Economic Incentives to Supply Sugar Beets in Europe

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Abstract

Currently European farmers produce considerable sugar quantities above their quota in different EU member states which cannot be explained with standard profit maximizing behaviour. This paper analyses how much two alternative behavioural models - expected profit maximization and utility maximization – can contribute to explain observed sugar production. The analysis is done for an average and the distribution of sugar producers in 13 EU countries based on analytical derivations of expected profit and profit variability under the quota regulation. Despite considerable differences between countries and farms, a significant amount of C-sugar production cannot be explained by these models.

1. Introduction

The reform of the Common Market Organisation (CMO) as drafted by the retired European Commission under the guidance of Franz Fischler currently resounds throughout the European countryside and beyond. It envisages reduced but tradable quota quantities and reduced prices for European sugar producers. The reform responds to some extent to external pressures from main sugar producing countries like Brazil. Their competitive position is confined by EU border protection and considerable amounts of subsidized EU sugar exports. Those measures limit the market for sugar and keep the world market price at a low level. Recently, in the preliminary report of the WTO panel against the subsidized EU sugar exports initiated by Brazil, Thailand and Australia, the WTO ruled that European exports of up to four times the permitted amount of subsidized sugar each year were illegal (OXFAM, 2004), seriously threatening the viability of the CMO Sugar in its current form. Further pressure originates from the *Everything But Arms Agreement* as laid out in EU Regulation (EC) 416/200. It will allow the 48 least developed countries obtain quota and duty free access to European markets by 2009. As a consequence, additional sugar imports into the EU up to three Million tons are expected substituting domestic production. But not only external pressures exist. The sugar using industry

in the EU lobbies for a reduction of sugar price support to improve their competitive position. On the other side, the lobby of sugar producers is very strong and works hard at preserving the CMO Sugar in its main features.

From this small summary is apparent that a lot of people are currently interested in impacts of changes in the CMO sugar. This paper examines two alternative behavioural models with respect to their ability to contribute to an explanation of observed supply behaviour and consequently for a more realistic simulation responses to policy changes than previous approaches. Yield uncertainty plays an important role under the framework of production quotas since a low yield can lead to considerable income losses if production quotas are not filled. Consequently, an analysis of expected profit maximization under yield uncertainty (risk neutrality) and of utility maximization (risk aversion) is provided for the national average farm as well as for the distribution of farms of 13 EU countries.

But before we go into this analysis, the basic features of the CMO sugar important at the farm level are repeated. More details can be found at several other places (for example Linde et al 2000, Blume et al. 2000, Schmidt 2003). The remainder of the paper is organized as follows: the next section shortly introduces the CMO sugar and considers the problems of a profit maximization model in explaining observed producer behaviour. Then, two main sections analyzing the alternative models of expected profit and utility maximization. Finally, a short summary of the results and conclusions are presented.

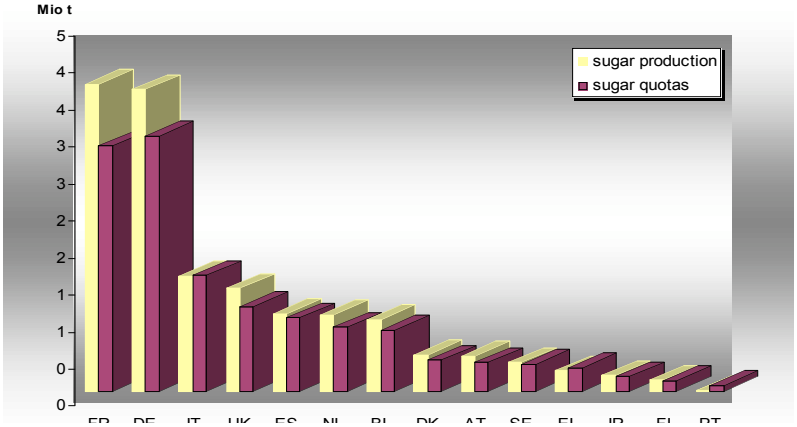
2. The CMO sugar and the limits of profit maximization

Production quotas in the sugar sector differ from milk quotas in two important respects: (1) There is a distinction between A and B quotas and (2) it is allowed to produce above those quotas without receiving any price support (so called C sugar). The A sugar quota allocated to each EU Member State were once designed to fit the domestic demand in each country. Since human consumption has risen since the days the CMO Sugar was established, about a third of B-quota sugar is sold on the EU market today. As a consequence, the part of the domestic sugar production that has to be exported with subsidies is about 2/3 of the B quota. The necessary financial resources are provided by collecting a basic levy of 2% of the intervention price for both, A- and B quotas and a variable levy on B quota sugar with a maximum of 37.5% of the intervention price from the processing firms. The sum of both levies has to cover the costs of quota exports. If those levies are not sufficient, an additional levy is collected on the total quota.

Those levies are collected by national agencies from the sugar processors; however they only bear 42% of those levies. The rest is passed on the sugar beet farmers by reducing the prices for A and B beets. Sugar processing firms and farmers sign contracts known as intertrade agreements, covering beet delivery rights, purchase prices, delivery periods, transportation compensation and quality. Sugar quotas and beet delivery rights are not (officially) tradable, neither between farmers, nor between processing firms or EU Member states at this point. Sugar beet producers have the possibility of making C sugar become a part of the next

year's sugar Quota. This so called *carry forward mechanism* can help to smooth out effects of good and bad harvests but it has become less attractive since the storage costs have not been financed by the EU since 2000/2001. *Carry forward possibilities* are limited to 20% of the A quota and were not fully used in the past years. Some EU Member States are allowed to pay a mixed price for quota beets making the distinction of A and B quotas superfluous. These countries are Italy, Ireland, Spain, Portugal, Greece, Belgium, The Netherlands and the United Kingdom.

As mentioned above, we observe considerable amounts of C sugar in the EU in the past. In fact, it stems not from all Member States as visible in **Figure 1**.



Source: COCO data base

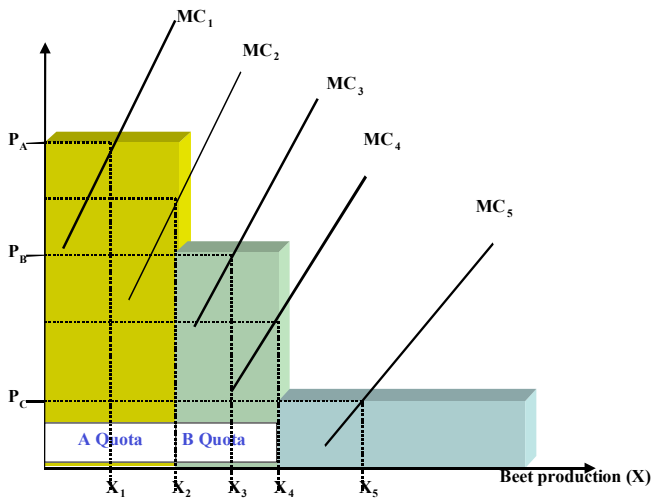
Figure 1. Sugar quotas and average production (1990-1999) per EU Member State

A major part of C sugar on average across the last decade originates in Germany and France. The Netherlands, the United Kingdom, Belgium and Denmark also contribute considerably, while the other countries obviously don't supply high C sugar amounts or even do not fill their quotas entirely (Greece and Portugal). Portuguese national statistics are not consistent. That is why we exclude this land from our further analysis.

We now turn to the economics of supply in the context of the CMO sugar. As sugar cane basically plays no role for the European sugar production, the key to analyze the impacts of changes in market regulations is to understand the economics of sugar beet production. A recent computable general equilibrium study on sugar reform options (Frandsen et al. 2003) assumes profit maximization for sugar beet producers. Consequently, they infer that marginal production costs equal the respective sugar beet price at the observed production quantity.

Figure 2 allows analyzing the implications of this behavioural model. The y axis shows (expected) prices for the three types of sugar or sugar beets, denoted by P_A, P_B, and P_C. The production value of the A and B quota is then given by the yellow and green box, respectively. Quantities beyond these belong to C sugar production (blue box on the right). Five marginal cost functions (MC_1-MC_5) characterize five different producer types. Producer type 1 is a high

cost producer who does not fill the A quota under profit maximization. For producer type 2 the A quota is a binding restriction because his marginal costs are somewhere between P_A and P_B at this quantity. Types 3 and 4 are similar to types 1 and 2, respectively with the difference that the B-Quota is referred to. The last type (5) is a low marginal cost producer because his marginal cost curve equals P_C at a production quantity above the total quota quantity.



Source: Own calculations

Figure 2. Sugar beet producer types

The five producer types are also distinguished by the quota rents they receive: Type 1 has no quota rent because his marginal costs equal the relevant beet price (P_a). The quota rent of the other types can be measured by the part of the yellow and green box above the respective marginal cost (dotted line). The lower the marginal costs, the bigger the quota rents.

The outlined profit maximization hypothesis might lead to an implausible supply response when applied at the aggregate level. Frandsen et al. (2003) assigned each EU country to a certain producer type according to the observed national sugar production relative to the quota. Countries with large observed C-sugar quantities are estimated to be low cost producers while countries not entirely filling their quotas are assumed to have higher marginal costs. They further assume that farmers deliberately overshoot their quotas by an amount of 2 times the standard deviation of total production of the respective country to take care of yield uncertainties. Using the producer types in

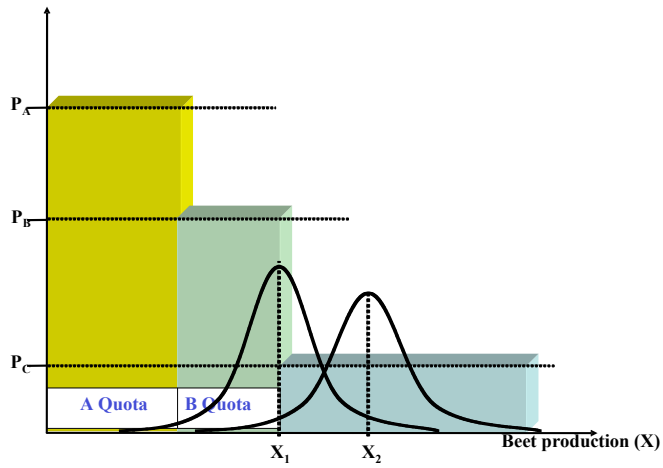
Figure 2 they allocate Portugal, Finland, Italy and Greece to the type MC_1, Sweden, the Netherlands and Ireland to type MC_2, Denmark, Belgium and Spain to MC_4 and France, Germany, Austria and the United Kingdom to the low cost producer group MC_5. Due to the quota regulation in this market, this neglect of farm heterogeneity has curious behavioural effects beyond the typical aggregation bias (Witzke 2002): At the margin, the countries only react to

changes of a single price of the system or – for the ones bounded by the quota – to a change in quota quantity. For example, competitiveness at C-beet prices is implied for the low cost producers France, Germany, United Kingdom, and Austria. Their production won't change if quotas or quota beet prices are reduced. Consequently, these four countries hardly react to reform options for the CMO sugar – a rather implausible result given that a large proportion of farmers in these countries have marginal production cost considerably above C-sugar prices.

Vierling (1996) and Bureau et al. (1997) estimate marginal costs of sugar beet production by stacking single farm LPs for major sugar producing regions in the entire EU. Their results show considerably higher marginal production costs than prices received for C sugar beets. Farm management specialists affirm that European sugar beet producers are hardly competitive at C-beet prices. Under profit maximization, this seems to contradict the large amount of C-sugar production across the entire EU (15% of total EU production in 1997-1999, going up to 34% for France). Consequently, profit maximization is not sufficient to explain observed production even considering the aggregation problem mentioned above, because it would require an unrealistically disperse distribution of farm efficiency and C-beet production in the Member States. Schmidt (2003) analyses if yield uncertainty or risk aversion might explain observed C-beet production in Germany. He calculates expected profits and the respective variance by Monte Carlo simulations, assuming normally distributed yields. Here, we follow his general idea, but use an analytical approach instead of simulations. We further extend Schmidt's work to 13 EU Member States and apply the behavioural models to an average as well as the distribution of farms.

3. Expected profit maximization

Yield uncertainty is a general phenomenon in agriculture. A farmer cannot perfectly predict the yields of his production activities, because they are influenced by weather and other environmental factors. In a quota system, this becomes even more relevant as there are typically additional economic incentives to fill the quota even in the case of a bad harvest. Frandsen et al (2003) and NEI (2000) use a common assumption on the impact of yield variance. They simply distinguish 'unintended' and 'planned' C sugar production. The first one is only caused by yield variance and the latter is planned by farmers. The magnitude of unintentional C sugar is predefined as a certain percentage of quota production (NEI) or according to the national yield variance (Frandsen). This assumption is an extreme simplification of the decision situation of European farmers. In fact, what they call unintentional C sugar production depends on production cost, observed yield variance, individual quota endowments, and expected prices. It cannot be simply set to a fixed proportional share.



Source: Own calculations

Figure 3. Yield variance

Similar to Schmidt (2003), let us assume normally distributed sugar beet yields with a certain variance as done in Figure 3. Suppose a farmer plans to produce – on average – the amount of sugar beets that is exactly equal to the quotas (X_1). In this case the quota is underfilled with 50% probability implying loss of high quota revenue. Maximizing *expected* profits may therefore suggest a higher planned production level (e.g. X_2). We now consider the details of this behavioural hypothesis.

Mathematical framework

Stochastic sugar beet yields imply stochastic revenues. Consequently we start with the mathematical definition of revenues of sugar beet production. In order to make the following derivations more transparent, let us for now assume that there is only one quota quantity Q and two prices for sugar beet produced within the quota and sugar beet produced above it. After deriving the mathematical framework for this case, it is straightforward to extend it to the slightly more complex actual quota regulation. The definition of sugar beet revenue (R_S) can be written as

$$R_S = p^Q y_S - \left(p^Q - p^C\right) y_S^C, \tag{1}$$

where y_S denotes sugar production quantity and y_S^C sugar quantity exceeding the quota. The respective prices are given by p^Q and p^C. We have chosen this specific formulation because it implies only one censored stochastic variable y_S^C resulting in less cumbersome derivations

compared to alternative formulations. Assuming prices to be non-stochastic, the expected value of the sugar beet revenue is a function of expected total and expected C-sugar production written as

$$ER_S = p^Q Ey_S - \left(p^Q - p^C\right)Ey_S^C, \tag{2}$$

where E denotes the expectation operator. Assume now that the production y_S is an outcome of a normally distributed random process with the probability density function (pdf)

$$f\left(y_S\right) = N\left(Ey_S, \sigma^S\right) \tag{3}$$

and the cumulated density function (cdf)

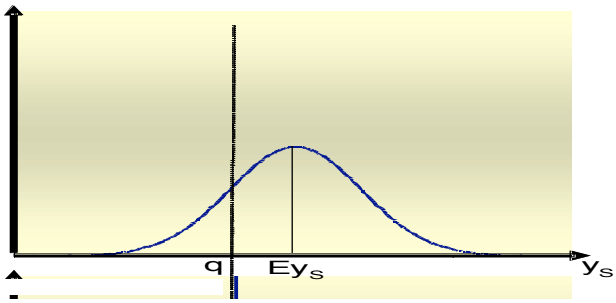
$$F(c) = \int_{-\infty}^{c} f\left(y_S\right)dy_S \tag{4}$$

where σ^S is the standard deviation of sugar beet yields. Then the density functions of y_S and y_S^C for a given land allocation may look as in Figure 4. Compared to the normally distributed variable y_S, the density function of the C-sugar quantity y_S^C is first mean-shifted by $-Ey_S$ and then censored at 0. Different from a truncation point, the censoring point receives all the probability mass of outcomes of y_S below the quota quantity Q, i.e. all cases where the C-sugar quantity is equal to 0. The censoring moves the mean of the variable to the right.

Using properties of censored random variables (Greene 1990, chapter 21) equation (2) becomes

$$\begin{aligned} ER_S &= p^Q Ey_S - \left(p^Q - p^C\right)Ey_S^C \\ &= p^Q Ey_S - \left(p^Q - p^C\right)\left(1 - F^C(0)\right)\left[\left(Ey_S - q\right) + \left(\sigma^S\right)^2 \frac{f^C(0)}{1 - F^C(0)}\right] \\ &= p^Q Ey_S - \left(p^Q - p^C\right)\left(1 - F(q)\right)\left[\left(Ey_S - q\right) + \left(\sigma^S\right)^2 \frac{f(q)}{1 - F(q)}\right] \\ &= p^Q Ey_S - \left(p^Q - p^C\right)\left[\left(1 - F(q)\right)\left(Ey_S - q\right) + \left(\sigma^S\right)^2 f(q)\right] \end{aligned} \tag{5}$$

where f^C and F^C are the pdf and cdf of the censored variable y_S^C, respectively. The second equality sign follows from the standard formula for a mean of a random variable censored from below and using the fact that the censoring point of the variable y_S^C is 0. The third equality sign reveals that all probability and density values can be expressed in terms of the distribution of the total sugar quantity and the fourth follows from algebraic manipulations.



Source: Own calculations

Figure 4. Density functions of total and C-sugar beet production for given land allocation

We now further assume that the standard deviation of sugar beet production is proportional to the planned sugar beet production, i.e. $\sigma^S = Ey_S \cdot \sigma^0$, where σ^0 is the standard deviation of one unit of expected sugar beet production. Under expected profit maximization, optimal expected sugar production is given were marginal costs equal expected marginal revenues. Therefore, we need a formula for the expected marginal revenues (EMR), i.e. the derivative of (6) with respect to Ey_S:

$$\frac{dER_S}{dEy_S} = EMR = p^Q - \left(p^Q - p^C\right)\left[\left(-\frac{dF(q)}{dEy_S}\right)(Ey_S - q) + \left(1 - F(q)\right) + 2\sigma^s\sigma^o f(q) + \left(\sigma^s\right)^2 \frac{df(q)}{dEy_S}\right] \tag{6}$$

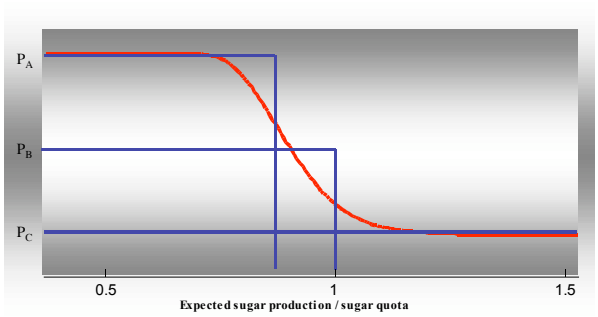
The expression involves several derivatives of density values and cumulative density values with respect to the mean of the distribution. Using properties of density functions and algebraic manipulations we can simplify (6) to

$$EMR = p^Q - \left(p^Q - p^C\right)\left[\left(1 - F(q)\right) + f(q)\sigma^S\sigma^0\right] \tag{7}$$

Equation (7) gives the expected marginal revenue of sugar production for a 'one quota assumption'. It can be easily extended to the relevant 'two quota" system. EMR is then given as

$$\begin{aligned} EMR = {} & p^A \\ & -\left(p^A - p^B\right)\left[\left(1 - F\left(q^A\right)\right) + f\left(q^A\right)\sigma^S\sigma^0\right] \\ & -\left(p^B - p^C\right)\left[\left(1 - F\left(q^{AB}\right)\right) + f\left(q^{AB}\right)\sigma^S\sigma^0\right] \end{aligned} \tag{8}$$

P^A, P^B, and P^C are the prices for the respective sugar type and q^A, q^{AB} the respective cumulated quotas. Consequently, EMR of sugar beet production depends on planned production, sugar prices, yield variance, and quota endowments. The general shape of the EMR function is given in Figure 5.



Source: Own calculation

Figure 5. Expected marginal revenues of sugar production

EMR of sugar beet production can be seen as a probability weighted average of the three prices. Hence, the EMR smoothes out the characteristic kinks of the marginal revenue function, while both are congruent at both endings of the graphs. It becomes apparent that expected marginal revenues could equal marginal costs at positive C-sugar quantities even if marginal costs are above the C-beet price. Similarly, it allows for a quota under utilization if they are below the respective quota beet price.

Can expected profit maximization explain observed C-sugar production?

We now examine, if the framework of expected profit maximization is able to explain the observed C-sugar amounts. First, we look at an average farm for each EU Member State assumed to own an average national quota endowment. A-, B- and C-sugar prices are taken from a single farm data analysis (Adenäuer 2005) from which weighted averages across the period 1997-1999 are calculated. Yield variation is calculated as the standard deviation across farms and the

years 1995 - 1999. Production quantities and average yields are taken from the COCO data base provided by the CAPRI modelling system for the same period. In order to compare observed sugar production with the theoretically optimal under expected profit maximization, we need estimates of marginal costs of sugar production. Recent Literature provides a number of studies that deal with production cost of sugar production (Frandsen 2003, Buerau et al 1997, Vierling 1996, Henrichsmeyer et al. 2003, Schmidt 2003).

For our purpose, we adopt the method of Vierling (1996) who uses FADN data as well. The general idea is to approximate marginal costs as variable production costs of sugar production + opportunity costs of land. Unfortunately both parts are not available in the FADN data. Variable costs only exist per farm and different categories (plant protection, fertiliser, …), while land rental prices – theoretically correlated with land opportunity costs – are sparely on hand and implausible the most times.

In order to allocate variable production costs to the different activities of sugar producing farms, each cost type is distributed according to the revenue share of a certain activity in total revenues among all activities where it is used. This is a quite simple method implying that the relation of total monetary output of an activity to its variable costs is constant for all activities on a farm. All fluctuations of the unit value of an activity are transferred into its cost estimates. This applies both to weather related yields as well as to output prices. Consequently the resulting variable cost estimates may only be used with great caution, especially on the farm level.

Opportunity costs of land are calculated as the gross margin of the aggregate of all competing crops. The latter are generally all activities on arable land except for fodder production with some exceptions. Both, variable costs and opportunity costs of land are calculated for a base year (1997-1999), defined in per ton of beet basis and finally added up to marginal costs of sugar beet production. Averaging over several years partly alleviates some of the problems related to overly fluctuating marginal costs.

Table 1 compares the means across EU Member States of our estimates with those of different other sources. All numbers are converted to an average sugar content of 16% to allow a better comparison across countries. It becomes apparent that our estimates mostly lie in a range spanned by the other sources.

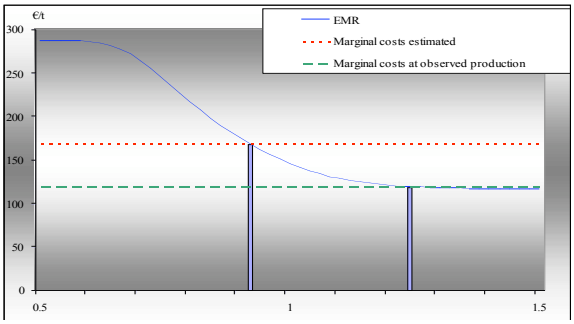
Marginal costs are presented for sugar beet production since it is common in literature although quotas are defined on sugar basis and farmers virtually get paid for delivered sugar. The better variable to refer to is therefore sugar rather than sugar beets. Consequently we use prices, quotas and marginal cost on sugar basis in the following. For simplification we assume further the national marginal production costs of sugar to be constant and, hence, independent of the production quantity.

Table 1. Marginal costs of sugar beet production (€/t) from different sources

	Bureau	Frandsen	Vierling	Adenäuer
AT	%	20.7	%	25.0
FR	29.6	21.9	34.0	26.9
DK	24.8	32.1	35.4	28.8
BL	31.0	33.5	33.1	29.2
DE	24.8	20.4	32.6	32.2
SE	%	41.1	%	32.7
IR	%	49.8	39.3	34.2
UK	32.0	19.9	35.9	34.3
ES	49.0	44.8	%	37.3
NL	34.8	49.2	36.2	37.8
FI	%	58.1	%	40.8
IT	65.7	65.1	44.5	41.7
EL	46.0	67.2	%	50.9

Source: Own calculations, Frandsen et al (2003), Bureau et al (1997), Vierling (1996)

Figure 6 shows exemplary for France the comparison of optimal and observed sugar production. The average marginal cost of French producers is estimated at 168 €/t of sugar. This is equal to expected marginal revenue at about 93% of the quota endowment which constitutes the optimal planned production. Observed production, however, is at 124% of the sugar quota. To make observed production optimal under expected profit maximization, marginal costs of sugar production would have to be only about 120 €/t which corresponds with only about 19 €/t of sugar beet (16% sugar content). In a French FADN sample, we estimated only about 4% of all farms with marginal costs around that value.



Source: own calculations

Figure 6. Expected profit maximization for an average French sugar beet farmer

The picture looks similar for most of the 13 EU Member States. But there are some where marginal costs at the observed production are closer to our estimates than in France. The op-

timal sugar production at estimated marginal costs under expected profit maximization, estimated marginal costs, and marginal cost at observed production quantities for the time period 1997 to 1999 are given in Table 2. Member States are ordered by the difference between estimated marginal costs and theoretical ones at observed sugar production under expected profit maximization. On top we find Greece. According to their EMR function, they produce even at higher marginal costs than the estimated ones. Consequently, observed production is below the theoretical optimum. Greece is followed by two countries, where estimated marginal costs and those at the observed production are almost equal, Spain and The Netherlands. In case of the average Dutch farmer this is only because we enhanced the national quota endowment by 6% since NEI (2000) points out that in the Dutch paying scheme for sugar beets, the mixed price is paid for up to 106% of the quota endowment. At position 4 and 5 we find Italy and Finland where observed and optimal production are not far away from each other. Starting with Austria the gap between estimated marginal costs and those at observed supply quantities is notably increasing. Especially in the main C-sugar producing countries, the United Kingdom, France and Germany, expected profit maximization seems to be insufficient to explain beet producer's behaviour.

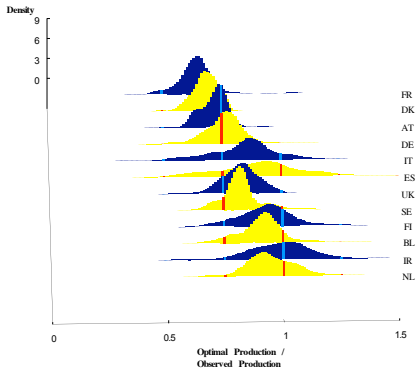
Already in the previous section we alerted to potential problems with aggregate or average analyses. In each country we will find a distribution of marginal costs across farms around the average. This implies the general inability of the aggregate model to represent producer behaviour, for example, national overfilling of quota might occur even if average values would indicate differently. To get at least an overview on distributional implications we calculate optimal sugar production quantities for sugar producing farms in the FADN database and compare them to observed ones – still based on three year averages from 1997 to 1999. Details about this farm analysis are found in Adenäuer (2005). Here we only present the results in terms of Kernel density estimates (based on Lewis et al. 1988) of the pdf of the ratio optimal production over observed production quantity.

Table 2. Optimal and observed sugar production and corresponding marginal costs of sugar production under expected profit maximization, averages for 1997-1999

	Sugar production in expected profit maximum / quota at estimated marginal costs	Observed sugar production / quota	Estimated marginal costs (€/t of sugar)	Marginal costs at the observed production (€/t of sugar)
EL	94%	82%	318.38	346.64
ES	103%	104%	233.02	224.73
NL	98%	100%	236.09	225.22
FI	96%	102%	254.72	237.32
IT	98%	104%	260.9	241.51
AT	102%	124%	156.48	126.6
DK	96%	126%	179.75	136.39
IR	94%	106%	213.58	167.2
FR	92%	124%	168.27	119.29
BL	100%	116%	182.61	130.93
SE	94%	108%	204.52	151.7
DE	92%	120%	201.03	141.35
UK	98%	132%	214.14	131.22

Source: own calculations

Figure 7 shows the estimated distributions in the form of a 3D graph. For better orientation, the functions are marked every 25% step of the probability mass. In France, Denmark, Austria, the United Kingdom, Sweden, and Germany we find hardly a single farm with observed production quantity above the expected profit maximum. In the other countries, one can suggest that there are farmers, where expected profit may be the maximized objective function as a number of farms actually produce around the derived quantity (ratio takes on value of 1).



Source: Own calculations

Figure 7. Kernel density estimates of optimal over observed production under expected profit maximization

Nonetheless, expected profit maximization seems to be insufficient to explain observed sugar productions for most farmers across the 12 member states considered. One would have to refer to particularly high yield variability at particular locations which is neglected in our use of the average standard deviation or speculate that highly efficient farmers do not fill out FADN forms to rescue the hypothesis. Greece is skipped in this analysis due to data problems in FADN.

4. Utility maximization under risk aversion

Expected profit maximization implies risk neutral behaviour of farmers. Risk averse behaviour can be modelled with a utility maximization framework where expected profit and variance of profits enter the utility function as arguments. To some extent risk averse farmers are willing to accept lower expected profits as long as the profit variance is decreasing sufficiently. Which combination of profit mean and variance is optimal depends on the degree of risk aversion. We now extend the analysis of the previous section to tackle the additional importance of the variance of profits.

Mathematical framework

The first required element, the definition of expected revenues, has already been derived in the previous section (equation (8)). It depends on planned production, the quota endowment, variance of yields, and prices. The variance of sugar beet revenues can be computed based on the definition of revenue given in equation (2) and applying the formula for linear combination of two random variables as follows:

$$\begin{aligned} VAR(R_S) &= \left(p^Q\right)^2 VAR\left(y_S\right) - \left(p^Q - p^C\right)^2 VAR\left(y_S^C\right) \\ &+2\left(p^Q\right)\left(p^C - p^Q\right) COV\left(y_S, y_S^C\right) \end{aligned} \tag{9}$$

Let us look at the different terms of the sum. The first one is well known from the definition of y_S:

$$VAR\left(y_S\right) = \left(\sigma^S\right)^2 \tag{10}$$

For the second term Greene (1990) provides a formula for the variance of censored variables

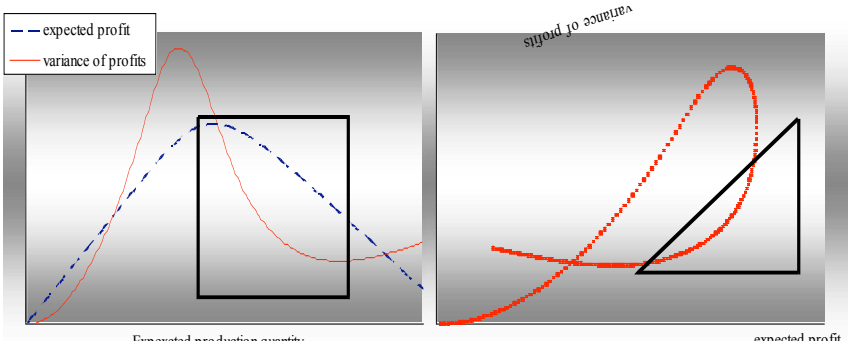
$$VAR\left(y_S^C\right) = \left(\sigma^S\right)^2 \left(\begin{array}{l} 1 - \frac{f(q)}{1-F(q)}\left(\left(\sigma^S\right)^2 \frac{f(q)}{1-F(q)} - \left(q - Ey_S\right)\right) \\ + \left(\frac{q - Ey_S}{\sigma^S} - \sigma^S \frac{f(q)}{1-F(q)}\right)^2 \sigma^S \frac{f(q)}{1-F(q)} \end{array} \right) \left(1 - \frac{f(q)}{1-F(q)}\right) \tag{11}$$

And finally we need the covariance of the two variables. Starting with the definition of the covariance one can write:

$$
\begin{aligned}
\mathrm{COV}\left(y_S, y_S^C\right) &= E\left[\left(y_S - E[y_S]\right)\left(y_S^C - E\left[y_S^C\right]\right)\right] \\
&= E_{y_S>q}\left[\left(y_S - E[y_S]\right)\left(y_S - q - E\left[y_S^C\right]\right)\right] P[y_S > q] \\
&+ E_{y_S\le q}\left[\left(y_S - E[y_S]\right)\left(0 - E\left[y_S^C\right]\right)\right] P[y_S \le q] \\
&= \begin{pmatrix} E_{y_S>q}\left[y_S^2\right] - E_{y_S>q}[y_S]q - E_{y_S>q}[y_S]E\left[y_S^C\right] \\ -E[y_S]E_{y_S>q}[y_S] + E[y_S]q + E[y_S]E\left[y_S^C\right] \end{pmatrix} P[y_S > q] \\
&+ \left(E\left[y_S^C\right]\left(E[y_S] - E_{y_S\le q}[y_S]\right)\right) P[y_S \le q]
\end{aligned}
\tag{12}
$$

The second equality sign follows from the possibility to split up expectations into conditional expectations. We distinguish two probability distribution conditional on y_s being above and below q. Consequently, both distributions are truncated normal distributions, the first one being truncated from below, the second from above. Note that $E_{ys>q}[y_s]$ is different from $E[y_S^C]$ since the former is a truncated and the latter a censored variable. We can now substitute the relevant formulas for means of truncated, censored, and squared variables into (12) (Green 1990, chapter 21). The weighting factors (P[y<q] and P[y>q] are given by the value of the cumulated normal distribution at q and its complement value, respectively.

The final formula derived by substituting (10), (11), and (12) into (9) is considerably more complex than the expected marginal revenue in the previous section. So we refrain from writing it out here. Instead, we show the general shape of this variance function in Figure 8.. We see that it is increasing on the left side, because the variance of the production quantity increases implying increasing variance of revenue as long as the A-beet price is the only relevant one. But as B and C sugar quantities and the corresponding prices come into play, the slope of the function is reduced and it reaches its maximum when the effect of increasing variance of production quantity is overcompensated by a decreasing average beet price. After reaching a minimum, the revenue variance starts to increase again as additional C-beet quantities do not change the average beet prices much anymore and the increasing variance of production takes over again. On the left side of Figure 8, we also plot an expected profit function. Where its maximum is located naturally depends on the assumed production costs. One thing we can say is, as long as the maximum lies to the left of the variance minimum, there is a certain range, where both, expected profits and their variance are decreasing which is marked with the black frame. Risk averse producers will operate within this range. On the right side of the figure, expected profits and variance are plotted on different axes and the triangle marks the same range. Only combinations within this range are of interest. The question is now whether risk averse behaviour can be sufficient to explain the observed C-sugar quantities.

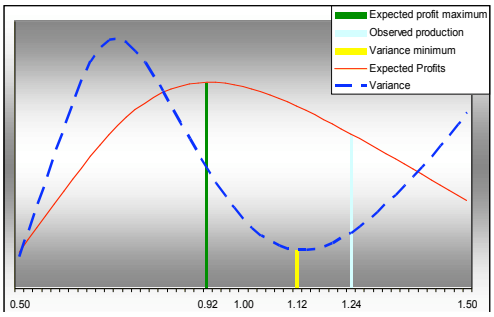


Source: Own calculations

Figure 8. Expected sugar beet profits and their variance

Can risk averse behaviour explain observed C-sugar production?

The assumptions on prices and marginal costs are the same as in the last section. Consequently we identify in Figure 9 the same maximum of expected profits at a production – quota relation of 92% in France. The calculated variance minimum is at a ratio of 112%. The observed production lies at 124% in a range, where profits are decreasing and the variance increasing. No matter how the actual utility function of a risk avers producer weights profits and variances, all combinations that are above the variance minimum lead to a lower utility than those within the range between profit maximum and variance minimum. We must therefore conclude, that utility maximization with risk aversion cannot explain the observed sugar production in France in this average producer model.

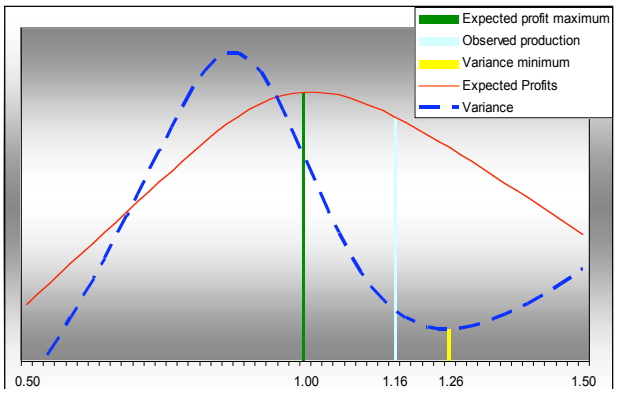


Source: Own calculations

Figure 9. Expected profits and variance of profits of an average French beet farmer

The picture looks different in Belgium as apparent from Figure 10. The observed production lies well within the range where risk averse behaviour is possible. Although the picture implies

a high degree of risk aversion because the observed production is close to the variance minimum than to the expected profit maximum, risk aversion might explain the observed sugar quantities in Belgium. But why do we find the variance minimum in France at 112% and in Belgium at 126% of the production over quota ratio? The variance function depends on several variables which are the price differences between the different beet types, the B- quota shares and the yield variance.

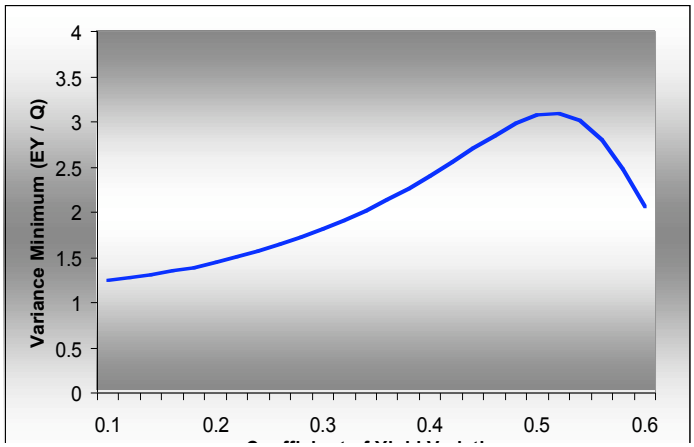


Source: Own calculations

Figure 10. Expected profits and variance of profits of an average Belgian beet farmer

In terms of yield variance, both countries do not differ a lot from each other. The B quota shares, however, are different. In Belgium it amounts to about 22% of the A quota and in France about 27%. A sensitivity analysis of the variance function shows that higher B quota shares move the variance minimum to the left. In terms of prices, a major difference between the two countries is that in Belgium a mixed price for A and B sugar is paid. Applying mixed prices ceteris paribus leads to a variance minimum lying at a higher production quantity to quota ratio compared to the classical paying scheme.

The influence of the price system on the variance minimum is further stressed in Table 3. The lowest production quantities over quota ratios at the variance minimum are found in countries applying the classical paying scheme while they are generally higher in mixed price countries. But no rule without exceptions, Greece shows the lowest value despite a mixed price system. This is due to a very high relative yield variance estimated from the FADN sample. Increasing yield variance moves the variance minimum upwards but beyond a certain value downward again as is the case for Greece. Relative small price differences strengthen that effect. The general effect is illustrated in Figure 11 where the location of the variance minimum of profits in terms of the ratio expected production/quota for different coefficients of yield variation is plotted. Relative small price differences strengthen that effect and will move the maximum of the presented function to the right.



Source: Own calculations

Figure 11. Variance minimum of sugar beet profits for different yield variances

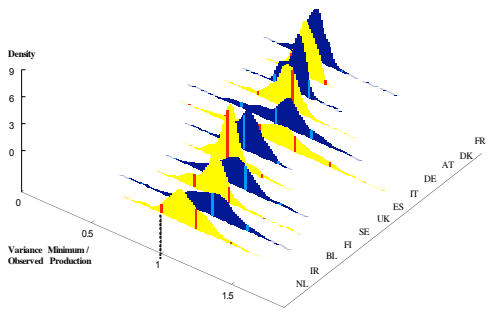
The last column in Table 3 is called "percent of maximum risk aversion". This measurement of risk aversion is simply calculated as the difference between observed production and profit maximum divided by the difference between variance minimum and profit maximum. Therefore, a value of 0% means risk neutrality and 100% implies production at the variance minimum as the maximal possible production that can be explained by risk averse behaviour. In Austria, Denmark, France, Germany and the United Kingdom risk aversion cannot fully explain observed production, since it is above the variance minimum. In Spain, Sweden, Belgium, Ireland, Italy, Finland and the Netherlands risk aversion would be a sufficient model. For Greece, it plays no role as observed production is below the profit maximum.

Table 3. Measures for average risk aversion model for 13 EU member states

	Sugar production in expected profit maximum / quota at estimated marginal costs	Observed production/quota	Sugar production/quota at variance minimum	Percent of maximum risk aversion
AT	102%	124%	114%	>100%
DK	96%	126%	114%	>100%
FR	92%	124%	112%	>100%
DE	92%	120%	114%	>100%
UK	98%	132%	128%	>100%
ES	103%	104%	122%	85%
SE	94%	108%	116%	64%
BL	100%	116%	126%	62%
IR	94%	106%	128%	35%
IT	98%	104%	118%	30%
FI	96%	102%	120%	25%
NL	98%	100%	124%	8%
EL	94%	82%	100%	<0%

Source: Own calculations

This variance analysis is also carried out at the farm level. We calculate kernel density estimates of the pdfs of the ratio variance minimum over observed production for 12 EU member states. This fraction indicates if risk aversion might explain observed production quantities, because this is only possible for values above 1. Figure **12** shows that in France, Denmark, Germany and Austria there is hardly a farm that supplies sugar below the minimum of profit variance. We can therefore confirm that risk aversion is insufficient to explain observed sugar quantities in these countries under the assumed marginal costs. From Table 3 the same conclusion might be drawn for the United Kingdom, but Figure 12 shows that about half of all farms in this country are producing below the variance minimum so that risk averse behaviour would be a sufficient model to explain observed behaviour for those farms.



Source: Own calculation

Figure 12. Kernel Density estimates of variance minimum over observed production

5. Conclusions

Yield uncertainty plays an important role in sugar beet production due to the specifics of the quota mechanism. This uncertainty in profits can contribute to explaining observed sugar beet production, but not for all countries and farms.

Expected profit maximization proofed to be insufficient to explain the observed sugar quantities in most of the 13 member stated considered. Only in Greece, Italy, Spain, Finland and the Netherlands, this objective function seems to be sufficient to explain the national production quantity, but even there, we find a significant number of farms where observed production is far away from the expected profit maximum.

Utility maximization with risk aversion generally rationalizes even higher production quantities compared to expected profit maximization. It has been shown that the observed production of a lot of sugar beet farmers in the 13 EU member states is found in a range where it can

be the result of risk averse behaviour. Unfortunately, especially in those countries that supply the biggest parts of C sugar, risk aversion is insufficient to explain the observed production. Consequently there must be other additional economic incentives to supply C-sugar quantities. The following ones have been suggested:

- To reconcile the low C beet price with observed C beet supply, it is frequently alleged that fixed costs are born by quota beets alone while C-beet supply only covers variable cost (Schmidt 2003). While this is a plausible explanation for the short run, beet growers should be inclined to reduce their capacity in the long run if the C-beet price permanently falls short of full cost coverage.
- Possibly, discontinuity in land allocation at the farm level might be relevant. Further research should analyze the incentives to grow single plots entirely with a single crop and its impact on aggregate quantities. In the case of sugar beet, this incentive is likely to be important because the price per ha charged by harvesting service firms is smaller the larger the plot size.
- Anecdotal evidence and persistent rumours in some Member States (e.g. Germany) suggest that sugar refineries distribute delivery rights above quota quantities. In this case, the aggregate C-beet production as perceived by growers is smaller than the quantity inferred from national statistics. Unfortunately, the relevance of this practice in the different EU countries is difficult to assess. Theoretical models evaluating possible incentives for sugar processors to engage in these practices could shed some light on this possibility.
- An additional motive to produce C-beet might be the expectation that future farm level quota cuts may be smaller if C-beet production is high or beet growers hope to receive additional quota rights if some delivery rights are redistributed among beet farms. Both of these considerations imply that a ton of C-beet may be rewarded by a speculative value on top of the market price for C-beet.

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