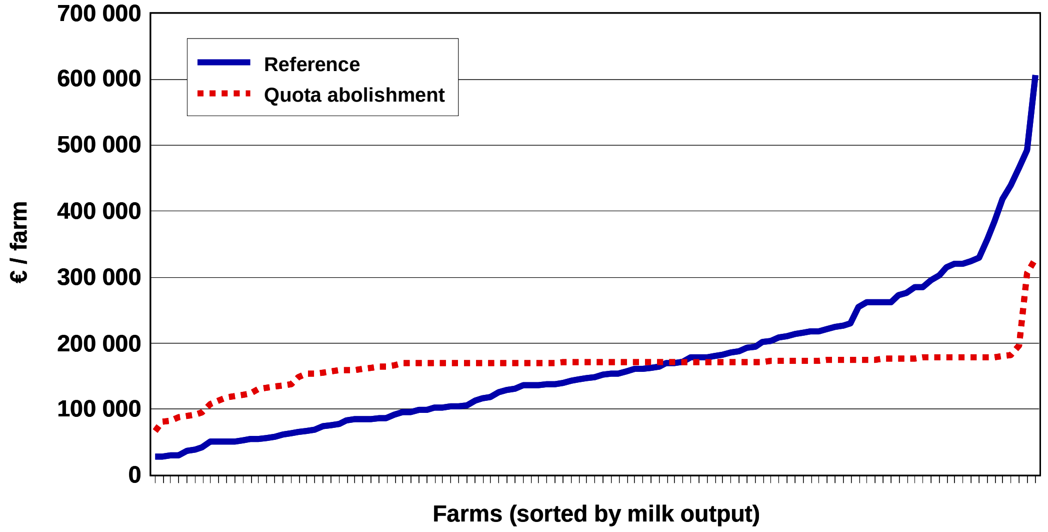
The comparatively small impacts of a milk quota abolishment on milk output at the regional and sub-regional levels hide large changes occurring at farm level. Figure 2 provides an overview of the changes in milk output (€/farm) in Weser-Ems region in Lower Saxony under the dairy reform scenario (P100) compared to the reference scenario. While many farms increase their production, others reduce it considerably as a consequence of the increased competition on the land market.

Figure 2: Changes in milk output (€/farm) in Weser-Ems region under the dairy reform scenario (P100) compared to the reference scenario



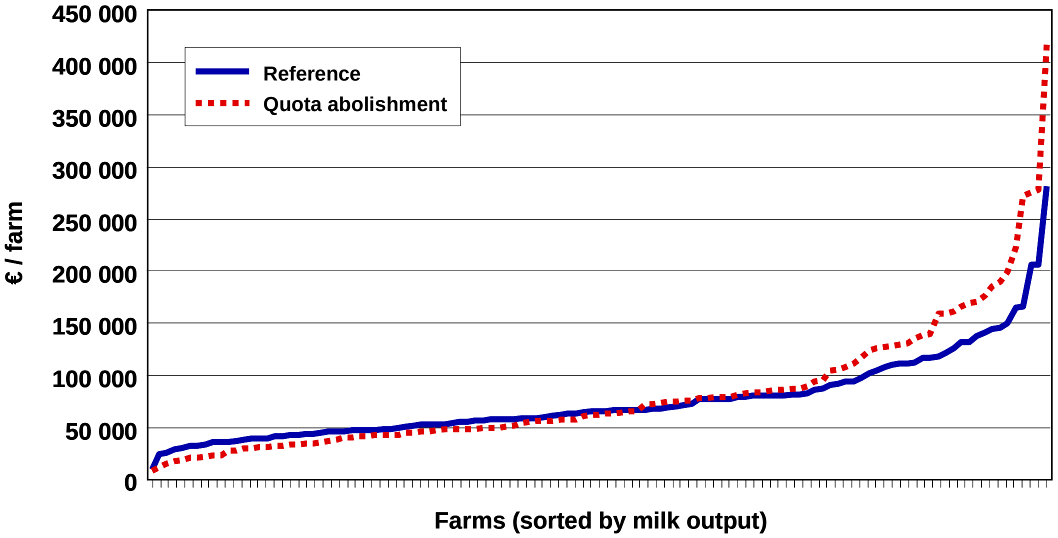
Quite interesting is also a comparison of the farm level distribution of milk output between the reference and the reform scenario in the Weser-Ems region in Lower Saxony: As Figure 3 highlights, the abolishment of the quota leads to a much more homogenous farm size in terms of milk output, indicating an 'optimal' farm size that the model farms converge to in the equilibrium process enabled by the quota abolishment.

Figure 3: Milk output (€/farm) in Weser-Ems region in the reference scenario and the dairy reform scenario (P100)



In contrast, in Oberbayern in Bavaria, the share of farms with a larger milk output increases, leading to more heterogenous farm sizes in terms of milk output (Figure 4).

Figure 4: Milk output (€/farm) in Oberbayern in the reference scenario and the dairy reform scenario (P100)



If the milk quota is abolished and prices remain constant, farm income increases by 9% in Lower Saxony and 1% in Bavaria, reflecting the different levels of quota rents in the reference year (Table 2.5). In both regions, income decreases by 11-13% if milk prices fall by 10%. For higher prices decreases, income falls more drastically in Lower Saxony, reflecting the stronger specialization of dairy farms, whereas in Bavaria income losses are partly cushioned by the higher importance of beef output in total output.

Table 4: Changes (%) in farm income with quota abolishment in Lower Saxony and Bavaria

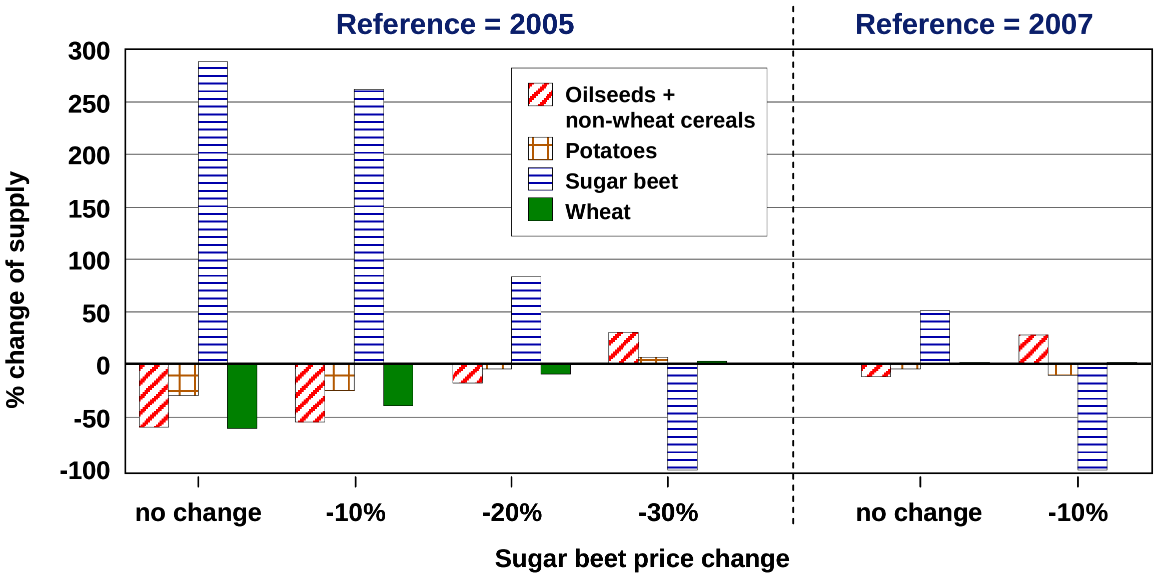
Milk price	Lower Saxony	Bavaria
no change	9 %	1 %
-10 %	-11 %	-13 %
-20 %	-31 %	-27 %
-30 %	-50 %	-34 %
-40 %	-70 %	-40 %
-50 %	-85 %	-45 %

5 Sugar market reform

For crop farms, an abolishment of the sugar quota regime is simulated. This simulation is performed for six different price levels of sugar beets, from 0 to 50% price decrease: P100, P90, P80, P70, P60 and P50. As sugar beet prices have fallen after the implementation of the last sugar market reform, the simulation is carried out based on two different reference years, i.e., 2005 and 2007.

The results highlight that the impact of sugar quota abolishment is strongly reduced by earlier sugar market reforms. Using 2005 as the reference year, an end of the quota regime would lead to a strong expansion of sugar beet supply unless prices fell by 30%. Using 2007 as the reference year, the increase in sugar beet supply at constant prices is smaller. Simulation results indicate that with a sugar beet price decrease of 10%, sugar beets would lose their profitability in all sample farms. Results for both reference years show that with low sugar beet prices, sugar beets would be replaced by oilseeds and other cereals, which is line with expectations.

Figure 5: Impact of sugar reform on supply of sugar beet in Lower Saxony, depending on the reference year



6 Conclusions

The model results point to a modest increase in milk supply in the regions of Lower Saxony and Bavaria in Germany if the milk quota is abolished. However, the effects on farm income are negative if the milk price decreases by 10% or more. Results also highlight that there are large differences of impacts between farms. The comparison of results using different reference years show that the impact of sugar quota abolishment is strongly reduced by earlier sugar market reforms. The results indicate that the supply base of sugar beet may disappear in Lower Saxony if prices fall further.

The ex-ante model proved to be capable of projecting the impact of policy reform and market changes on production, input demands and farm incomes, providing a complete picture of variability of impacts across farms. The aggregate simulation results are reasonable, sometimes with high responses due to high supply elasticities at farm level. Results also point to the large diversity in simulation results across farms due different marginal costs and elasticities, and structural changes that can be observed within the same type of farms, thus showing the need to perform simulations at the farm level.

Our experiences with the model point to the importance of screening the data for outliers, both for the estimation as well as for the simulation. Due to its econometric base, the model may underestimate technology flexibility for “extreme” scenarios. In the future, further developments could improve land market modelling by taking into account that all farm types in a region compete for land simultaneously. Further development may also replace the cost functions with ex-ante cost functions to introduce risk aversion (see, e.g., Hansen et al., 2009), which might restrain level of responses. Linking the farm models to a market model (such as, e.g., AGMEMOD; http://www.agmemod.eu) would allow to endogenise output price formation.

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