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UK Sugar Beet Farm Productivity under Different Reform Scenarios: A Farm Level Analysis

by

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Abstract

The purpose of this paper is to study the effect that the imminent reform in the European Union (EU) sugar regime may have on farm productivity in the United Kingdom (UK). We perform the analysis on a sample of sugar beet farms representative of all the UK sugar beet regions. To estimate the changes in productivity, we estimate a multi-output cost function representing the cropping part of the farm, which is the component that would be mostly affected by the sugar beet reform. We use this cost function to compute the new allocation of outputs and inputs after the changes in the sugar beet quota and price support. This are subsequently used to compute measures of total factor productivity. Our results show slight decreases in the productivity at the individual farm level under both quota and price support reduction. However, when considering the aggregate level, the reduction in the price support shows significant increases in productivity, in contrast to the results obtained from a reduction in quota.

Keywords: EU sugar reform; UK agriculture; UK sugar beet production; Multi-output cost function; Total factor productivity

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I. Introduction

The EU sugar regime has been part of the Common Agricultural Policy (CAP) since 1968, and during that time has never been fundamentally reformed. The current regime is based on minimum support prices, production quotas, export refunds and tariff protection, whilst preferential arrangements allow raw cane sugar to be imported from traditional African Caribbean and Pacific (ACP) suppliers. As sectors of the CAP, other than sugar were reformed in 1992, 2000 or 2003, the sugar regime is coming under increasing pressure to promote greater competitiveness and stronger market orientation in line with the reformed CAP. Without reform, the EU sugar market is likely to be undermined by unlimited duty-free preferential imports under the Everything but Arms (EBA) and Balkans initiatives, the future World Trade Organisation (WTO)-agreed reductions in non-preferential import duties, and the potential impact of the WTO case led by Brazil, Australia and Thailand.

In September 2003, the European Commission (EC) proposed three broad possible ways forward: (1) extend the present regime beyond 2006, cutting quotas as necessary; (2) reduce the EU internal price, with a view to eliminating quotas; (3) completely liberalise the current regime, including tariffs. Furthermore, the most recent proposal made in July 2004 (CEC, 2004) considers a combination of quota and support price reductions.

As the reform of the EU sugar regime is supposed to aim to increases in competitiveness and efficiency, the purpose of this paper is to estimate the possible effects that the changes in the sugar regime will have on the productivity of UK farms currently producing sugar beet at two levels: based on the results at individual farm level and using the results aggregated at a regional level.

In the UK, sugar beet is only grown in England. In 2002 sugar beet represented less than two per cent of the crops and grass area of England (and just under four per cent of the cropped area). However, these figures contradict its regional importance as production of English sugar beet crop remains concentrated in the Eastern England between Essex and Yorkshire with a satellite area of production in the West Midlands. Norfolk has the largest area of sugar beet accounting for 30 per cent of the national sugar beet crop area. Lincolnshire, Suffolk and Cambridgeshire accounted for 17, 11 and, respectively 11 per cent of the national sugar beet crop area (for a productivity analysis for some of the crops considered in this paper and only for the Eastern Counties of England, see Amadi et al. (2004)).

Measuring changes in productivity in agriculture due to changes in the policy environment is a difficult task because, with the exception of the specialised ones, most farms are of a multi-output character. Changes either in the quota or the support price for a specific crop will modify not only the supply and the use of inputs for this crop but also the supply and the use of inputs for other crops simultaneously produced, since these policies affect the relative profitability of all the crops. Therefore, to compute measures of total factor productivity we first need to estimate the farm outputs and inputs after the policy change. In addition, the presence of the quota and support price for sugar beet makes it difficult to evaluate the expected change in the area under sugar beet, and, accordingly the changes in the areas planted with other crops. This is due to the fact that one would expect sugar beet to continue being cultivated up to the quota level as long as it provides the grower with a rent (i.e., the difference between the support price and the marginal cost of the crop).

The methodology employed by this paper consists of estimating a variable cost function, which allows us to estimate both the marginal cost function and the use of inputs, such as in

Guyomard et al. (1996), yet in a multi-output framework. We concentrate the analysis only on the cropping part of the farm (hence excluding livestock production), which is the one expected to be mostly affected by the reform, at least in the short term. With the estimated cost function we simulate changes in both outputs and inputs due to changes in the sugar beet policy.

Total factor productivity indices are constructed for each policy scenario taking as a baseline the initial situation. We consider three scenarios - a reduction in the sugar beet quota and two different levels of reduction in the support price. We compare the changes at the individual farm level (farm average productivity per region) with the changes in productivity considering the aggregates of output and input by region. The results show substantial differences especially with regard to the decrease in the support price.

The paper is structured as follows: Section II, dealing with the empirical analysis presents the data, the model used to estimate the variable cost function, the econometrics and the measures of productivity used. Section III discusses the results and Section IV gives some conclusions about the possible effects of the reform on the farms' productivity.

II. Empirical Analysis

a. Data

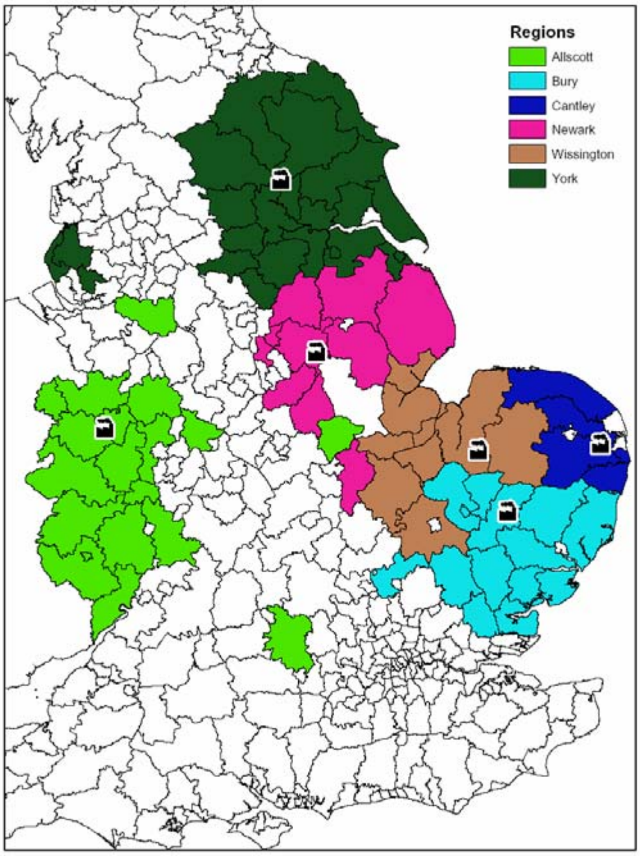
We used two datasets comprising information about the sugar beet producers. The first dataset is the 2002 Defra's Farm Business Survey (FBS) for farmers producing sugar beet in the UK (a total of 310 farms). The data do not present the information by crop; however, it is possible to estimate the gross 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 vary 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 analysis. 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 made a classification of the 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 1 presents a map of the regions and factory locations.

Figure 1. Sugar Beet Regions in the UK



b. Production Model

The starting point to estimate the multi-output cost function is to select an appropriate functional form. We chose the generalised translog cost function based on Caves, Christensen and Tretheway (1981). They evaluated the generalised Leontief cost function, 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 production[1], (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 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.

As mentioned before, to estimate measures of productivity we needed to compute the factor demands. Since the available surveys did not report the input prices paid by the growers, but only their outlays, it was necessary to assume that the input prices were the same for all the farmers, though varying over time. Therefore, the cost function had to be estimated using a panel dataset. The estimation of price-related coefficients was done based only on the sub-sample comprising the regions Bury St. Edmunds, Cantley, and Wissington for which the

[1] 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.

panel data was available (Newark, York and Alscott were covered only by the 2002 FBS). These estimated 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 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 have regressors that are correlated with the error term. We estimated individual fixed effect terms for the farms within the Bury St. Edmunds, Cantley and Wissington regions, but in the case of Newark, York and Alscott we were only able to estimate regional fixed effect terms. The cost function (in its variable cost form) to be estimated is given by equation (1), where the sub-index t for "period" has been suppressed:

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

Where $\alpha, \beta, \delta, \Psi, \varsigma, \xi, \vartheta$ 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 nine outputs and five 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_1 is the transformed output of sugar beet, Q_2 for winter wheat, Q_3 for spring wheat, Q_4 for spring barley, Q_5 for winter barley, Q_6 for beans, Q_7 for peas, Q_8 for oilseed rape and Q_9 for potatoes. The only fixed factor considered due to data availability was family labour.

The output in 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 in equation (2), where λ is the Box-Cox parameter. We assumed the same λ for all the crops in order to reduce the estimation burden.

$$(2) \qquad f(Q) = \begin{cases} \dfrac{(Q^{\lambda} - 1)}{\lambda} & \lambda \neq 0 \\ \ln(Q) & \lambda \to 0 \end{cases}$$

Even if according to Caves et al. (1980) the generalised translog is the function with the fewest number of parameters to estimate, this number is still high. In our case 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 three stages.

We first 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.

Due to the high number of parameters it was not possible, such as in Caves et al. (1980), 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.

The next step was to recover the remaining parameters of the cost function, which were associated to the output terms (not associated to input prices) and the fixed effect terms. To estimate these terms we averaged the data by farm (or region in those cases were 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. Table 1 presents the estimation results and Figure 2 shows a histogram of the individual fixed effect terms (only for Bury St. Edmunds, Cantley and Wissington).

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 and the input use, which are given by equations (3) and (4):

$$(3) \qquad MgC_{i-f} = Q_i^{\lambda-1} \cdot \exp\left\{ H_f + \sum_{i=1}^{9} \delta_i^* \frac{\left(Q_{if}^{\lambda} - 1\right)}{\lambda} + \frac{1}{2} \sum_{i=1}^{9} \sum_{k=1}^{9} \gamma_{ik} \frac{\left(Q_{if}^{\lambda} - 1\right)}{\lambda} \cdot \frac{\left(Q_{kf}^{\lambda} - 1\right)}{\lambda} \right\} \cdot \left\{ \delta_i^* + \frac{1}{2} \sum_{k=1}^{9} \gamma_{ik} \cdot \frac{\left(Q_{kf}^{\lambda} - 1\right)}{\lambda} \right\}$$

$$(4) \qquad X_j = \left(\frac{1}{W_j} \right) \cdot \exp\left\{ H_f + \sum_{i=1}^{9} \delta_i^* f(Q_{if}) + \frac{1}{2} \sum_{i=1}^{9} \sum_{k=1}^{9} \gamma_{ik} f(Q_{if}) \cdot f(Q_{kf}) \right\} \cdot \left\{ \alpha_j^* + \sum_{i=1}^{9} \Psi_{ji} \cdot f(Q_{if}) \right\}$$

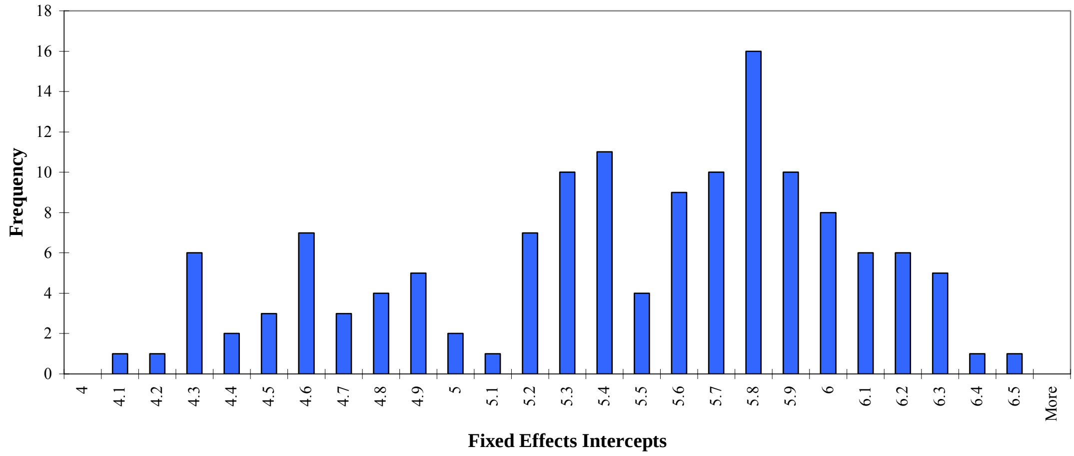
Table 1. Variable Cost Function: Results for the Cropping Area of the Farm 1/ 2/

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_5*Q_1	0.002728	8.440
W_1	0.220338	44.584	W_5*Q_2	-0.004042	-13.180
W_2	0.192743	33.990	W_5*Q_3	0.003755	7.390
W_3	0.343697	48.870	W_5*Q_4	0.000527	1.617
W_4	0.047666	2.200	W_5*Q_5	-0.002556	-8.975
W_5	0.195556	23.009	W_5*Q_6	0.000622	1.376
W_1*W_1	-0.017090	-0.741	W_5*Q_7	0.001616	3.905
W_1*W_2	0.004160	0.259	W_5*Q_8	-0.000167	-0.389
W_1*W_3	0.028968	1.447	W_5*Q_9	-0.002482	-15.712
W_1*W_4	-0.033366	-1.125	Q_1	0.009944	15.765
W_1*W_5	0.017328	0.629	Q_2	0.005453	14.344
W_2*W_1	0.004160	0.259	Q_3	0.001770	5.493
W_2*W_2	0.166006	8.568	Q_4	0.001039	4.768
W_2*W_3	-0.072119	-4.539	Q_5	0.002810	9.331
W_2*W_4	-0.029935	-1.131	Q_6	0.001472	5.347
W_2*W_5	-0.068111	-2.646	Q_7	0.001405	4.146
W_3*W_1	0.028968	1.447	Q_8	0.001670	6.452
W_3*W_2	-0.072119	-4.539	Q_9	0.008434	20.749
W_3*W_3	0.091094	3.613	Q_1*Q_1	0.000086	6.379
W_3*W_4	0.059153	1.767	Q_1*Q_2	0.000063	10.876
W_3*W_5	-0.107096	-3.530	Q_1*Q_3	0.000018	3.402
W_4*W_1	-0.033366	-0.024	Q_1*Q_4	0.000020	4.796
W_4*W_2	-0.029935	-2.949	Q_1*Q_5	0.000007	1.153
W_4*W_3	0.059153	2.792	Q_1*Q_6	0.000030	4.844
W_4*W_4	-0.188132	-3.395	Q_1*Q_7	0.000017	2.203
W_4*W_5	0.192281	3.611	Q_1*Q_8	-0.000028	-4.643
W_5*W_1	0.017328	0.629	Q_1*Q_9	0.000025	3.559
W_5*W_2	-0.068111	-2.646	Q_2*Q_2	0.000368	15.631
W_5*W_3	-0.107096	-3.530	Q_2*Q_3	0.000007	0.613
W_5*W_4	0.192281	2.373	Q_2*Q_4	-0.000035	-2.812
W_5*W_5	-0.034402	-0.460	Q_2*Q_5	-0.000010	-0.904
W_1*Q_1	-0.000139	-0.768	Q_2*Q_6	0.000022	2.486
W_1*Q_2	-0.000815	-4.746	Q_2*Q_7	0.000035	3.456
W_1*Q_3	-0.000458	-1.612	Q_2*Q_8	0.000074	8.708
W_1*Q_4	-0.000053	-0.288	Q_2*Q_9	0.000031	2.605
W_1*Q_5	0.000432	2.710	Q_3*Q_3	0.000223	4.433
W_1*Q_6	-0.000166	-0.655	Q_3*Q_4	-0.000138	-3.417
W_1*Q_7	0.000885	3.824	Q_3*Q_5	0.000092	2.577
W_1*Q_8	-0.001349	-5.626	Q_3*Q_6	0.000173	3.068
W_1*Q_9	0.001661	18.796	Q_3*Q_7	0.000127	1.376
W_2*Q_1	-0.000344	-1.586	Q_3*Q_8	-0.000131	-1.738
W_2*Q_2	0.001880	9.140	Q_3*Q_9	-0.000002	-0.061
W_2*Q_3	-0.001484	-4.355	Q_4*Q_4	0.000189	5.068
W_2*Q_4	0.001003	4.582	Q_4*Q_5	-0.000006	-0.346
W_2*Q_5	0.001967	10.305	Q_4*Q_6	-0.000014	-0.335
W_2*Q_6	-0.000144	-0.475	Q_4*Q_7	-0.000138	-2.980
W_2*Q_7	-0.001864	-6.716	Q_4*Q_8	-0.000154	-4.257
W_2*Q_8	0.000686	2.387	Q_4*Q_9	0.000075	3.515
W_2*Q_9	-0.001699	-16.025	Q_5*Q_5	0.000326	10.176
W_3*Q_1	-0.001968	-7.298	Q_5*Q_6	-0.000067	-2.719
W_3*Q_2	0.003132	12.239	Q_5*Q_7	-0.000041	-1.306
W_3*Q_3	-0.000694	-1.637	Q_5*Q_8	-0.000066	-2.829
W_3*Q_4	-0.000767	-2.819	Q_5*Q_9	-0.000086	-3.601
W_3*Q_5	0.000445	1.872	Q_6*Q_6	0.000021	0.308
W_3*Q_6	0.000103	0.272	Q_6*Q_7	0.000084	1.126
W_3*Q_7	0.000580	1.678	Q_6*Q_8	-0.000041	-0.773
W_3*Q_8	0.000084	0.235	Q_6*Q_9	-0.000167	-4.027
W_3*Q_9	-0.000914	-6.932	Q_7*Q_7	0.000052	1.434
W_4*Q_1	-0.000258	-1.381	Q_7*Q_8	-0.000086	-1.061
W_4*Q_2	0.000019	0.107	Q_7*Q_9	-0.000057	-1.758
W_4*Q_3	-0.001415	-4.815	Q_8*Q_8	0.000685	12.454
W_4*Q_4	-0.000566	-3.008	Q_8*Q_9	-0.000107	-2.695
W_4*Q_5	0.000546	3.318	Q_9*Q_9	0.000243	6.440
W_4*Q_6	-0.000293	-1.124			
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.

Figure 2. Histogram of Individual Fixed Effect Terms



Where:

$$H_0^W = \sum_{j=1}^{5} \alpha_j \ln W_j$$

$$H_1^W = \frac{1}{2} \sum_{j=1}^{5} \sum_{h=1}^{5} \beta_{jh} \ln W_j \ln W_h$$

$$H_f = \alpha_f + H_0^W + H_1^W$$

$$\delta_i^* = \delta_i + \sum_{j=1}^{5} \Psi_{ij} \ln W_j$$

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.

$$(5) \qquad \underset{Q_{if}}{\text{Max}} \quad \pi_f = \sum_{i=1}^{9} P_i Q_{if} - C(W, Q, Z)$$

Where P_i is output i price, Q_i is the i-th output, and $C(W,Q)$ is the estimated variable cost function. Because the cost function is non-linear with a high number of parameters, instead of maximising equation (5) we obtained the change in farm output by solving the following linear system based on the differentiation of equation (5) 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 (6), where the sub-index f has been dropped to simplify:

$$(6)\quad \begin{pmatrix} -\dfrac{\dfrac{\partial MC_2(\bullet)}{\partial Q_2}}{\dfrac{\partial MC_2(\bullet)}{\partial Q_{beet}}}\cdot\dfrac{Q_2}{Q_{beet}} \;\cdots\; -\dfrac{\dfrac{\partial MC_2(\bullet)}{\partial Q_9}}{\dfrac{\partial MC_2(\bullet)}{\partial Q_{beet}}}\cdot\dfrac{Q_9}{Q_{beet}} \\ \vdots \\ -\dfrac{\dfrac{\partial MC_2(\bullet)}{\partial Q_2}}{\dfrac{\partial MC_9(\bullet)}{\partial Q_{beet}}}\cdot\dfrac{Q_2}{Q_{beet}} \;\cdots\; -\dfrac{\dfrac{\partial MC_9(\bullet)}{\partial Q_9}}{\dfrac{\partial MC_9(\bullet)}{\partial Q_{beet}}}\cdot\dfrac{Q_9}{Q_{beet}} \end{pmatrix} \begin{pmatrix} \dfrac{dQ_2}{Q_2} \\ \vdots \\ \dfrac{dQ_9}{Q_9} \end{pmatrix} = \begin{pmatrix} \dfrac{dQ_{beet}}{Q_{beet}} \\ \vdots \\ \dfrac{dQ_{beet}}{Q_{beet}} \end{pmatrix}$$

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 (7):

$$(7)\quad \begin{pmatrix} \dfrac{\partial MC_{beet}(\bullet)}{\partial Q_{beet}}\cdot\dfrac{Q_{beet}}{P_{beet}} \;\cdots\; \dfrac{\partial MC_{beet}(\bullet)}{\partial Q_9}\cdot\dfrac{Q_9}{P_{beet}} \\ \vdots \\ \dfrac{\partial MC_9(\bullet)}{\partial Q_{beet}}\cdot\dfrac{Q_{beet}}{P_{beet}} \;\cdots\; \dfrac{\partial MC_9(\bullet)}{\partial Q_9}\cdot\dfrac{Q_9}{P_{beet}} \end{pmatrix} \begin{pmatrix} \dfrac{dQ_{beet}}{Q_{beet}} \\ \vdots \\ \dfrac{dQ_9}{Q_9} \end{pmatrix} = \begin{pmatrix} \dfrac{dP_{beet}}{P_{beet}} \\ \vdots \\ 0 \end{pmatrix}$$

In the case of a decrease in the price support, before applying (7) 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 (7) to find the new crop allocation.

Once the relative changes in the output of each crop were computed, the new output Q_{if}^{n} was obtained such as in equation (8), where Q_{if}^{0} is the initial output. We estimated the changes in output and input based on the 2002 information.

$$(8)\qquad Q_{if}^{N} = \left(1+\frac{dQ_{if}}{Q_{if}}\right)\cdot Q_{if}^{0} \qquad\qquad i=1,\ldots,9$$

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

c. Productivity Measurement

The productivity measurement is carried out using Christensen and Jorgenson’s (1970) Tornqvist-Theil Divisia index of total factor productivity[2]. The index, i.e., the change from a situation 0 to a situation 1 for each farm, is defined as in equation (9) (in its logarithmic version):

$$(9)\qquad \ln\left(\frac{TFP_1}{TFP_0}\right) = \sum_{i=1}^{m}\frac{(R_{i1}+R_{i0})}{2}\cdot\ln\left(\frac{Q_{i1}}{Q_{i0}}\right) - \sum_{j=1}^{n}\frac{(S_{i1}+S_{i0})}{2}\cdot\ln\left(\frac{X_{j1}}{X_{j0}}\right)$$

[2] An example of the use of this index in agricultural production can be found in Ball (1985).

where Q_i represents the farm i-th output, X_j is the use of the j-th input, R_i represents the share of the i-th output in the total farm revenue, and S_i is the cost share of the j-th input.

III. Results

We simulated the impact on productivity based upon three stylised scenarios, which consider the impacts of a 25 per cent cut in quota, a 25 per cent cut in support price and a deeper 40 per cent cut in support price. In the cases of the reduction in the support price we assumed that the unfilled quota was not redistributed amongst the remaining sugar beet producers, thus these cases might be understood as a reduction in both support price and quota. In addition, as input prices are held constant in the simulations any change in the use of inputs arises from a different scale of production and changes in the crop portfolio.

For comparison purposes we computed the TFP indices in two different ways. The first way considered the regional average of individual TFP changes and the second used the regional aggregates of outputs and inputs. The tables present the change with respect to the initial situation in the TFP indices as well as in the output index and in the input index to help the analysis of the TFP results.

Table 2 presents the changes in the TFP for the individual farm averages. At the UK average all the scenarios show a decrease in the TFP. It is important to note that this result is due to a decrease in the aggregate output since all the cases show a decrease in the input index.

Table 2. Change in Total Factor Productivity - Average of Individual Results 1/
Percentage change with respect to the initial situation

Scenarios	**Regions**						**UK**
	Bury St Edmunds	Cantley	Newark	Wissington	York	Allscott	
Simulation 1: Reduction of quota by 25 percent							
TFP Index	-2.6	-11.9	3.4	-0.7	9.0	-0.4	-0.5
Output Index	-9.4	-7.8	-1.3	-5.4	6.8	0.2	-2.8
Input Index	-7.0	4.7	-4.5	-4.8	-2.0	0.5	-2.2
Simulation 2: Reduction of average price by 25 percent							
TFP Index	-0.5	-2.0	4.7	-0.1	3.5	-7.2	-0.4
Output Index	-2.5	-0.9	-1.6	-2.0	3.0	-4.3	-1.4
Input Index	-2.0	1.1	-6.0	-1.9	-0.4	3.1	-1.0
Simulation 3: Reduction of average price by 40 percent							
TFP Index	-1.1	-5.4	8.8	-1.6	1.8	-10.5	-1.6
Output Index	-3.7	-2.6	-4.1	-3.8	-0.4	-6.0	-3.4
Input Index	-2.6	2.9	-11.8	-2.3	-2.1	5.1	-1.8

1/ Geometric averages of individual results.

The aggregate results mask the differences at the regional level. Thus all the scenarios show that, in terms of productivity, both Newark and York regions benefit from the reduction of sugar beet production and its substitution by other crops. However, in the case of Newark the increase in productivity is due to a greater reduction in the input index whilst in York it is due to an increase in the output and decrease in the use of inputs. In the regions of Bury St. Edmunds, Cantley and Wissington the decrease in the TFP is due to a decrease in the output index. In all the regions the results between scenarios are quite similar, except for the case of Allscott where the decrease in the support price triggers a higher reduction in productivity than the reduction in quota due to both a decrease in the output index and an increase in the input index.

The decrease in productivity associated to the quota cut arises from the fact that the input use does not decrease in the same proportion as the level of output, indicating that the quota cut is forcing growers to produce at a technically inefficient scale of production, increasing their costs per hectare and decreasing their profitability per hectare.

The results with changes in TFP when considering regional totals are presented in Table 3. They indicate gains in productivity under the price reduction scenario when compared to the quota cut. The increases in output indices indicate that there are gains from the changes in crop portfolio.

The results contrast with the averages of individual farm results, which show decreases in individual farm productivity due to the reduction in the price support. This is due to two factors: first, a reduction in the support price forces the least efficient growers to stop the production of sugar beet and turn to other crops and second, the reduction in the support price of sugar beet increases the weight of the other crops in the total farm revenue. In fact, it is this second factor that affects most the regions with the lowest marginal cost in the production of sugar beet, since they keep producing this crop which now gives them lower revenue.

Table 3. Change in Total Factor Productivity (TFP) - Using Regional Totals 1/
Percentage change with respect to the initial situation

Scenarios	**Regions**						**UK**
	Bury St Edmunds	Cantley	Newark	Wissington	York	Allscott	
Simulation 1: Reduction of quota by 25 percent							
TFP Index	0.2	-27.7	-2.0	-0.6	-4.0	-8.8	-4.9
Output Index	-3.8	-5.1	-5.0	-4.0	-5.2	-5.2	-4.4
Input Index	-4.0	31.3	-3.1	-3.5	-1.2	3.9	0.6
Simulation 2: Reduction of average price by 25 percent							
TFP Index	1.0	-5.0	6.8	6.1	9.0	5.6	5.7
Output Index	-0.8	-0.6	5.2	3.5	-1.3	5.8	3.2
Input Index	-1.8	4.6	-1.5	-2.4	-9.4	0.2	-2.4
Simulation 3: Reduction of average price by 40 percent							
TFP Index	0.6	-12.3	28.0	18.4	38.5	15.3	18.7
Output Index	-1.4	-1.7	22.5	11.9	9.5	11.9	11.8
Input Index	-2.1	12.1	-4.3	-5.5	-21.0	-2.9	-5.8

1/ Based on regional totals.

With respect to the regional results, Bury St. Edmunds presents slight increases in productivity under all scenarios. The opposite behaviour can be seen in Cantley, which shows severe decrease in productivity mainly due to the increase in the input index. The remaining regions show substantial increases in productivity due to the farms migration to other crops and the consequent change in the input use.

IV. Conclusions

The purpose of this paper has been to analyse the effect that changes in the sugar beet support price and quota, as part of the reform in the EU sugar regime may have on farm productivity in the UK. We performed the analysis using farm level data, which were weighted to produce aggregate results. To analyse changes in the total factor productivity, we estimated a multi-output cost function representing the cropping part of the farm. We use this cost function to compute the new allocation of outputs and the use of inputs after the changes in sugar beet quota and support price, from which we construct total factor productivity measures.

Our results show qualitative differences in the effect of a reduction in the support price when comparing averages of individual farm productivity with productivity measured using the aggregate regional outputs and inputs. Thus, at the individual farm level the changes indicate mild decreases in productivity (except for the Newark and York regions that show increases in productivity under both quota and support price reduction). However, the aggregate results show significant gains in productivity that might be attributed to the fact that only the most efficient producers of sugar beet remain in production and the others emigrate to other crops that, after the reduction in sugar beet prices, are relatively more profitable.

With respect to the quota cut, most of the individual and aggregate results show decreases in productivity. This is due to the fact that sugar beet will continue being produced although at a lower scale. Since under this scenario, the support price remains the same, the land not used anymore for the sugar beet production is allocated to other crops that are less profitable than sugar in relative terms.

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Annex

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):

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

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

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

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 $\sum_{i=2}^{9} \Delta A_j^{F,i} = \gamma_j \cdot (-\Delta A_j^{Beet})$. Operating (3) we can arrive to the following condition:

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

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:

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

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).

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

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:

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

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