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**Analysis of the Impact on UK Sugar Production
Efficiency of Reforming the EU Sugar Regime**

by

Alan W. Renwick, Cesar L. Revoredo Giha

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Renwick, A. W.; Revoredo Giha, C. L.

Land Economy Research Group, Scottish Agricultural College, UK
Department of Land Economy, University of Cambridge, UK

Abstract

The purpose of the paper is examining the potential implications for the UK sugar beet sector of the EU sugar regime reform. Although the reform has yet to be formalised, the initial proposals centre on price and quota cuts. Using panel data from the Farm Business Survey for England, the paper estimates two cost functions: one for the sugar enterprise and another for the cropping part of the farm (i.e., excludes any livestock enterprise) and use them to analyse the impacts on profitability and costs of three possible reform scenarios: a 25 per cent cut in UK quota, a 25 per cent cut in price, a 40 per cent cut in price. The results show that the largest gains in terms of economic efficiency would be achieved under the 40 per cent price cut; however, the models suggest that this would also lead to the greatest reduction in production if the fixed costs of producing sugar were not adjusted.

Keywords: EU sugar reform; UK agriculture; UK sugar beet production; Multi-output cost function.

Address for correspondence

Dr. Cesar L. Revoredo Giha
Address: 19 Silver Street, Cambridge CB3 9EP, UK
Tel: 44 1223 337168
Fax: 44 1223 337130
E-mail: clr41@cam.ac.uk

Analysis of the Impact on UK Sugar Production Efficiency of Reforming the EU Sugar Regime

Alan W. Renwick and Cesar L. Revoredo Giha¹
Scottish Agricultural College and University of Cambridge

I. Introduction

This paper is based on a project undertaken for the Department for Environment Food and Rural Affairs (DEFRA) examining the potential implications for the UK sugar beet sector of reform to the EU sugar regime (RBU, 2004). Using economic theory it attempts to estimate the economic gains associated with the (partial) liberalisation of the EU sugar regime. It focuses on the farm business and highlights the nature and extent of the economic impacts of potential reform scenarios.

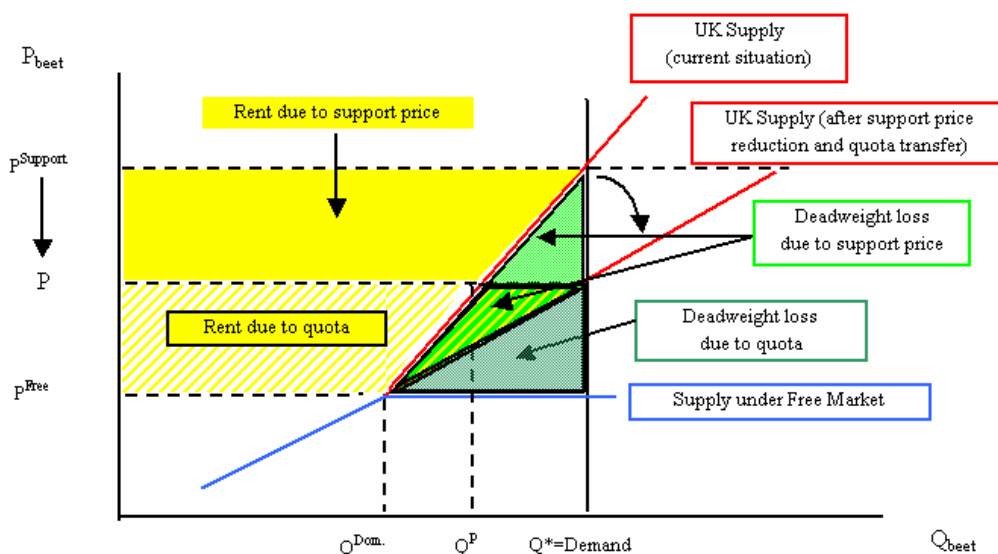
The EU has begun the process of reforming the sugar regime (see CEC, 2004 for the most recent reform proposal). Although the reform has yet to be formalised, the initial proposals centre on price and quota cuts. The impacts of the reform, both direct and indirect, are far reaching. However, this paper examines the reform in the context of the impact on the economics of sugar beet production at the *farm level*. In particular, this paper considers the current situation at the farm level in the UK and the likely impact of reform on the economic efficiency of sugar beet production.

The current policy of supported prices and effectively non-tradeable production contracts has been argued to lead to economic inefficiency, as higher cost producers are able to maintain production. Therefore, an important issue surrounding possible reforms is the extent to which they will lead to efficiency gains in economic terms. Clearly there are also other issues relating to the social impact of reform and the effect on the environment but this paper focuses on the economic impact.

Figure 1 can be used to explain the inefficiencies introduced by the sugar beet regime into UK sugar beet production. In the figure we assume that the derived demand for sugar beet (by the British Sugar factories) is perfectly price inelastic, that is the factories are producing at full capacity and that total capacity coincides with the level of sugar beet quota (Q^*).

¹ Corresponding author: Cesar L. Revoredo Giha, Department of Land Economy, University of Cambridge, 19 Silver Street, Cambridge CB3 9EP, UK. E-mail: clr41@cam.ac.uk.

Figure 1: Aggregate Inefficiency and Rent due to the Sugar Beet Regime



Under a free market situation (supply curve in blue), UK domestic growers would produce an amount equal to Q^{Dom} , and the remaining raw material requirements would have to be imported (Q^* minus Q^{Dom}). These imports do not need to be sugar beet imports but any intermediate raw material (though measured in the figure in terms of sugar beet) that can be processed by the sugar beet factories.

The figure presents two additional UK supply curves of sugar beet (in red). The first curve corresponds to the current situation, where the domestic production is subject to a quota and a support price (and the quota is not tradable). This supply curve is comprised of two line segments: the blue segment under the free market price (p^{Free}) and the respective red segment. The supply curve is not a straight line in the figure because the support price allows inefficient growers to enter into the production of sugar beet.

The total support received by the growers due to the sugar beet regime is given by the difference between the support price and the free market price multiplied by the sugar beet quota produced. This total support can be subsequently divided into two amounts: (1) the “regime rent”, which is the amount received by those growers that can produce sugar beet at a cost below the support price but greater than the free market price (total yellow area), and (2) the “deadweight loss” (total green area), which measures the inefficiency of producing sugar beet at a cost greater than the free market price.

Let us now assume that the support price is gradually reduced. The effect of this reduction is to remove from sugar beet production those growers with costs above the new support price (highlighted here as P). If each of the remaining growers continues to produce their originally allocated quota share, then the total production of sugar

beet reduces to Q^P . However, under the assumption that those growers who are still producing sugar beet can expand their production (or lower cost producers can enter the industry), a redistribution of the remaining quota would allow production of the quota in a more efficient way (i.e., at a lower cost).

The effect of the reduction in the price support and redistribution of the remaining quota would rotate the supply curve to the right. The figure shows the minimum price P at which UK producers would produce a quantity of beet equal to the sugar beet quota. Under this situation the rent due to the support price disappears and the remaining rent is only due to the fact that the support price is set so that quota is attained (this rent is equal to the light yellow area plus the green-and-yellow triangle (which was formerly part of the deadweight loss). Therefore the deadweight loss associated with this situation (equal in the figure to the dark green triangle) can be attributed to price being set at a level so that the quota is fulfilled.

The deadweight losses attributed to quota and price support may at a first glance seem to be around the wrong way. However, if we express the analysis in another way it becomes clear why these terms have been used. In the absence of support, the UK would be producing at Q^{Dom} . However, to produce up to the quota amount, the price is raised to P . The deadweight loss associated with this is the green triangle. This deadweight loss is therefore due to the fact that the target production level (quota) is higher than that which would occur otherwise and is attributed to the quota.² The fact that price support is set above this level (and quota is not generally tradable) means that higher cost producers can produce profitably and there is an additional deadweight loss which therefore is deemed to arise from the fact that there is a high level of price support and not because there is a quota in place.

In what follows we present the methodology used to estimate the impact that modification of the EU sugar regime may have on the UK sugar beet agriculture. Using estimated cost functions we simulate three reform scenarios: a cut by 25 percent in the UK quota; and two cuts in the support price by 25 and 40 percent respectively.

II. Empirical Methodology

This section briefly presents the data available for the estimation and the methodology used.

a. Data Source

We used two datasets comprising information about the sugar beet producers. The first dataset is the 2002 DEFRA's Farm Business Survey (FBS) for farmers producing

² Although it should be noted that the imposition of a quota at Q^* on its own would not incur any deadweight loss as producers in the absence of price support would only produce Q^{Dom} and the quota would not be binding.

sugar beet in the UK (a total of 310 farms). The data do not present the information by crop; however, it is possible to estimate the gross margins for the cropping part of the farm.

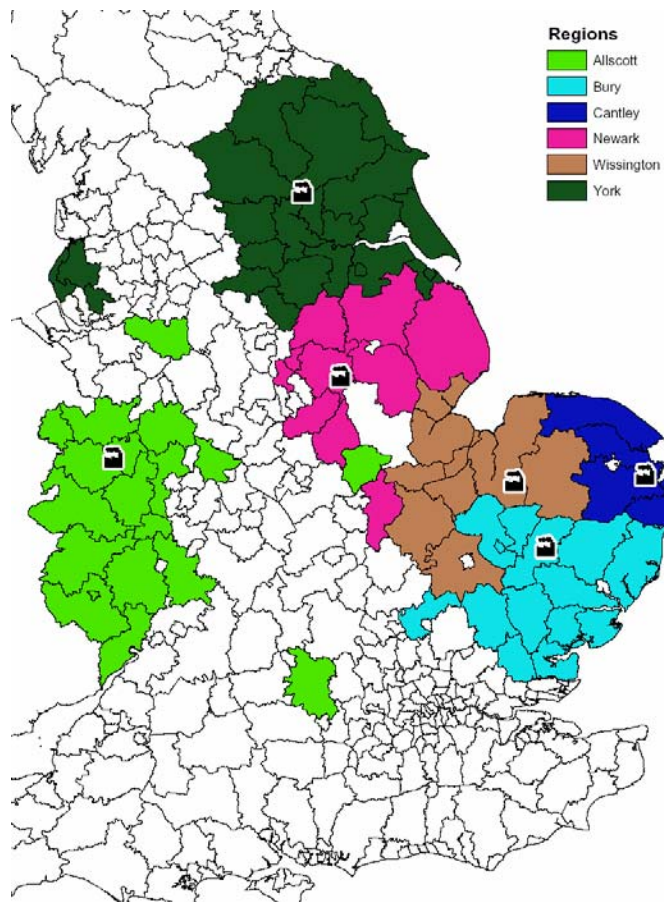
The second dataset originated from the Farm Business Survey employed by the University of Cambridge for the Eastern Region (the main sugar beet producing region of England). This dataset reports information on variable costs by crop and has been available for estimation since 1994. Furthermore, the data allowed us to construct an unbalanced panel dataset. This panel is unbalanced due to the fact that not all the farmers remain in the survey permanently as 10 per cent of the sample varies each year. The number of farms in this dataset is 251 and the total number of observations is 1,345.

A problem faced with the FBS is that it does not report either the quantity of inputs used or the input prices. Therefore, it was necessary to assume, such as in other works (see Guyomard et al., 1996, Alvarez et al., 2003) that all the farmers faced the same input costs. While this assumption is suitable for the goal of measuring economies of scale, it is not appropriate when the objective is to recover the conditional demands for factors needed for the productivity analysis³. For this purpose, we assume that the input prices vary over time and we use panel data to recover the information related to inputs as it will be explained later in the paper. The information on input prices was collected from DEFRA. All the prices were deflated by DEFRA's crop output prices base year 1995.

In order to assess the regional impact of the reform we classified the farmers in regions based on the location of British Sugar factories (the specific factory locations are given in parentheses): Allscott (Shropshire), Bury St. Edmunds (Suffolk), Cantley (Norwich), Newark (Newark), Wissington (Norfolk) and York (York). The growers were classified using DEFRA's 2002 Agricultural Census. Figure 2 presents a map of the regions and factory locations.

³ The results of the productivity analysis are available in Renwick, Revoredo and Reader (2005).

Figure 2: Sugar Beet Regions



b. Empirical Model

As it is well known from the economic literature, the presence of quotas affects producers' decisions which face a constrained optimisation problem, which in turn makes difficult to recover unconstrained producers' supply elasticities needed to evaluate the effect of changes in prices or quota. Due to this reason and the available data, the methodology consisted of estimating two generalised translog cost functions and using them to simulate farmers' response to the change in quota and prices.

The choice of the generalised translog cost function is based on Caves, Christensen and Tretheway (1981). They evaluated the generalised Leontief cost function, the translog cost function and the quadratic cost function and found that none of them fitted all the criteria for empirical work. They came across the following flaws (not all of them applying to each function) affecting the aforementioned functions: (1) violation of the regularity conditions on the structure of production⁴, (2) excessive number of parameters to be estimated, and (3) inability to accommodate observations that contain zero levels for some of the outputs. They proposed the use of the generalised translog multi-output cost function, which transforms the outputs by

⁴ Regularity conditions on the cost function stipulate that it has to be nonnegative, real valued, non-decreasing, strictly positive for nonzero levels of output, and linearly homogeneous and concave in the input prices for each one of the outputs.

means of a monotonic function instead of logarithms, thus it is possible to evaluate it at zero levels of output. In addition, it preserves the advantages of the translog function for empirical work since the prices are still expressed in logarithms. Consequently it is possible to estimate many of the function parameters from the cost-share equation.

We estimated three cost functions: one for sugar beet only using the Eastern Region dataset (i.e., only for Bury St. Edmunds, Cantley and Wissington), and two cost function for the entire cropping area using the England and Wales dataset (one for Bury St. Edmunds, Cantley and Wissington, and another for Allscott, Newark and York). As mentioned above as we wanted to compute the factor demands we had to assume that the input prices were the same for all the farmers during a year, though they vary over time. Therefore, to recover the price coefficient we relied on the panel data estimation. However, this was only possible for Bury St. Edmunds, Cantley, and Wissington as Newark, York and Alscott were covered only by the 2002 FBS. The estimated price coefficients were later used for all the regions.

The use of panel data allowed us to control by the specific characteristics of the farm that can be associated to soil or to other factors that do not change over time. We estimated the cost function using a fixed effect model. The reason behind this choice is due to Mundlak's (1978) argument that individual characteristics (e.g., managerial ability) may be correlated with the explanatory variables (e.g., level of output) and, therefore treating the farm characteristics as part of the error term, such as in the random effect model, we may have regressors that are correlated with the error term.

The variable cost function for the sugar beet enterprise is given by equation (1). This equation was estimated using individual fixed effect terms for the farms within the Bury St. Edmunds, Cantley and Wissington regions (the results of the estimation are presented in the appendix):

$$(1) \quad \ln C_{sf} = \alpha_f + \sum_{j=1}^5 \alpha_j \ln W_j + \sum_{j=1}^5 \xi_j \ln W_j \ln Z_f + \frac{1}{2} \sum_{j=1}^5 \sum_{h=1}^5 \beta_{jh} \ln W_j \ln W_h + \sum_{j=1}^5 \psi_j f(Q_f) \cdot \ln W_j \\ + \delta \cdot f(Q) + \varsigma \cdot f(Q_f) \ln Z_f + \frac{1}{2} \gamma \cdot f(Q_f) \cdot f(Q_f)$$

Where $\alpha, \beta, \delta, \psi, \varsigma, \xi, \theta$ and γ are the function parameters. C_f is the variable cost function for the farm 'f'. The sub-index related to time has been dropped to simplify the notation. Function (1) considers one output and five variable inputs and one quasi-fixed input (Z_f). w_1 is the log of the price seed, w_2 for fertilisers, w_3 for crop protection products, w_4 for hired labour, w_5 for miscellaneous, which includes contracting of harvester and haulage, Q_f is the transformed output of sugar beet. The only fixed factor considered due to data availability was family labour. The generalised translog cost function uses $f(Q)$, which is a monotonic function instead of logarithms. Such as in Caves et al. (1981), $f(\bullet)$ is given by the Box-Cox transformation, where λ is the Box-Cox parameter (we assumed the same λ for all the crops in order to reduce the estimation burden).

$$(2) \quad f(Q) = \begin{cases} \frac{(Q^\lambda - 1)}{\lambda} & \lambda \neq 0 \\ \ln(Q) & \lambda \rightarrow 0 \end{cases}$$

Based on (1) and (2) the marginal cost of producing sugar beet is given by (3):

$$(3) \quad \text{MgC}_{\text{sf}} = \exp\{\ln C_{\text{sf}}\} \cdot Q^{\lambda-1} \cdot \left\{ \delta + \sum_{j=1}^5 \Psi_j \cdot \ln W_j + \gamma \cdot \left[\frac{Q^\lambda - 1}{\lambda} \right] \right\}$$

The variable cost equation for the cropping part of the farm is given by equation (4), where the sub-index t for “period” has been suppressed:

$$(4) \quad \ln C_f = \alpha_f + \sum_{j=1}^5 \alpha_j \ln W_j + \sum_{j=1}^5 \xi_j \ln W_j \ln Z_f + \frac{1}{2} \sum_{j=1}^5 \sum_{h=1}^5 \beta_{jh} \ln W_j \ln W_h \\ + \sum_{i=1}^9 \delta_i f(Q_{if}) + \sum_{i=1}^9 \zeta_i f(Q_{if}) \ln Z_f + \sum_{i=1}^9 \sum_{j=1}^5 \psi_{ij} f(Q_{if}) \cdot \ln W_j + \frac{1}{2} \sum_{i=1}^9 \sum_{k=1}^9 \gamma_{ik} f(Q_{if}) \cdot f(Q_{kf}) + \frac{1}{2} \theta (\ln Z_f)^2$$

Where in addition to the variables and parameters already defined we considered nine crops: Q_1 is sugar beet, Q_2 winter wheat, Q_3 spring wheat, Q_4 spring barley, Q_5 winter barley, Q_6 beans, Q_7 peas, Q_8 oilseed rape and Q_9 potatoes. We estimated individual fixed effect terms for the farms within the Bury St. Edmunds, Cantley and Wissington regions, but in the case of Alscott, Newark and York we were only able to estimate regional fixed effect terms.

It is important to note that even if according to Caves et al. (1981) the generalised translog is the function with the fewest number of parameters to estimate, this number is still high. In the case of the multi-output cost function with five inputs and nine outputs and a quasi-fixed factor, the total number of slope parameters to estimate (even when imposing symmetry of the cross products and excluding the fixed effect intercepts) is equal to 145 (including the Box-Cox parameter). Due to this fact, we divide the estimation of the parameters in four stages. As the estimation of the sugar beet function was quite similar we shall describe only the estimation corresponding to the multi-output function.

The randomness of the agricultural output may create the problem of “regression fallacy” (Walters, 1960), where the output (a regressor) is correlated to the error term. To avoid this problem we first regressed the output with respect to the intercept, land and land squared and then obtained the predicted output that we used later in the regressions.

Next, we estimated the Box-Cox parameter in view of the fact that, once this parameter was computed, it was possible to transform the production parameters and make the system linear. This was done by means of a grid search procedure to find the value of the Box-Cox parameter that maximised the log likelihood value of the non-linear share equations (i.e., set of equations obtained by applying Shephard’s lemma).

Due to the high number of parameters it was not possible, such as in Caves et al. (1981), to estimate the entire cost function and the input share equations together. Instead, the next step consisted of transforming the outputs, using the estimated Box-

Cox parameter and estimating the input share equations using an iterative seemingly unrelated regression equations procedure, imposing symmetry and price homogeneity to be sure that the parameters corresponded to a well-behaved cost function. This estimation was carried out using only the panel dataset (i.e., only for Bury St. Edmunds, Cantley and Wissington).

The next step was to recover the remaining parameters of the cost function, which were associated to the output terms (i.e., not associated to input prices) and the fixed effect terms. To estimate these terms we averaged the data by farm (or region for Alscott, Newark and York where we only had data for 2002) and estimated the equation as deviations of the means, such as in Hsiao (1993) for the fixed effects model. This estimation stage used the entire sample.

After we estimated all the parameters of the model we computed the estimated input shares, which have to be positive in order to satisfy the concavity conditions and we also checked the Hessian matrix over input prices to be negative semi-definite. We did not impose any condition on the outputs. All but five cases presented negative shares. Similar results were obtained for the Hessian.

Once we estimated the cost function, we computed the marginal cost functions for each output i , which is given by equations (5):

$$(5) \quad \text{MgC}_{i-f} = Q_i^{\lambda-1} \cdot \exp \left\{ H_f + \sum_{i=1}^9 \delta_i^* \frac{(Q_{if}^{\lambda} - 1)}{\lambda} + \frac{1}{2} \sum_{i=1}^9 \sum_{k=1}^9 \gamma_{ik} \frac{(Q_{if}^{\lambda} - 1)}{\lambda} \cdot \frac{(Q_{kf}^{\lambda} - 1)}{\lambda} \right\} \\ \times \left\{ \delta_i^* + \frac{1}{2} \sum_{k=1}^9 \gamma_{ik} \cdot \frac{(Q_{kf}^{\lambda} - 1)}{\lambda} \right\}$$

Where:

$$H_0^W = \sum_{j=1}^5 \alpha_j \ln W_j \\ H_1^W = \frac{1}{2} \sum_{j=1}^5 \sum_{h=1}^5 \beta_{jh} \ln W_j \ln W_h \\ H_f = \alpha_f + H_0^W + H_1^W \\ \delta_i^* = \delta_i + \sum_{j=1}^5 \Psi_{ij} \ln W_j$$

III. Simulation of Reform Scenarios

While to simulate the effects of changes in the sugar beet support price and in the quota are relatively straightforward, simulation of changes in cropping is far more difficult. To find the values of the output due to changes in the sugar beet policy we solved the following non-linear mathematical problem using the estimated cost function for each estimated farm (f) constrained by the land availability:

$$(6) \quad \text{Max}_{Q_{if}} \quad \pi_f = \sum_{i=1}^9 P_i Q_{if} - C(W, Q, Z)$$

Where p_i is output i price, Q_i is the i -th output, and $c(w, Q)$ the estimated variable cost function.

To simplify the analysis of the change in cropping we made a number of assumptions to simplify the complex decision making process that surrounds choice of cropping on farms. First, it was assumed that if land goes out of sugar beet production it will be substituted by one of the eight alternative crops considered in the model. The extent that crops increase or decrease in area depends upon the price levels in 2002 as well as the level of support. Therefore changes in the relative prices will affect the outcome of the model. In addition, it is assumed that yields at the individual farm level are constant and this implies that the level of production and area under crops change together.

Because the cost function is non-linear with a high number of parameters, instead of maximising equation (6) we obtained the change in farm output by solving the following linear system based on the differentiation of equation (6) and evaluating the Jacobian matrix at the individual farm output values. Thus, for the case of a decrease in the sugar beet quota the change in output is given by the system (7), where the sub-index f has been dropped to simplify:

$$(7) \quad \begin{pmatrix} \frac{\partial MC_2(\bullet)}{\partial Q_2} \cdot Q_2 & \dots & \frac{\partial MC_2(\bullet)}{\partial Q_9} \cdot Q_9 \\ \frac{\partial MC_2(\bullet)}{\partial Q_{beet}} \cdot Q_{beet} & \dots & \frac{\partial MC_2(\bullet)}{\partial Q_{beet}} \cdot Q_{beet} \\ \vdots & & \vdots \\ \frac{\partial MC_2(\bullet)}{\partial Q_2} \cdot Q_2 & \dots & \frac{\partial MC_9(\bullet)}{\partial Q_9} \cdot Q_9 \\ \frac{\partial MC_9(\bullet)}{\partial Q_{beet}} \cdot Q_{beet} & \dots & \frac{\partial MC_9(\bullet)}{\partial Q_{beet}} \cdot Q_{beet} \end{pmatrix} \begin{pmatrix} \frac{dQ_2}{Q_2} \\ \vdots \\ \frac{dQ_9}{Q_9} \end{pmatrix} = \begin{pmatrix} \frac{dQ_{beet}}{Q_{beet}} \\ \vdots \\ \frac{dQ_{beet}}{Q_{beet}} \end{pmatrix}$$

For the case of a change in the support price we differentiate with respect to all the marginal cost equations including the sugar beet equation and we get the following linear system (8):

$$(8) \quad \begin{pmatrix} \frac{\partial MC_{beet}(\bullet)}{\partial Q_{beet}} \cdot Q_{beet} & \dots & \frac{\partial MC_{beet}(\bullet)}{\partial Q_9} \cdot Q_9 \\ \vdots & & \vdots \\ \frac{\partial MC_9(\bullet)}{\partial Q_{beet}} \cdot Q_{beet} & \dots & \frac{\partial MC_9(\bullet)}{\partial Q_9} \cdot Q_9 \end{pmatrix} \begin{pmatrix} \frac{dQ_{beet}}{Q_{beet}} \\ \vdots \\ \frac{dQ_9}{Q_9} \end{pmatrix} = \begin{pmatrix} \frac{dP_{beet}}{P_{beet}} \\ \vdots \\ 0 \end{pmatrix}$$

In the case of a decrease in the price support, before applying (8) we verify whether the marginal cost of producing sugar beet at the current situation was greater than the new support price. If it was greater (i.e., sugar beet was producing a rent) then we assumed that the farmer would continue producing the sugar beet quota, in which case (as we assumed other output prices constant) the crop allocation was unaffected. Otherwise, we used (8) to find the new crop allocation.

It is important to note that, as the change in output given by equations (7) and (8) is not constrained by the land availability, the results were rescaled to the availability of land by a procedure presented in the Appendix. Whilst this modified the magnitude of the changes, the procedure preserved the sign predicted by the model.

In what follows we present the results for the sugar beet enterprise and for the cropping part of the farm corresponding to three scenarios: a 25 per cent cut in UK quota, a 25 per cent cut in price, a 40 per cent cut in price. We present two sets of results: first the change in output and second the average economic results for the farms by region.

a. Results for the Sugar Beet Enterprise

Table 1 presents the model baseline, which corresponds to the information for crop year 2002/03 (sugar beet planting season starts in March and early April and it is harvested between mid-September and late April). Between Bury St. Edmunds, Cantley and Wissington (i.e., the three regions for which we have panel data information) represent approximately 62 percent of the total production.

Table 1: Model Baseline, Year 2002 1/

Region	Cases in sample	Area (Ha)	Yield (Tonnes/Ha)	Production Tonnes
Sugar Beet Enterprise Only				
Bury St Edmunds	42	32,330	55.2	1,785,315
Cantley	20	23,250	52.8	1,227,085
Newark	40	21,500	52.7	1,132,692
Wissington	81	41,500	55.5	2,305,109
York	49	25,750	50.8	1,307,965
Allscott	24	15,500	52.3	811,264
Entire sample	256	159,830	53.6	8,569,430

Note:

1/ Sample values expanded to their population values.

Table 2 presents the changes in sugar beet areas, yields and production in terms of percentage changes with respect to the model baseline (table 1)⁵ and table 3 present the economic results for the sugar beet enterprise.

The yields at the individual farm level are assumed to remain constant under all scenarios. However, this does not imply that they remain constant at an aggregate level as for instance support price reductions may force less productive farmers out of sugar beet production increasing the average yield in aggregate terms.

⁵ The sample results are weighted using the areas reported by British Sugar and sample yields.

All the statistics presented in tables 2 and 3 are for those farmers that remain producing sugar beet. We consider two criteria to decide whether stops growing sugar beet: according to sugar beet gross margin and net margin. The difference between both criteria is whether the production of sugar beet can cover sugar beet fixed costs. One may interpret that in the short run, farms will continue production of sugar beet as long as it generates a positive gross margin. In the longer run, net margin is the relevant figure for considering whether production will continue.

Table 2: Percentage Change in Sugar Beet Areas, Yield and Production with Respect to the Baseline Case 1/

Scenario and Region	Cases in sample	Area (%)	Yield (%)	Production (%)
Simulation 1: Reduction of quota by 25 percent				
Gross Margin Criterion 2/				
Bury St Edmunds	41	-25.3	-0.2	-25.4
Cantley	19	-24.2	0.1	-24.1
Newark	29	-25.7	0.8	-25.1
Wissington	76	-25.7	0.4	-25.5
York	41	-25.8	0.6	-25.4
Allscott	22	-25.4	0.2	-25.2
Total	228	-25.4	0.3	-25.2
Net Margin Criterion 3/				
Bury St Edmunds	24	-49.7	4.5	-47.5
Cantley	10	-41.6	-1.5	-42.5
Newark	16	-49.9	2.2	-48.8
Wissington	34	-64.0	8.5	-60.9
York	14	-59.6	1.4	-59.1
Allscott	11	-50.0	6.0	-47.0
Total	109	-53.9	3.5	-52.3
Simulation 2: Reduction of average price by 25 percent				
Gross Margin Criterion 2/				
Bury St Edmunds	38	-6.3	0.0	-6.2
Cantley	18	-2.8	0.0	-2.9
Newark	28	-11.8	0.8	-11.1
Wissington	72	-7.3	0.4	-6.9
York	34	-11.5	1.3	-10.4
Allscott	20	-7.4	0.5	-7.0
Total	210	-7.7	0.5	-7.3
Net Margin Criterion 3/				
Bury St Edmunds	18	-46.7	4.0	-44.6
Cantley	9	-25.6	-1.6	-26.8
Newark	11	-51.7	2.4	-50.5
Wissington	23	-62.1	10.5	-58.2
York	12	-51.8	1.1	-51.3
Allscott	7	-52.2	3.9	-50.3
Total	80	-49.7	3.3	-48.0
Simulation 3: Reduction of average price by 40 percent				
Gross Margin Criterion 2/				
Bury St Edmunds	35	-11.3	1.7	-9.8
Cantley	17	-7.7	-0.4	-8.1
Newark	22	-21.7	0.2	-21.5
Wissington	64	-12.5	0.5	-12.1
York	22	-27.9	0.9	-27.3
Allscott	16	-17.6	0.7	-17.0
Total	176	-15.8	0.8	-15.1
Net Margin Criterion 3/				
Bury St Edmunds	3	-89.2	8.3	-88.3
Cantley	3	-87.3	15.4	-85.4
Newark	1	-93.3	-4.4	-93.6
Wissington	8	-75.7	11.5	-72.9
York	3	-83.0	4.8	-82.2
Allscott	4	-64.8	2.5	-63.9
Total	22	-82.6	8.1	-81.2

Notes:

1/ Based on the sugar beet cost function. Areas and production expanded according to British Sugar data.

2/ All the farms with negative gross margins are assumed not to produce sugar beet.

3/ All the farms with negative net margins are assumed not to produce sugar beet.

Table 3: Sugar Beet Enterprise: Revenue, Costs of Production, and Profitability (Values per Output and Ha) 1/

Scenario and Region	Cases in sample	Actual Price (£)	Average Cost (£)	Marginal Cost (£)	Per Hectare Values					
					Fixed Cost (£/Ha)	Var. Cost (£/Ha)	Total Cost (£/Ha)	Revenue (£/Ha)	Gross M. (£/Ha)	Net M. (£/Ha)
Model Baseline (2002 Situation)										
Bury St Edmunds	42	28.38	22.26	9.14	528.9	700.2	1,229.0	1,552.9	852.7	323.9
Cantley	20	29.02	22.32	8.55	566.6	611.3	1,178.0	1,652.2	1,040.9	474.3
Newark	40	29.43	24.66	12.58	545.1	754.2	1,299.3	1,543.5	789.4	244.3
Wissington	81	27.78	21.74	9.37	544.5	662.8	1,207.3	1,534.6	871.7	327.3
York	49	31.26	26.05	12.72	545.1	778.3	1,323.4	1,595.5	817.2	272.1
Allscott	24	30.94	23.37	10.68	545.1	678.2	1,223.3	1,660.9	982.7	437.6
Entire sample	256	29.20	22.78	10.53	544.4	687.8	1,232.2	1,568.4	880.6	336.1
Simulation 1: Reduction of quota by 25 percent										
Gross Margin Criterion 2/										
Bury St Edmunds	41	28.53	26.65	8.21	682.4	787.3	1,469.7	1,563.2	775.9	93.5
Cantley	19	29.66	27.72	7.83	740.7	724.6	1,465.2	1,660.2	935.6	194.9
Newark	29	29.64	26.81	8.79	664.8	758.8	1,423.5	1,581.9	823.2	158.4
Wissington	76	28.09	26.77	8.23	716.4	776.3	1,492.6	1,550.1	773.9	57.5
York	41	31.58	30.44	10.12	702.4	852.6	1,555.0	1,608.9	756.3	53.8
Allscott	22	31.91	28.11	9.07	706.1	768.3	1,474.4	1,686.5	918.3	212.2
Entire sample	228	29.49	27.35	8.69	705.4	778.5	1,483.9	1,585.3	806.8	101.5
Net Margin Criterion 3/										
Bury St Edmunds	24	29.03	24.93	7.15	682.4	755.8	1,438.2	1,695.7	939.9	257.5
Cantley	10	32.69	26.77	7.14	741.7	650.8	1,392.5	1,713.7	1,062.9	321.2
Newark	16	31.40	25.16	7.89	664.8	689.7	1,354.5	1,681.1	991.3	326.6
Wissington	34	29.39	23.09	6.89	716.4	675.0	1,391.4	1,766.2	1,091.2	374.8
York	14	34.02	26.90	7.81	702.4	682.6	1,385.1	1,735.6	1,053.0	350.5
Allscott	11	32.34	25.13	7.42	706.1	687.5	1,393.6	1,825.1	1,137.6	431.5
Entire sample	109	30.80	24.74	7.29	704.8	690.9	1,395.7	1,736.1	1,045.2	340.4
Simulation 2: Reduction of average price by 25 percent										
Gross Margin Criterion 2/										
Bury St Edmunds	38	21.50	21.68	7.95	528.9	668.8	1,197.7	1,177.9	509.1	-19.7
Cantley	18	22.64	22.22	7.75	567.4	604.6	1,172.0	1,252.8	648.2	80.8
Newark	28	22.50	23.01	8.77	545.1	676.6	1,221.7	1,197.3	520.7	-24.4
Wissington	72	21.31	21.27	8.08	544.5	642.0	1,186.5	1,178.5	536.5	-7.9
York	34	23.67	24.35	9.47	545.1	707.3	1,252.4	1,216.4	509.1	-36.0
Allscott	20	24.40	22.72	8.83	545.1	649.8	1,194.9	1,279.1	629.4	84.3
Entire sample	210	22.30	22.05	8.41	544.6	653.6	1,198.2	1,200.9	547.2	2.6
Net Margin Criterion 3/										
Bury St Edmunds	18	22.11	20.15	6.95	528.9	628.7	1,157.5	1,279.2	650.5	121.7
Cantley	9	24.48	21.23	6.96	567.4	535.8	1,103.2	1,283.7	747.9	180.5
Newark	11	23.70	20.77	7.31	545.1	575.7	1,120.8	1,267.3	691.6	146.5
Wissington	23	22.09	17.31	6.26	544.5	518.2	1,062.7	1,343.1	824.8	280.4
York	12	25.47	21.72	7.48	545.1	570.6	1,115.7	1,297.9	727.3	182.2
Allscott	7	25.82	20.01	6.98	545.1	543.5	1,088.6	1,418.8	875.3	330.2
Entire sample	80	23.42	19.52	6.89	545.6	556.7	1,102.4	1,312.8	756.0	210.4
Simulation 3: Reduction of average price by 40 percent										
Gross Margin Criterion 2/										
Bury St Edmunds	35	17.04	21.17	7.60	528.9	659.3	1,188.1	951.7	292.5	-236.4
Cantley	17	18.39	22.00	7.58	567.4	589.0	1,156.3	1,015.3	426.4	-141.0
Newark	22	18.29	22.37	8.21	545.1	635.8	1,180.9	964.9	329.1	-216.0
Wissington	64	17.24	20.91	7.78	544.5	622.3	1,166.7	948.2	325.9	-218.5
York	22	19.34	22.97	8.32	545.1	632.1	1,177.2	988.0	355.9	-189.2
Allscott	16	20.08	22.02	8.42	545.1	615.2	1,160.3	1,040.8	425.6	-119.5
Entire sample	176	17.96	21.49	7.91	544.6	626.6	1,171.2	969.3	342.6	-202.0
Net Margin Criterion 3/										
Bury St Edmunds	3	18.19	17.69	5.86	528.9	528.9	1,057.8	1,107.1	578.2	49.4
Cantley	3	18.04	16.27	4.60	567.4	423.6	991.0	1,100.5	676.8	109.5
Newark	1	22.56	19.63	6.12	545.1	443.1	988.2	1,135.9	692.8	147.7
Wissington	8	18.50	16.23	5.87	544.5	461.2	1,005.6	1,099.5	638.3	93.8
York	3	19.99	19.28	6.19	545.1	480.7	1,025.8	1,063.0	582.3	37.2
Allscott	4	21.61	18.99	6.10	545.1	473.8	1,018.9	1,150.8	677.0	131.9
Entire sample	22	19.35	17.13	5.79	544.8	468.1	1,013.0	1,105.2	637.1	92.3

Notes:

1/ Based on the sugar beet cost function.

2/ All the farms with negative gross margins are assumed not to produce sugar beet.

3/ All the farms with negative net margins are assumed not to produce sugar beet.

As the price cuts considered still leave many farms with a positive gross margin from beet, the short run impact is less than that of a quota cut which forces farmers to

reduce their production by the quota amount. However, under the net margin criteria the price cuts begin to have a much more significant impact. For example, a 40 per cent reduction is estimated to reduce production by over 80 per cent. Of course, it should be noted that these estimates are based on current production costs and structures. The actual impacts will depend upon the ability of farmers to restructure their sugar beet in the face of reform.

One aspect of the results that warrants further attention is the impact of quota cuts on production. It might be assumed that a 25 per cent reduction in quota will simply lead to a 25 per cent reduction in production in the short and long run. However, the model suggests that cuts in quota lead to higher unit costs of production (see average cost in table 3) and therefore farms currently growing may well cease production altogether rather than simply cut back by the 25 percent, when one observes the results according to the gross margin criterion. The net margin figures reflect two effects: on the one hand, the increase in the average cost due to the reduction in the production scale and on the other hand, the fact that under the net margin many high cost producers have ceased producing sugar beet.

The results highlight differences in the regional impacts on production of the different scenarios. For example, under the 25 per cent cut and net margin criterion the fall in production is predicted to vary between around 25 per cent for Cantley (E2) to over 60 per cent for Wissington (E4).

b. Results for the Farm Cropping Enterprises

Tables 4 and 5 present the results for the cropping part of the farm. The criterion used in Tables 4 and 5 to decide whether a crop is planted was whether the gross margin was positive. This is undertaken because the model is based on the assumption that fixed costs are fixed and that the farm determines the allocation between crops on the basis of gross margin.

At an aggregate level, all the crops increase as a response to the reduction in the sugar beet quota and the reduction in the average price for sugar beet. With the exception of winter barley, the findings do not differ significantly between scenarios. All the scenarios indicate an increase in the area destined to winter wheat, oilseed rape and potatoes, which indicate that these crops are probably going to replace, at least partially, sugar beet in the rotation. Market conditions may, however, mitigate against a significant increase in potato area. Again though it must be emphasised that these results are based upon the relative performance of the specific crops in 2002 and therefore the apparent substitution will be sensitive to changes in the relative prices.

Table 4: Percentage Changes in Crop Production with Respect to 2002 Situation

Scenario and Region	Crops								
	Sugar Beet	Winter Wheat	Spring Wheat	Spring Barley	Winter Barley	Beans	Peas	Oilseed Rape	Potatoes
Simulation 1: Reduction of quota by 25 percent 1/									
Bury St Edmunds	-25.0	5.3	11.9	0.3	2.9	12.8	7.5	6.7	6.1
Cantley	-24.0	2.7	-1.5	10.7	11.1	-3.0	-0.6	0.5	4.1
Newark	-27.0	1.7	0.0	27.2	7.8	-16.2	-3.7	8.6	2.0
Wissington	-25.0	3.3	3.4	-1.7	25.1	1.8	7.3	3.5	1.3
York	-27.9	8.6	0.0	33.5	-3.6	11.0	-24.6	13.3	10.1
Allscott	-25.6	5.1	0.0	2.6	0.7	13.9	53.5	0.5	1.1
Total	-25.5	4.2	6.8	6.1	10.4	4.5	3.3	5.7	2.4
Simulation 2: Reduction of average price by 25 percent									
Bury St Edmunds	-6.24	1.54	5.65	-1.91	-0.58	5.78	3.54	0.71	2.91
Cantley	-2.89	0.30	-0.19	1.38	1.40	-0.77	-0.08	-0.01	0.53
Newark	-31.30	2.29	0.00	29.55	7.99	-10.90	-2.82	8.48	1.96
Wissington	-15.46	1.77	2.75	-3.46	18.35	1.34	4.17	2.83	-0.34
York	-40.19	11.00	0.00	22.77	1.82	8.07	-2.99	9.04	6.85
Allscott	-27.88	5.59	0.00	2.83	0.78	15.32	58.84	0.53	1.23
Total	-17.73	3.08	3.84	2.93	6.85	3.21	5.36	3.82	0.59
Simulation 3: Reduction of average price by 40 percent									
Bury St Edmunds	-9.82	2.23	6.29	-1.30	0.42	6.44	3.94	2.12	3.23
Cantley	-8.07	0.84	-0.53	3.87	3.91	-2.15	-0.23	-0.03	1.47
Newark	-38.75	3.17	0.00	33.65	8.84	-4.19	-1.83	9.09	2.10
Wissington	-21.98	2.90	3.14	-1.90	22.70	1.66	6.35	3.22	0.95
York	-49.05	13.09	0.00	25.72	2.54	9.48	-1.35	10.21	8.09
Allscott	-43.91	9.36	0.00	4.74	1.30	25.68	98.59	0.90	2.06
Total	-24.64	4.35	4.29	4.80	8.94	5.07	9.60	4.51	1.71

Note:

1/ The simulated decrease in the production of sugar beet is as close as it is possible to reach the goal of an average decrease in the sugar beet quota by 25 percent.

The results from table 5 are less clear due to the number of factors affecting the results, such as the change in the portfolio of crops and therefore the change in the total cost (sugar beet is a more expensive crop to grow than the others) and total revenue or the change in the cost of producing sugar beet.

The reduction in the quota shows a reduction in the profitability for all the regions. Although this final result is common for all the regions, the reasons behind the result differ slightly among them. For instance, the variable costs of some of the regions (Cantley, Newark, and Allscott) increase with respect to the baseline.

All the regions and under all the scenarios show a decrease in revenues. This is explained by the fact that sugar beet is a well remunerated crop relative to other crops. The reduction quota forces substitution of a well paid crop by other less profitable crops. In the case of the reduction in the support price the result is a combination of a lower price together with planting crops with lower prices than the baseline prices for sugar beet.

With respect to the results related to the reduction in support price, since all the regions show lower revenues than the baseline revenues, the economic result (i.e., gross margins) will depend on the savings in variable costs made in each region, and which are associated to the new portfolio of crops.

Table 5: Farm Cropping Enterprises: Revenue, Costs of Production, and Profitability (Values per Output and Ha) 1/ 2/

Scenario and Region	Actual Price 3/ (£)	Ratio Total Cost to Total Revenue (Ratio)	Marginal Cost 3/ (£)	Per Hectare Values		
				Var. Cost (£/Ha)	Revenue (£/Ha)	Gross M. (£/Ha)
Model Baseline (2002 Situation)						
Bury St Edmunds	28.38	1.16	7.50	345.9	793.9	447.9
Cantley	29.02	1.02	6.72	352.2	917.1	565.0
Newark	29.43	1.54	21.16	596.1	773.4	177.2
Wissington	27.78	1.11	9.50	440.7	987.0	546.4
York	31.26	1.55	20.27	724.3	848.6	124.4
Allscott	30.94	1.80	25.97	838.3	987.4	149.2
Entire sample	29.20	1.33	14.38	534.1	890.0	356.0
Simulation 1: Reduction of quota by 25 percent						
Bury St Edmunds	28.32	1.24	7.16	340.6	765.8	425.2
Cantley	29.07	1.18	7.95	390.5	857.5	467.0
Newark	29.41	1.61	17.01	601.8	754.3	152.5
Wissington	27.81	1.15	7.74	428.5	974.0	545.5
York	31.16	1.51	15.64	714.8	821.3	106.5
Allscott	31.02	2.29	20.59	847.3	939.6	92.3
Entire sample	29.20	1.42	11.56	534.2	864.6	330.4
Simulation 2: Reduction of average price by 25 percent						
Bury St Edmunds	21.24	1.17	6.48	341.6	791.9	450.3
Cantley	21.81	1.07	5.98	358.0	888.9	530.9
Newark	22.06	1.60	17.03	585.9	748.2	162.3
Wissington	20.86	1.12	7.66	429.7	986.1	556.5
York	23.37	1.68	15.77	750.3	819.4	69.1
Allscott	23.26	2.30	20.65	850.2	936.7	86.5
Entire sample	21.90	1.42	11.22	574.7	873.5	298.8
Simulation 3: Reduction of average price by 40 percent						
Bury St Edmunds	16.99	1.18	6.60	341.5	786.8	445.3
Cantley	17.44	1.10	6.39	366.3	881.4	515.2
Newark	17.65	1.57	17.44	555.3	735.9	180.5
Wissington	16.69	1.14	7.63	428.4	977.7	549.3
York	18.70	1.73	16.03	750.6	797.2	46.6
Allscott	18.61	2.34	19.65	847.0	922.0	75.0
Entire sample	17.52	1.44	11.27	569.8	861.8	292.1

Notes:

1/ Based on the variable cost function for all the crops in the farm.

2/ Unless explicitly mentioned the figures correspond for all the crops.

3/ Sugar beet.

Finally, based on framework presented in figure 1, table 6 estimates the inefficiency (deadweight loss) and the rent for the current regime (“entire regime”) assuming two different free market prices (£17.50 and £16 per tonne, equivalent to a 40 and 45 percent reduction in the average support price of £29.10, respectively). In addition, the table presents an estimate of the inefficiency when the support price produces a total level of output equal to the quota (“only quota”). Under this situation it is assumed that the quota is produced by the most efficient growers.

Table 6: Estimate of the Inefficiencies of Supporting Sugar Beet Prices (£m)

	Free market sugar beet price 1/	
	£17.5/tonne	£16.0/tonne
Total Support (Entire regime)	102.08	128.48
Rent	59.55	73.73
Deadweight loss (inefficiency)	42.53	54.75
Total Support (Only quota 2/)	21.12	47.52
Rent	12.32	37.49
Deadweight loss (inefficiency)	8.8	10.03

1/ Free market price estimated at 40 and 45 per cent lower than current average support price. Figures computed using the net margin criteria.

2/ The price at which efficient UK growers will produce sufficient quantity to fulfil the national quota was estimated at £19.90 per tonne.

Conclusions

The analysis has considered the impacts on production and profitability three reform scenarios: a 25 per cent cut in UK quota, a 25 per cent cut in price, a 40 per cent cut in price.

Using panel data from the Farm Business Survey for England, the paper estimates two cost functions: one for the sugar enterprise and another for the cropping part of the farm (i.e., excludes any livestock enterprise) and use them to analyse the impacts of the reform measures.

It is clear from the analysis that the largest gains in terms of economic efficiency (productions of sugar beet at the least cost) would be achieved by a reduction in price instead of a reduction in quota. From both price cuts the one by 40 per cent is the one that produces the greater aggregate reduction in cost. However, the models suggest that this would also lead to the greatest reduction in production, some 84 per cent when the net margin criterion is considered as the relevant to exit the production of sugar beet.

It is important to emphasise that the reduction in average cost obtained from this analysis is not due to a change in the ways farmers operate but basically due to the fact that those farmers with the highest cost producing sugar beet are going to quit its production.

Estimation results indicate that quota reduction is accompanied with an increase in the average cost of production and therefore it might be consider just a measure to reduce budget outlays instead of a way to increase economic efficiency.

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Appendix

a. Estimation Results

Table A.1: Variable Cost Function: Regression Results for the Sugar Beet Enterprise 1/ 2/

Dependent Variable: Log(Variable Cost)
Log-Likelihood - factor demands block : 7,845.19

Variable	Coefficient	t -stat.
Box-Cox λ	0.215040	9.843
W_1	0.149890	24.368
W_2	0.092475	10.623
W_3	0.215730	23.963
W_4	-0.003700	-2.085
W_5	0.545610	33.928
W_1*W_1	0.061282	3.481
W_1*W_2	0.016588	1.650
W_1*W_3	-0.065658	-6.800
W_1*W_4	-0.010209	-1.292
W_1*W_5	-0.002003	-0.080
W_2*W_1	0.016588	1.650
W_2*W_2	0.081911	5.580
W_2*W_3	0.054337	5.112
W_2*W_4	0.000277	0.072
W_2*W_5	-0.153110	-6.836
W_3*W_1	-0.065658	-6.800
W_3*W_2	0.054337	5.112
W_3*W_3	0.141610	9.503
W_3*W_4	-0.011110	-1.308
W_3*W_5	-0.119180	-5.231
W_4*W_1	-0.010209	-1.292
W_4*W_2	0.000277	0.072
W_4*W_3	-0.011110	-1.308
W_4*W_4	0.044484	1.130
W_4*W_5	-0.023443	-0.822
W_5*W_1	-0.002003	-0.080
W_5*W_2	-0.153110	-6.836
W_5*W_3	-0.119180	-5.231
W_5*W_4	-0.023443	-0.822
W_5*W_5	0.297740	5.485
W_1*Q	0.001346	4.094
W_1*Q	0.005193	10.988
W_1*Q	0.001693	3.468
W_1*Q	0.000390	4.149
W_1*Q	-0.008622	-9.891
Q	0.152690	5.184
$Q*Q$	-0.002190	-1.497

Notes:

1/ Variables are in logs or transformed by the Box-Cox transformation.

2/ Standard deviation was computed using the heteroskedasticity-consistent covariance matrix.

Table A.2: Variable Cost Function: Regression Results for the Cropping Area of the Farm 1/ 2/

Dependent Variable: Log(Variable Cost)
 Log-Likelihood - factor demands block : 7,845.19
 Log-Likelihood - only output block: 1,138.76

Variable	Coefficient	t-stat.	Variable	Coefficient	t-stat.
Box-Cox λ	0.338000		Grid Search		
W ₁	0.220338	44.584	W ₅ *Q ₁	0.002728	8.440
W ₂	0.192743	33.990	W ₅ *Q ₂	-0.004042	-13.180
W ₃	0.343697	48.870	W ₅ *Q ₃	0.003755	7.390
W ₄	0.047666	2.200	W ₅ *Q ₄	0.000527	1.617
W ₅	0.195556	23.009	W ₅ *Q ₅	-0.002556	-8.975
W ₁ *W ₁	-0.017090	-0.741	W ₅ *Q ₆	0.000622	1.376
W ₁ *W ₂	0.004160	0.259	W ₅ *Q ₇	0.001616	3.905
W ₁ *W ₃	0.028968	1.447	W ₅ *Q ₈	-0.000167	-0.389
W ₁ *W ₄	-0.033366	-1.125	W ₅ *Q ₉	-0.002482	-15.712
W ₁ *W ₅	0.017328	0.629	Q ₁	0.009944	15.765
W ₂ *W ₁	0.004160	0.259	Q ₂	0.005453	14.344
W ₂ *W ₂	0.166006	8.568	Q ₃	0.001770	5.493
W ₂ *W ₃	-0.072119	-4.539	Q ₄	0.001039	4.768
W ₂ *W ₄	-0.029935	-1.131	Q ₅	0.002810	9.331
W ₂ *W ₅	-0.068111	-2.646	Q ₆	0.001472	5.347
W ₃ *W ₁	0.028968	1.447	Q ₇	0.001405	4.146
W ₃ *W ₂	-0.072119	-4.539	Q ₈	0.001670	6.452
W ₃ *W ₃	0.091094	3.613	Q ₉	0.008434	20.749
W ₃ *W ₄	0.059153	1.767	Q ₁ *Q ₁	0.000086	6.379
W ₃ *W ₅	-0.107096	-3.530	Q ₁ *Q ₂	0.000063	10.876
W ₄ *W ₁	-0.033366	-0.024	Q ₁ *Q ₃	0.000018	3.402
W ₄ *W ₂	-0.029935	-2.949	Q ₁ *Q ₄	0.000020	4.796
W ₄ *W ₃	0.059153	2.792	Q ₁ *Q ₅	0.000007	1.153
W ₄ *W ₄	-0.188132	-3.395	Q ₁ *Q ₆	0.000030	4.844
W ₄ *W ₅	0.192281	3.611	Q ₁ *Q ₇	0.000017	2.203
W ₅ *W ₁	0.017328	0.629	Q ₁ *Q ₈	-0.000028	-4.643
W ₅ *W ₂	-0.068111	-2.646	Q ₁ *Q ₉	0.000025	3.559
W ₅ *W ₃	-0.107096	-3.530	Q ₂ *Q ₂	0.000368	15.631
W ₅ *W ₄	0.192281	2.373	Q ₂ *Q ₃	0.000007	0.613
W ₅ *W ₅	-0.034402	-0.460	Q ₂ *Q ₄	-0.000035	-2.812
W ₁ *Q ₁	-0.000139	-0.768	Q ₂ *Q ₅	-0.000010	-0.904
W ₁ *Q ₂	-0.000815	-4.746	Q ₂ *Q ₆	0.000022	2.486
W ₁ *Q ₃	-0.000458	-1.612	Q ₂ *Q ₇	0.000035	3.456
W ₁ *Q ₄	-0.000053	-0.288	Q ₂ *Q ₈	0.000074	8.708
W ₁ *Q ₅	0.000432	2.710	Q ₂ *Q ₉	0.000031	2.605
W ₁ *Q ₆	-0.000166	-0.655	Q ₃ *Q ₃	0.000223	4.433
W ₁ *Q ₇	0.000885	3.824	Q ₃ *Q ₄	-0.000138	-3.417
W ₁ *Q ₈	-0.001349	-5.626	Q ₃ *Q ₅	0.000092	2.577
W ₁ *Q ₉	0.001661	18.796	Q ₃ *Q ₆	0.000173	3.068
W ₂ *Q ₁	-0.000344	-1.586	Q ₃ *Q ₇	0.000127	1.376
W ₂ *Q ₂	0.001880	9.140	Q ₃ *Q ₈	-0.000131	-1.738
W ₂ *Q ₃	-0.001484	-4.355	Q ₃ *Q ₉	-0.000002	-0.061
W ₂ *Q ₄	0.001003	4.582	Q ₄ *Q ₄	0.000189	5.068
W ₂ *Q ₅	0.001967	10.305	Q ₄ *Q ₅	-0.000006	-0.346
W ₂ *Q ₆	-0.000144	-0.475	Q ₄ *Q ₆	-0.000014	-0.335
W ₂ *Q ₇	-0.001864	-6.716	Q ₄ *Q ₇	-0.000138	-2.980
W ₂ *Q ₈	0.000686	2.387	Q ₄ *Q ₈	-0.000154	-4.257
W ₂ *Q ₉	-0.001699	-16.025	Q ₄ *Q ₉	0.000075	3.515
W ₃ *Q ₁	-0.001968	-7.298	Q ₅ *Q ₅	0.000326	10.176
W ₃ *Q ₂	0.003132	12.239	Q ₅ *Q ₆	-0.000067	-2.719
W ₃ *Q ₃	-0.000694	-1.637	Q ₅ *Q ₇	-0.000041	-1.306
W ₃ *Q ₄	-0.000767	-2.819	Q ₅ *Q ₈	-0.000066	-2.829
W ₃ *Q ₅	0.000445	1.872	Q ₅ *Q ₉	-0.000086	-3.601
W ₃ *Q ₆	0.000103	0.272	Q ₆ *Q ₆	0.000021	0.308
W ₃ *Q ₇	0.000580	1.678	Q ₆ *Q ₇	0.000084	1.126
W ₃ *Q ₈	0.000084	0.235	Q ₆ *Q ₈	-0.000041	-0.773
W ₃ *Q ₉	-0.000914	-6.932	Q ₆ *Q ₉	-0.000167	-4.027
W ₄ *Q ₁	-0.000258	-1.381	Q ₇ *Q ₇	0.000052	1.434
W ₄ *Q ₂	0.000019	0.107	Q ₇ *Q ₈	-0.000086	-1.061
W ₄ *Q ₃	-0.001415	-4.815	Q ₇ *Q ₉	-0.000057	-1.758
W ₄ *Q ₄	-0.000566	-3.008	Q ₈ *Q ₈	0.000685	12.454
W ₄ *Q ₅	0.000546	3.318	Q ₈ *Q ₉	-0.000107	-2.695
W ₄ *Q ₆	-0.000293	-1.124	Q ₉ *Q ₉	0.000243	6.440
W ₄ *Q ₇	-0.001040	-4.353			
W ₄ *Q ₈	-0.000104	-0.420			
W ₄ *Q ₉	0.003111	34.113			

Notes:
 1/ Variables are in logs or transformed by the Box-Cox transformation.
 2/ Standard deviation was computed using the heteroskedasticity-consistent covariance matrix.

b. Procedure followed to constrain the total agricultural area to be unchanged

Since it was not possible to constraint the parameters of the cost function to produce a change in the area of the other crops equal to the reduction in the area under sugar beet, we rescaled the results obtained from the model so the reduction in the area dedicated to sugar beet was absorbed according to the directions indicated to the model. We performed this change in scale by considering the information about the cropping area by region and by simulation scenario.

The starting point was the condition that the decrease in the sugar beet area in the region j (ΔA_j^{Beet}) with respect to the base case had to be distributed by considering the changes in the other crops. Mathematically this is equal to (A.1):

$$(A.1) \quad -\Delta A_j^{\text{Beet}} = \sum_{i=2}^9 \Delta A_j^i$$

The scaling weight for the region j is then equal to:

$$(A.2) \quad \gamma_j = \frac{-\Delta A_j^{\text{Beet}}}{\sum_{i=2}^9 (A_j^{U,i} - A_j^{0,i})}$$

Where $A_j^{U,i}$ is the (unadjusted) area in region j for crop i predicted by the model after simulating the change in policy, and $A_j^{0,i}$ is the area in the baseline case for crop i . Therefore, for region j it has to hold the following condition:

$$(A.3) \quad \sum_{i=2}^9 \Delta A_j^{F,i} = \gamma_j \cdot \sum_{i=2}^9 \Delta A_j^{U,i}$$

Where $\Delta A_j^{F,i} = A_j^{F,i} - A_j^{0,i}$ is the change in the area of the crop i after we have scaled the unadjusted results. In addition, it should be noted that $\sum_{i=2}^9 \Delta A_j^{F,i} = \gamma_j \cdot (-\Delta A_j^{\text{Beet}})$.

Operating (3) we can arrive to the following condition:

$$(A.4) \quad \sum_{i=2}^9 A_j^{F,i} = \gamma_j \cdot \sum_{i=2}^9 A_j^{U,i} + (1 - \gamma_j) \cdot \sum_{i=2}^9 A_j^{0,i}$$

Our goal is to find a set of $A_j^{F,i}$ that satisfies (A.4). There are several ways to do this; however, an appealing solution is one that conserves the sign in the change in area predicted by the model. Hence, we choose the following solution to (A.4) that says that the final area is a linear combination of the baseline solution and the unadjusted solution. This is:

$$(A.5) \quad A_j^{F,i} = \gamma_j \cdot A_j^{U,i} + (1 - \gamma_j) \cdot A_j^{0,i}$$

It should be noted that (A.5) is also satisfied for the output, assuming that there are no changes in yields. This is easy to see after multiplying (A.5) by y_j^i (crop i yield in region j).

$$(A.6) \quad Q_j^{F,i} = A_j^{F,i} \cdot y_j^i = \gamma_j \cdot A_j^{U,i} \cdot y_j^i + (1 - \gamma_j) \cdot A_j^{0,i} \cdot y_j^i = \gamma_j \cdot Q_j^{U,i} + (1 - \gamma_j) \cdot Q_j^{0,i}$$

Finally, with respect to the change in area, dividing (A.7) by the baseline area we get:

$$(A.7) \quad \frac{A_j^{F,i}}{A_j^{0,i}} = \gamma_j \cdot \frac{A_j^{U,i}}{A_j^{0,i}} + (1 - \gamma_j)$$

Which can be simplified as:

$$\left(1 + \frac{\Delta A_j^{F,i}}{A_j^{0,i}} \right) = \gamma_j \cdot \left(1 + \frac{\Delta A_j^{U,i}}{A_j^{0,i}} \right) + (1 - \gamma_j)$$

$$(A.8) \quad \frac{\Delta A_j^{F,i}}{A_j^{0,i}} = \gamma_j \cdot \frac{\Delta A_j^{U,i}}{A_j^{0,i}}$$