Global welfare effects of transgenic sugar beet

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Abstract

Although the EU is still in a *quasi* moratorium stage concerning GM crops, doors for GM crops in the sugar industry seem to open. Herbicide tolerant sugar beet could mean a boost for the sugar beet sector. The *ex ante* impact assessment shows a created welfare of €15 billion during 1996-2014. The rule of thumb found in *ex post* impact studies of a sharing out between downstream and upstream sector of 2/3 versus 1/3 is seems to be applicable to this case as well. The sugar beet sector and consumers worldwide are the winners while cane growers lose due to technology eroded world prices. The reform of the EU Common market organization for sugar in 2006 seems to create an incentive for innovation to efficient European sugar producers. Crowding out of inefficient producers could take place as was one of the goals of the reform.

In 2006, the global area of genetically modified (GM) crops reached 102 million hectares. The number of countries planting GM crops increased to 22 worldwide. Slovakia, planting GM maize for the first time in 2006 brought the total number of countries planting GM crops in the EU to six out of 25. Spain continued to be the lead country in Europe planting 60,000 hectares in 2006. Importantly, the collective Bt maize area in the other five countries (France, Czech Republic, Portugal, Germany, and Slovakia) increased over fivefold from approximately 1,500 hectares in 2005 to approximately 8,500 hectares, albeit on small hectarages, and growth in these five countries is expected to continue in 2007 (James 2006). The reason for the limited adoption of GM crops in the EU can be found in the regulatory issues. From 1998 till 2004 a *de facto* moratorium on the approvals of new GM crops, claimed the adoption of the precautionary principle by the European Parliament meeting public concerns (environmental impact and public health safety) on GM crops. Despite the official end of the moratorium in 2004 and new approvals of GM crops, adoption of national guidelines on coexistence has been relatively slow and due to regulatory uncertainty and consumer hostility, the adoption of GM crops is still limited. This means that the EU is still in a state of *quasi*-moratorium regarding the introduction of GM crops, foregoing important benefits of these new technologies.

Since most of the recent agricultural biotechnology innovations have been developed by private companies, the central focus of societal interest is not on the rate of return to research, but on the distribution of the gains from these technologies among all stakeholders involved in the agribusiness chain, i.e. input suppliers, farmers, processors, distributors, consumers and government. A popular argument used by the opponents of agricultural biotechnology is the idea of the life science sector extracting all benefits generated by these innovations. The first *ex post* impact studies of agricultural biotechnology indicate that farmers are clearly capturing sizeable gains of the new technology. On average, one third (33%) of the global benefits is extracted by the innovators (gene developers and seed suppliers), while two thirds (67%) are shared among domestic and foreign farmers and consumers (Demont et al. 2007). This typical welfare partition of one third upstream[1] versus two thirds downstream seems to be the general rule of thumb in the welfare distribution of the first generation of agricultural biotechnology innovations both for industrial and developing countries.

In Europe, only a limited number of countries have been growing GM crops so far and only a few *ex post* welfare studies have been published, i.e. on Bt maize in Spain (Demont and Tollens 2004b) and herbicide tolerant soybeans in Romania (Brookes 2005). Some *ex ante* EU distributional impact studies on transgenic sugar beet are documented as well (Demont and Tollens 2004a;Demont, Wesseler, and Tollens 2004;Demont 2006a), reporting a global welfare increase of €1.1 billion during the five-year period 1996-2000, shared among EU producers (26%), the seed industry (24%) and the rest of the world (50%). Two studies use the GTAP (Global Trade Analysis Project, Purdue University) model to assess the global trade and/or welfare effects of the EU moratorium on GM crops (van Meijl and van Tongeren 2004;Nielsen and Anderson 2001). Finally, one case study on Ireland uses farm level gross margin comparisons to estimate the impact of transgenic sugar beet, winter wheat, spring barley, and potato (Flannery et al. 2004).

Model

The case of herbicide tolerant (HT) sugar beet is very appealing for EU agriculture as this crop is grown in most EU countries. Moreover, weed control is crucial to economic beet production (Demont 2006b), which makes the HT trait very attractive to farmers. Dillen, Demont and Tollens (2007b) develop a framework to model heterogeneity among potential adopters in *ex ante* welfare assessments which allows endogenizing the technology fee and adoption rate in the case of a monopolistic price setting. They also calculate farmer rents and the revenue for the innovator. However, Frisvold, Sullivan, and Raneses (2003) argue distributional effects cannot be assessed adequately without aggregating results and incorporating market effects. Therefore we develop a partial equilibrium model.

To analyse the welfare effects of the adoption of HT sugar beet in the sugar industry, we need to choose an appropriate spatial model. The production data (F.O.Licht 2005) show a differentiation into sugar cane and sugar beet appears logical. The sugar beet region can be further divided into the EU and the Rest of the World (ROW), both responsible for half of global beet sugar. Within the ROW beet, main producers are non-EU-Europe, followed by the USA. Hence, we believe that we can adequately capture the essence of production and trade in the global sugar market with a three-region model: EU, ROW beet, and ROW cane.

Conventionally, research benefits were estimated assuming that the research is publicly funded and innovated inputs competitively sold in the input market. In contrast, most of the recent agricultural biotechnology innovations have been developed by private firms protected by intellectual property rights (IPR), such as patents, which confer monopoly rights to the discoverer. Monopolistic prices are higher than competitive ones. Therefore, Moschini and Lapan (1997) complete the conventional framework by including welfare measurement in the input market. However, in a more recent paper Moschini, Lapan and Sobolevsky (2000) adapt their methodology to a model that is closer to the actual working of the herbicide tolerance innovation and apply it to the case of Roundup Ready® soybeans. Our model is inspired by the latter. The spatial dimension is defined by 16 regions for the EU-15 and 19 regions for the EU-25 (the 7 remaining New Member States produce less than 3% of European sugar), i: the ROW cane (i = 0), the ROW beet (i = 1), and the production blocks in the EU (i = 2, …, 15^19). Belgium and Luxembourg are united in one block. The temporal dimension includes 20 agricultural seasons j: one 'benchmark year' 1996/97 (j = 0) without adoption, nineteen sequential years of adoption 1996/97, …, 2014/15 (j = 1, …, 19), and one 'evaluation year' 2006/07 (j = 11) to which the welfare effects are actualised and aggregated. Average .profit per hectare is modelled through four terms: (i) a constant, (ii) a fixed per-hectare technology induced profit increase, (ii) a yield effect (β), and (iv) a seed price effect (μ) (Moschini, Lapan, and Sobolevsky 2000). The input market used is the supply of land to the sugar industry in a non linear constant elasticity form. Multiplying the land supply function with the (optimal) yield function results in a region- and year specific supply function, enabling the parameterisation of the HT innovation. Aggregation of these supply functions will allow us to model the effect on world sugar prices of the interaction between two aggregate blocks, the EU and the ROW, as a consequence of the introduction of the HT technology. However, the structure of these functions implies that all 19 regions in the model are able to participate in the aggregate supply response to prices. While all regions certainly respond to a certain region-specific 'incentive price', in reality not all of them respond to world prices, owing to price regulations interfering in their domestic market.[2] This means that the technology-induced production surplus of those regions will not be exported on the world market, but will free up land allocated to sugar beets instead, so that their total production remains unchanged. All quantities and prices are converted to their white sugar equivalent. The aggregate EU sugar supply function in year j can be modelled by adding up all country-specific supply functions.[3] Note that this aggregate supply function contains a constant and a variable term, which is a function of the world price:

$$(1) \qquad Q_{\mathrm{EU},j}(p,\boldsymbol{\rho}_{\mathrm{EU},j}) = \sum_{i=2}^{15} Q_{i,j}(p,\rho_{i,j}) = \sum \overline{Q}_{i,j} + \sum Q_{i,j}(p,\rho_{i,j})$$

In Equation 1, $\boldsymbol{\rho}_{\mathrm{EU},j}$ represents the 17x1 adoption vector of the new technology in the EU in year j, with elements $\rho_{i,j}$ (i = 2, 3, …, 18). This aggregate sugar supply function is very detailed in that it contains 10 parameters per country, totalling 170 parameters, of which 68 are related to the new technology. In an analogous way, ROW aggregate supply can be modelled as a function containing a constant and a variable term:

$$(2) \qquad Q_{\mathrm{ROW},j}(p,\boldsymbol{\rho}_{\mathrm{ROW},j}) = \sum_{i=0}^{1} Q_{i,j}(p,\rho_{i,j}) = \sum \overline{Q}_{i,j} + \sum Q_{i,j}(p,\rho_{i,j})$$

In Equation 2, $\boldsymbol{\rho}_{\mathrm{ROW},j}$ represents the 2x1 adoption vector of the new technology in the ROW in year j with elements $\rho_{i,j}$ (i = 0, 1). The 19x1 adoption vector in the whole world in year j is denoted by $\boldsymbol{\rho}_{\mathrm{W},j}$, containing elements $\rho_{i,j}$ (i = 0, 1, …, 18).

Next, we model the innovation as occurring in a large, open economy with technology spillovers and shape the two-region framework of Alston, Norton, and Pardey (1995, p. 219) to the specific features of the EU's Common Market Organisation (CMO) for sugar. For each country, the four technology-specific parameters engender a pivotal, divergent shift of the supply curve. At the centre of the analysis is the calculation of a counterfactual world price p_j (after decline) in year j to isolate the effect of the technology-induced supply shift from other exogenous changes in supply and demand. This price change differs from the observed change in world price if the technology is adopted as assumed. It rather represents what the world price would be if all supply and demand conditions are identical except for the introduction of the new technology (Falck-Zepeda, Traxler, and Nelson 2000). Hence, in our analysis we represent the world price as a function of the worldwide adoption vector: $p_j(\boldsymbol{\rho}_{\mathrm{W},j})$.

We assume a constant-elasticity EU demand function for sugar:

(3) $$D_{\mathrm{EU},j}(p) = \kappa_{\mathrm{EU},j}\, p^{-\varepsilon_{\mathrm{EU},j}}$$

The EU's export supply curve in year j can then be modelled as:

(4) $$ES_j(p, \boldsymbol{\rho}_{\mathrm{EU},j}) = Q_{\mathrm{EU},j}(p, \boldsymbol{\rho}_{\mathrm{EU},j}) - D_{\mathrm{EU},j}(p) = Q_{\mathrm{EU},j}(p, \boldsymbol{\rho}_{\mathrm{EU},j}) - C_j$$

with C_j the fixed consumption level in year j, due to fixed annual intervention prices.

The world price reduction (from $p_j(0)$ to $p_j(\rho_{W,j})$ in Figure 1) is a synergy of two forces. First, the EU's export supply expansion (from $ES_j(p,0)$ to $ES_j(p,\rho_{EU,j})$), due to a technology-induced pivotal shift of the EU's aggregate supply function (from $Q_{EU,j}(p,0)$ to $Q_{EU,j}(p,\rho_{EU,j})$), would cause the world price to decline from $p_j(0)$ to $p_j(\rho_{EU,j})$. This price decrease can be determined using a reduced form equation, extracted from the of the University of Missouri's Food and Agricultural Policy Research Institute (FAPRI) world sugar model, which calculates the world sugar price as a function of actual and lagged EU net sugar exports (Poonyth et al. 2000). By taking the first differential, and if we assume that imports are not affected by the innovation, due to fixed ACP (African, Caribbean, and Pacific) import agreements, the reduction in intervention price and the Everything But Arms arrangement, we can calculate the world price as a function of the EU's export supply expansion.

For each year j the model transforms the observed world price into the price that would result from the EU's technology-induced export expansion in year j and $j-1$:

$$(5) \qquad p_j(\rho_{\text{EU},j}) = p_j(0)\left[1+\sigma_1 \frac{ES_j(p_j(0),\rho_{\text{EU},j}) - ES_j(p_j(0),0)}{ES_j(p_j(0),0)} + \sigma_2 \frac{ES_{j-1}(p_{j-1}(0),\rho_{\text{EU},j-1}) - ES_{j-1}(p_{j-1}(0),0)}{ES_{j-1}(p_{j-1}(0),0)}\right] \text{ with } \sigma_1 = -1.0 \text{ and } \sigma_2 = 0.46$$

The short-run flexibility σ_1 is -1 and the long-run flexibility is approximately half that of the short-run ($\sigma_1 + \sigma_2 = -0.54$), reflecting sugar export demand elasticities that are twice as large in the long run as in the short run. The positive value for the coefficient of the lagged export supply expansion term reflects the output contraction of the ROW as a reaction on the world price decline from $p_j(0)$ to $p_j(\rho_{\mathrm{EU},j})$. Inclusion of this reaction transforms our model into a dynamic equilibrium displacement model.

The former Common Market Organisation for sugar (1996-2006)

The overall world price change (from $p_j(0)$ to $p_j(\rho_{\mathrm{W},j})$) can now be transmitted to EU domestic prices using the principles of the EU's Common Market Organisation (CMO) for sugar, which came into full effect in 1968 and ended on the 30th of June 2006. Each year j, the Council fixes an *intervention price* ($p^{i}_{\mathrm{EU},j}$) for sugar and *minimum prices* for beet. Anticipating an increase in consumption, the quotas ($\overline{Q}_{a,j}$ and $\overline{Q}_{b,j}$) are set at a higher level than internal consumption C_j, i.e. the internal demand ($D_{\mathrm{EU},j}$) at the intervention price $p^{i}_{\mathrm{EU},j}$ (Figure 1). This overproduction $\overline{Q}_{d,j}$ (= $\overline{Q}_{a,j}$ + $\overline{Q}_{b,j}$ − C_j), although receiving a guaranteed B sugar price, is exported on the world market and hence subsidised. This export subsidy system is completely auto-financed by levies on A and B quota production. Consumers, who pay a high internal intervention price, subsidise the internal within-quota production. A levy τ^{a}_{j} of maximum 2% of the intervention price applies on the entire quota. Moreover, B quota production receives an additional, more variable, levy τ^{b}_{j} of maximum 37.5% of the intervention price. Both levies serve to satisfy the auto-financing constraint AFC_j, which is a function of the world price, while the latter is a function of worldwide adoption (Combette, Giraud-Heraud, and Réquillart 1997):

$$(6)\ AFC_j(p_j(\rho_{W,j})) = p^i_{EU,j}\tau^a_j(p_j(\rho_{W,j}))(\overline{Q}_{a,j} + \overline{Q}_{b,j})$$

$$+ p^i_{EU,j}\tau^b_j(p_j(\rho_{W,j}))\overline{Q}_{b,j} - (\overline{Q}_{a,j} + \overline{Q}_{b,j} - C_j)(p^i_{EU,j} - p_j(\rho_{W,j})) = 0$$

The levies have to fill the gap between the world price and the high internal price for quota production which is in excess of consumption and exported on the world market. If the auto-financing constraint does not solve by combining Equations 6 and 7, the system of Equations 6 and 8 is solved. Finally, when the latter neither yields a solution, a multiplicator ν_j is defined solving the system 17 and 20:

$$\begin{cases}\tau^a_j(p_j(\rho_{W,j})) \in [0,0.02[\\ \tau^b_j(p_j(\rho_{W,j})) = 0\end{cases} \quad (7) \qquad \begin{cases}\tau^a_j(p_j(\rho_{W,j})) = 0.02 \\ \tau^b_j(p_j(\rho_{W,j})) \in [0,0.375[\end{cases} \quad (8) \qquad \begin{cases}\tau^a_j(p_j(\rho_{W,j})) = 0.02(1+\upsilon_j) \\ \tau^b_j(p_j(\rho_{W,j})) = 0.375(1+\upsilon_j)\end{cases} \quad (9)$$

By imputing the technology-induced world price $p_j(\rho_{W,j})$ into Equation 6, the system of Equations 6 to 9 yields an estimate of the levies that have to be imposed on quota-production to satisfy the auto-financing constraint. This specification clearly visualises how the levies are a function of the world price, while the world price on its turn is a function of worldwide adoption. Taking the partial derivatives of the auto-financing constraint, i.e. $\partial AFC_j / \partial \tau^a_j$, $\partial AFC_j / \partial \tau^b_j$ and $\partial AFC_j / \partial \upsilon_j$, allows us to transmit world price changes to levy changes. For each Member State, A and B quota prices can be deducted from the State's intervention price $p^i_{i,j}$ and the levies:

$$(10) \qquad p^a_{i,j}(p_j(\rho_{W,j})) = p^i_{i,j}[1 - \tau^a_j(p_j(\rho_{W,j}))]$$

$$(11) \qquad p^b_{i,j}(p_j(\rho_{W,j})) = p^i_{i,j}[1 - \tau^a_j(p_j(\rho_{W,j})) - \tau^b_j(p_j(\rho_{W,j}))]$$

By imputing $p_j(\rho_{W,j})$ into equations 10 and 11, the model allows us to transform technology-induced world price changes into domestic quota price changes. Thus, the producer price is endogenous since it depends on sugar production, internal demand and the gap between the intervention and the world price. All out-of-quota production is called 'C sugar' and can either be: (i) stocked to be carried over to the following marketing year, enabling to smooth out annual production variations, or (ii) exported on the world market at the world price, i.e. without export subsidies.

Finally, the EU's CMO for sugar contains some additional features, such as the ACP import arrangements, conferring free access to the EU market for ACP countries, up to a certain maximum limit. These arrangements are essentially aid flows accruing to ACP countries and are omitted from our welfare framework, since they do not affect the flow of research benefits.[4] The same argument holds for the EU's stocking and carrying-over policy, at least in the medium- and long-run.[5]

The opposite effects of technology-induced cost-reduction and depression of world and domestic prices are transmitted to average land rents by imputing the corresponding prices and adoption rates. Note that the land rents are a function of (i) the region-specific and (ii) the worldwide adoption rates, the latter through the world price: $\bar{\pi}_{i,j}\left[p^a_{i,j}(p_j(\rho_{W,j})),\rho_{i,j}\right]$ for A quota, $\bar{\pi}_{i,j}\left[p^b_{i,j}(p_j(\rho_{W,j})),\rho_{i,j}\right]$ for B quota, and $\bar{\pi}_{i,j}\left[p_j(\rho_{W,j}),\rho_{i,j}\right]$ for C sugar beets. If $L_{i,j}(\bar{\pi})$ denotes the optimal allocation of land to sugar beets in country i in year j, the variation in producer surplus (relative to the benchmark without adoption) due to the innovation can be measured in the land market (Moschini, Lapan, and Sobolevsky 2000). The producer surplus change strongly depends on the country's competitiveness in sugar production. Therefore, we introduce a new categorical parameter $\varphi_{i,j}$ to denote the region's production efficiency. Depending on the value this parameter takes, the model automatically selects the appropriate formula for the calculation of the welfare effects. Detailed information about the formulas can be found in Dillen, Demont and Tollens (2007a). High-cost country *i* not fulfilling its A quota gets $\varphi_{i,j} = 0$. Portugal and Greece are the only examples. Note that the benefit resulting from the technology not only depends on the adoption within the region, but also on worldwide adoption rates through the technology-induced world price depreciation. A high-cost country, fulfilling its A but not its B quota is assigned $\varphi_{i,j} = 1$. The farmers in these countries aim at fulfilling their A quota and in order to ensure this objective they choose to accept a minimal precautionary overproduction, even in low-yield years. For medium-cost countries fulfilling their A quota and a significant part of its B quota, $\varphi_{i,j} = 2$. Exporting low-cost EU country responding to the world price at last get $\varphi_{i,j} = 4$. According to different authors, different countries fulfil this criterion. A combination of Frandsen *et al* (2003), a recalculation of Frandsen *et al* (2003) on data an extended dataset (1996-2006), Poonyth (1998) and the success of the buy-out scheme under the new CMO for sugar, gives Austria, Belgium, France, Germany, and the UK complying with this criterion (Table 1, fulfilling three out of five criteria). Figure 1 illustrates graphically how the benefits are split up in (i) a within-quota (areas $b - a$), and (ii) an out-of-quota part (areas $d - c$), earned on the world market. An exporting low-cost EU region not responding to the world price ($\varphi_{i,j} = 3$) would normally not supply C-sugar, since the rents of the latter are not sufficient to cover the production costs.

However, to ensure quota fulfilment farmers accept a risk premium (some out-of quota production). Since quota fulfilment is the primary objective of these countries, we assume that stock decisions and risk premiums are not affected by the new technology.

New Common Market Organisation for sugar (2006/2015)

On the first of July 2006 a new CMO for sugar was introduced. The key features of the reform are (i) a progressive cut of the EU institutional price (the *reference price*) up to 36% over four marketing years, (ii) direct compensatory payments of 64.2% of the estimated revenue loss over three marketing years and (iii) a single quota arrangement for the term 2006/07-2014/15. The goal of this reform is to reduce domestic EU sugar production in order to comply with WTO, be prepared for the EBA and the commitment of the EU to make agriculture more competitive. In order to facilitate this reduction in production, a buy-out scheme is setup. Sugar producers giving up production due to the lower prices can sell their quota to the EU for an in time decreasing amount (€730-€730-€625-€520/ton). This should stimulate less competitive producers to reduce or abandon production. If the reduction in production is insufficient in 2010, the EU can decide on a linear quota cut for all European producers.

For the model this has several structural effects. A and B quota are replaced by one quota with a price independent from the world market price, the reference price. The value of parameter $\varphi_{i,j}$ changes for all countries. Producers not filling their quota before ($\varphi_{i,j}$=0,1or2), will sell their excess quota under the new institutional price and become part of a group that fills their quota ($\varphi_{i,j}$=7). Producers filling their quota before ($\varphi_{i,j}$=3) will also be part of this group although some selling of quota can occur due to the reduced sugar prices. Having quota but not filling them is taxed by a restructuring amount to be paid on each quota, a further incentive to sell excess quota. Countries which reacted on world market prices before ($\varphi_{i,j}$=4) are affected the most. Due to a complained by the WTO export of out of quota sugar (former C-sugar, 4 million ton) is very limited. Total export from is limited by the WTO to 1.4million ton white sugar/year. Since this allocation is first filled with excess quota sugar (as long as the budget is sufficient) and can only be used for out of quota sugar in special cases, there aren't any possibilities to produce for the world market. However, under the new CMO for sugar, the possibility exists to produce industrial sugar outside quota production. Competitive producers will produce sugar for industrial use which means European industrial users will import less sugar off the world market. This decrease in demand on the world market makes that the EU still influences the world market to some extent.

The ROW cane industry is assumed to respond to the world price, but since no technology-induced surplus is generated by the model[6], the change in producer surplus reflects the losses of cane growers due to eroding world prices:

$$(12) \qquad \Delta PS_{i,j}(p_j(\rho_{W,j}),\rho_{i,j}) = \int_{\bar{\pi}_{i,j}(p_j(0),0)}^{\bar{\pi}_{i,j}(p_j(\rho_{W,j}),\rho_{i,j})} L_{i,j}(\bar{\pi})d\bar{\pi}$$

The ROW beet region can be considered 'small', i.e. facing an infinitely elastic export demand function and not able to influence world prices significantly. Non-EU European countries are part of this group. In addition, the US sugar sector is highly protected by a tariff quota system, eliminating any link between domestic prices and supply and world prices (Roberts and Wish-Wilson 1991). Therefore, neither supply shift nor negative export demand shift are assumed for the ROW region, i.e. $ED_j(p,0) = ED_j(p, \rho_{\mathrm{ROW},j})$ in Figure 1. Instead of allocating more land, the ROW beet region responds to new technologies by freeing up land allocated to sugar beet. This implies that innovation rents for these regions can be calculated as:

$$(13) \qquad \Delta PS_{i,j}(p_j(\rho_{\mathrm{W},j}),\rho_{i,j}) = \frac{\overline{Q}_{i,j}}{y\left(p_j(\rho_{\mathrm{W},j}),\rho_{i,j}\right)}\left[\overline{\pi}_{i,j}\left(p_j(\rho_{\mathrm{W},j}),\rho_{i,j}\right) - \overline{\pi}_{i,j}\left(p_j(0),0\right)\right]$$

The EU's aggregate welfare increase is simply the sum of all production blocks' producer surplus changes:

$$(14) \qquad \Delta PS_{\mathrm{EU},j}(p_j(\boldsymbol{\rho}_{\mathrm{W},j}),\rho_{\mathrm{EU},j}) = \sum_{i=2}^{19}\Delta PS_{i,j}(p_j(\rho_{\mathrm{W},j}),\rho_{i,j})$$

In Figure 1, the aggregate benefit for the EU can be assessed by a pivotal shift of the aggregate EU supply function. The exported surplus Q_d is subsidised, since it receives the guaranteed B quota price, while it is exported at the world price. Decline of the world price from $p_j(0)$ to $p_j(\rho_{\mathrm{W},j})$ raises subsidy costs up to $Q_d\ (p_j(0) - p_j(\rho_{\mathrm{W},j}))$, represented by the lower area a. These extra costs have to be borne by the producers via increased levies on their quota production (Equations 6 to 9). In most cases, adapting only the B quota levy is sufficient, visualised in Figure 1 through a decline of the B quota price. Hence, the cost for producers equals $Q_b[p^b_{i,j}(p_j(0)) - p^b_{i,j}(p_j(\rho_{\mathrm{W},j}))]$, represented by the upper area a, which is essentially the same as the lower area a. Thus, the total within-quota benefits equal area $b - a$. To these rents, out-of-quota benefits have to be added, represented by the difference between areas d and c. The EU's change in consumer surplus can be modelled as:

(15) $$\Delta CS_{EU,j}(p_j(\rho_{\mathrm{W},j}),\rho_{\mathrm{EU},j}) = \int_{p^i_{\mathrm{EU},j}(p_j(\rho_{\mathrm{W},j}),\rho_{\mathrm{EU},j})}^{p^i_{\mathrm{EU},j}(p_j(0),0)} D_{\mathrm{EU},j}(p)dp = 0$$

In our model however, the EU's intervention price is fixed, so it is neither a function of the world price, nor of the adoption rate within the EU:

(16) $$p^i_{\mathrm{EU},j}(p_j(\rho_{\mathrm{W},j}),\rho_{\mathrm{EU},j}) = \overline{p}^i_{\mathrm{EU},j}$$

This means that technology-induced welfare effects for consumers would only be possible in the long term within the CMO for sugar if the EU endogenised world prices and/or technology adoption rates in their intervention/reference price. In contrast, world price changes are endogenous to producer prices through the auto-financing constraint. The ROW aggregate innovation rents (area $g - e$ in Figure 1) are simply the sum of cane ($i = 0$) and beet ($i = 1$) producers' surplus changes:

(17) $$\Delta PS_{\mathrm{ROW},j}(p_j(\rho_{\mathrm{W},j}),\rho_{\mathrm{ROW},j}) = \sum_{i=0}^{1} \Delta PS_{i,j}(p_j(\rho_{\mathrm{W},j}),\rho_{i,j})$$

The ROW consumers' surplus change (area e + area f in Figure 1) equals:

(18) $$\Delta CS_{\mathrm{ROW},j}(p_j(\rho_{\mathrm{W},j}),\rho_{\mathrm{ROW},j}) = \int_{p_j(\rho_{\mathrm{W},j})}^{p_j(0)} D_{\mathrm{ROW},j}(p)dp$$

Finally, to calculate the profit of the input suppliers, we need an estimate for all regions i of the supply of land to the sugar beet industry in equilibrium: $L_{i,j}[p_j(\rho_{\mathrm{W},j}),\rho_{i,j}]$. Note again the double dependence of land supply on local as well as global adoption rates, the latter through the technology-induced world price depreciation. Again, we include the possibility for some regions not responding to world prices, to respond to the new technology by freeing up land allocated to sugar beet. In that case the yield-increasing effect of the new technology negatively affects its own demand, due to the quota system. The profit of the input suppliers can now be computed as:

$$(19) \qquad \Pi_j(p_j(\boldsymbol{\rho}_{W,j}), \boldsymbol{\rho}_{W,j}) = \sum_{i=0}^{18} \rho_{i,j} L_{i,j}(p_j(\boldsymbol{\rho}_{W,j}), \rho_{i,j}) \mu_i \delta w_i$$

Total welfare increase is simply the sum of all welfare increases. Finally, by using a risk adjusted rate of return of 10.5%, derived from the CAPM[7], we can aggregate all year-specific welfare changes and actualise them to the year 2006/07.

Data and model calibration

In our simulation model we assume hypothetically that both the EU's beet sugar industry, being a competitive player in the world market, and the ROW beet region embraced the new technology since the marketing year 1996/97, and progressively adopted it up to 2014/15. Our model is calibrated on the observed production data from this period. Observed yields ($y_{i,j}$), 'incentive prices' (see below), London n°5 world sugar prices, quantities ($\overline{Q}_{i,j}$) and quota ($\overline{Q}_{i,j}^a$ and $\overline{Q}_{i,j}^b$) are taken from various sources (European Commission 1999;F.O.Licht 2001;FAO 2006;F.O.Licht 2005;USDA 2006b).[8] Data for the future come from the FAPRI model, extrapolations of historical trends (yield/ha) and from decision 290/2007 from the EU. We assume only the efficient producers ($\varphi_{i,j}$=8), produce industrial sugar and this up to an amount of 1.5 million ton (SUBEL 2007) shared weighted on their quota. The other Member States are assumed to just fill their quota. To calibrate the average rent function, we need an approximate estimate of the observed land rent in all regions.[9] Thelen (2004) compares per-hectare profits among four beet producers (Poland, Ukraine, USA and Germany) and six cane producers (Brazil, Australia, Thailand, South-Africa, India and USA). We use the estimate of Germany for the EU-15 and calculate the area-weighted averages for the ROW cane and beet regions. All cost and price data are first deflated and actualised to the agricultural season 2006/07 using the GDP country deflators form the world development indicators, and then converted to Euro using the exchange rate of 2006. Institutional prices are deflated using both agricultural and financial exchange rates. Because HT sugar beet is not yet adopted, we estimate the adoption parameters of a comparable technology in the USA, i.e. HT Roundup Ready® soybeans(USDA 2006a)[10]. Therefore, we first transform the logistic adoption curve (Griliches 1957): $\rho_{i,j} = K_i \big/ (1 + e^{a_i + b_i j})$ into its log-linear form:

(20) $$\ln\left(\frac{\rho_i(t)}{\rho_{\max,i} - \rho_i(t)}\right) = a_{\rho,i} + b_{\rho,i} t \, .$$

By assuming a ceiling of $\rho_{\max,\mathrm{US}}$ = 0.9, the estimated OLS parameters using linear regression are $a_{\rho,\mathrm{US}}$ = 2.49, and $b_{\rho,\mathrm{US}}$ = 0.61. As a benchmark for HT sugar beet in the EU, we assume a logistic adoption curve with the same constant of integration, $a_{\rho,\mathrm{US}}$, and adoption speed, $b_{\rho,\mathrm{US}}$, as in the US. $\rho_{\max,i,j}$ is calculated as in Dillen, Demont and Tollens (2007b). We assume the innovating firm set their technology fee (μ) in 1996 upon introduction of the technology and in 2004 with the introduction of 10 New Member States. Distribution were created based on herbicide and application costs from Hermann

(2006;1997) (Table 3). We allow technology spillovers to the ROW beet region, subject to the same adoption pattern, but assume a *ceteris paribus* in the ROW cane region. Since we are only focusing on a single technology in a single sector, in our model the technology cannot 'spillover' to the ROW cane region. As a result, our estimated 'welfare effects foregone' have to be interpreted as functions, conditional on the assumed counterfactual adoption pattern.

As we carry out the analysis from an *ex ante* perspective, i.e. before adoption has taken place, the relevant adoption data (yield increases, cost reductions and price premiums) are not yet available. Moreover, the estimation of certain parameters, such as elasticities, is surrounded by uncertainty. Therefore, using the computer program @Risk 4.5 from Palisade Corporation, we construct subjective distributions for these parameters, using all prior information available. Through Monte Carlo simulations, stochastic distributions are generated for the outcomes of the model.

Technology-induced cost reduction estimates are crucial to economic surplus calculations. Dillen, Demont, and Tollens (2007b) calculated the rents accruing to farmers for 2004. We repeated their calculations for 1996 upon the hypothetical introduction of HT sugar beet.

We assume that the ROW beet area is able to achieve the same efficiency gain and use the area-weighted average of the EU-25 Member States' efficiency gains.

To calibrate the model, we need to define regional 'incentive prices' $\hat{p}_{i,j}$ for all regions. For the ROW, $\hat{p}_{0,j}$ represents the world price. For EU regions, the incentive price depends on the region's production efficiency $\varphi_{i,j}$ and the national pricing system applied to pay beet growers and processors. The incentive prices for the former CMO for sugar are modelled in a dynamic way and depend on the world price, which, on its turn, depends on world-wide adoption rates. Incentive prices can be A sugar prices $p^a_{i,j}(p_j(\boldsymbol{\rho}_{W,j}))$, B sugar prices $p^b_{i,j}(p_j(\rho_{W,j}))$, a region-specific mixed price $p^m_{i,j}\left[p^a_{i,j}(p_j(\rho_{W,j})), p^b_{i,j}(p_j(\rho_{W,j})), p_j(\rho_{W,j})\right]$, or the world price $p_j(0)$). For the new CMO for sugar the incentive price for in quota sugar ($p^o_{i,j}$) is fixed (although decreasing in time) and the out of quota incentive price is the world price $p_j(0)$. The model is calibrated on the pre-innovation equilibrium, i.e. we set $\rho_{W,j} = 0$.

In Table 2 we combine different sources to define the regions' production efficiencies, incentive prices and supply elasticities. Structural parameters such as supply elasticities σ and demand elasticities ε are taken from the literature (see Table 2). To calibrate $\theta_{i,j}$, it is useful to relate this parameter to the more standard notion of elasticity of land supply with respect to sugar prices. If we define $r_{i,j}$ as the farmer's share (rent) of unit revenue, the parameter $\theta_{i,j}$ can be calibrated as (Sobolevsky, Moschini, and Lapan 2005, p. 632):

(21) $$\theta_{i,j} = \psi_i r_{i,j} = \psi_i \left[\frac{\hat{\pi}_i}{\hat{p}_{i,j} y_{i,j}} \right]$$

Since our model features disaggregated area response (ψ_i) and yield response (η_i) to prices ($\psi = (\partial L/\partial p)(p/L) \geq 0$, $\eta = (\partial Y/\partial p)(p/Y) \geq 0$ and $\zeta = \psi + \eta$), we need to find elasticities that correctly represent farmers' behaviour and incentives in the global sugar beet industry. In a quota system with fixed prices, annual within-quota price variation is too small to obtain reliable estimates of supply response. While quota rents of world price irresponsive regions are not significantly affected by supply response, world price responsive regions significantly affect world prices and global welfare through technological innovation. Therefore, for these regions in particular, i.e. Germany, Belgium, France, Austria and the UK, precise estimates of supply response to world prices are needed. Poonyth *et al.* (2000) report short- and long-run area elasticity estimates for all EU-15 Member States, except Portugal and Greece. As Poonyth *et al.* (2000) do not include any standard deviations for ψ_i, we construct symmetric triangular distributions with the short-run estimate as minimum value, the long-run estimate as maximum value and the medium-run, i.e. the average of both estimates, as most likely value. For the export supply flexibilities σ_1 and σ_2 (Equation 5), we construct symmetric triangular distributions, centred on the base value and ranging from zero to twice the base value. Devadoss and Kropf (1996) report supply elasticities for all major sugar producers in the world. For the ROW cane and ROW beet regions, we calculate a production-weighted average supply elasticity of 0.269 and 0.207, respectively, and a consumption-weighted average demand elasticity ε_{ROW} of -0.034.[11] For Greece and Portugal we use Devadoss and Kropf's (1996) supply elasticity estimate of 0.228 for A quota sugar. As supply elasticities ζ_i already incorporate yield response to prices, we set $\eta_i = 0$ for these regions. For EU-25 regions we use the yield response to prices from the ESIM-model[12] (Banse, Grethe, and Nolte 2005), $\eta_i = 0.08$ surrounded by a triangular distribution constructed analogously to the rest of the elasticities. The ESIM-model also supplies us with supply elasticities for the New Member States.

Given the assumed, estimated and retrieved parameters, structural parameters, such as $A_{i,j}$, $G_{i,j}$, and $\lambda_{i,j}$ are calibrated so as to retrieve pre-innovation acreage, quantity, yield and price data for each year j.

We allow technology spillovers to the ROW beet region, subject to the same adoption pattern, but assume a *ceteris paribus* in the ROW cane region. Since we are only focusing on a single technology in a single sector, in our model the technology cannot 'spillover' to the ROW cane region. As a result, our estimated 'welfare effects foregone' have to be interpreted as functions, conditional on the assumed counterfactual adoption pattern.

Results

We conduct a Monte Carlo simulation of 6000 simulations to generate stochastic distributions for our welfare estimates, using the @Risk software. Table 4 reports the mean values. The downstream sector captures the largest share (61%) of the benefits. This result is in line with the *ex post* impact studies on first generation GM crops which show a distribution of 2/3 downstream, 1/3 upstream. 31% of the benefits is accruing to the ROW if we assume that beet producers in these countries are able to achieve the same efficiency enhancing effects trough the new technology, and are not able to export the technology-induced export on the world market which would further erode the world market price. Worldwide sugar beet growers gain €8.22 billion almost equally shared between EU-25 producers (58%) and ROW producers (42%). The input suppliers (seed industry and gene developers) extract €6.07 billion of the global welfare gain. If we do not take into account any market effects, 58% of the benefits flow to the beet growers, while 42% accrues to the input industry.

The depressing effect on world prices engendered by innovating world price responsive regions causes ROW consumers to gain €8.64 billion, but this is largely offset by the ROW cane growers' loss of €7.25 billion. Since we assume that the technology spillovers to the ROW beet sector do not depress the world price, the EU is not affected. Instead, the world price responsive EU region is able to erode its own profitability through technological innovation, an ambiguity called 'immiserising growth' (Bhagwati 1958), but our results show that the CMO for sugar largely protects domestic producers against this perverse side effect of innovation. The model suggests a world price decrease of 1.6% is expected to occur over a period of 19 years, a annual decrease of 1.3%. Compared with other studies, reporting annual price declines of 0.64% due to the adoption of Bt cotton in the USA (Falck-Zepeda, Traxler, and Nelson 2000) and 0.88% (Moschini, Lapan, and Sobolevsky 2000) and 0.97% (Qaim and Traxler 2005) due to the adoption of Roundup Ready® soybeans in the USA and South America, our estimate is relatively big but this is due to the bigger time span of our study.

Since EU institutional prices are exogenously fixed[13], no important price declines are possible. As a result, the benefits essentially flow to farmers without affecting EU processors and consumers. However, if weed control based on transgenic HT technology increases the sugar beet's sucrose content (Kniss et al. 2004), processors will gain as the processing costs are approximately the same per ton of beets regardless of sugar content

(DeVuyst and Wachenheim 2005). Moreover, if the EU government endogenised public and private agricultural research expenditures (see e.g. Swinnen and De Gorter 1998) in the CMO for sugar, benefits would be shared among farmers and consumers. The global welfare gain, finally, amounts to €15.68 billion after 19 years of adoption.

As we assume no supply response for the majority of beet producers, the enhanced yields of the new technology engender important land contractions in the beet industry. Table 4 presents the average land supply response (LSR). Our model predicts that due to the adoption of HT sugar beet, the EU-25 beet area will shrink 1.2% on average. World price irresponsive Member States' areas are expected to decline between 1.99% and 4.29%, whereas world price responsive regions are expected to allocate more land to sugar beet, i.e. between 0.18% and 0.63%, in response to increased profits. The ROW beet region will remove 2.75% of sugar beet area from cultivation, while the ROW cane area shrinks with 0.37%. On the global scale, the sugar industry is expected to contract its area allocation to sugar beet and cane with an average of 0.70%.

In Table 5, we present some descriptive statistics of the generated welfare estimates. Given the assumed subjective distributions, reflecting the uncertainty in the data, EU-25 producer surplus ranges from € 3,750 billion to €5,347 billion in 95% of the cases. Total welfare increase is lest robust, ranging with the same probability from €12.5 billion to €18.5 billion.

The reform of the CMO for sugar in 2006 will affect the benefits accruing to farmers. The effect is studied by a multiple regression on the production weighted average for each group of sugar producers, A-producers ($\varphi_{i,j}$=0,1), B-producers[14]

($\varphi_{i,j}$=2,3), exporters ($\varphi_{i,j}$=4). The variables used are yield, world price, technology fee (which depends on the heterogeneity among farmers) and a dummy variable for the change in policy. The results in Table 6 show A- producers will be negatively affected during the restructuring period and even more there after. This because the reference price for sugar (P_R) is between A en B quota prices, i.e. $p_b<P_R<p_a$. B-producers gain from the new policy. Most of this gain in generated in the restructuring period during which the reference price is much higher than the B-sugar price. After restructuring the new CMO affects their innovation rents less. C-producers also gain significantly from the new technology due to the less disturbing effect of EU sugar exports on the world market. It seems the regime is tailored towards efficient producers and will probably lead towards the crowding out of inefficient A-producers. This is exactly what the purpose of this reform was. Besides these expected effects, some counterintuitive results come up. The technology fee has a significant positive effect for each group of producers. This is the case because tech fee is based on herbicide expenditures which decreased through time through better management and products. In further analyses it seems the herbicide expenditures could be a better variable to regress. The insignificant effect of world prices is not expected either. The independence of the producer welfare of the world market allows some more advanced stochastic testing in the next part of our research.

Conclusion

We developed a model shaped to the European sugar sector to assess the size and distribution of the benefits of genetically modified sugar beet adoption in the EU-25 and the ROW. The potential size of benefits is large with a €15 billion worldwide. These benefits are not created at the moment due to the risk acceptance of consumers worldwide. The framework suggests 39% of the created welfare accrues to the input industry while 61% of the created welfare goes to the downstream sector (farmers and consumers). This is in line with the rule of thumb of 1/3 versus 2/3 as found in *ex post* impact assessments. The share of benefits going to farmers and consumers is divided between ROW and EU-25 (31%-30%). Cane growers in the world lose due the depressing effect of the innovation on world sugar prices. Consumers outside the EU profit from this price reduction while EU consumers do not profit from the innovation in the short run due to fixed prices in the CMO for sugar. The technology induced land contraction in the EU is estimated -1.2%. Inefficient producers lose significantly more (<-3%) while efficient, exporting countries can even expand there allocated area slightly. The reform of the CMO for sugar in 2006 had a significant effect on the farmer rents due to reduced sugar prices. The efficient producers gain more under the new CMO while the inefficient losers seem to lose rents. The reform is tailored to efficient producers an promotes innovations in the sugar sector. Crowding out of inefficient A producers could take place, as is one of the incentives of the reform.

[1] In the literature, the monopoly rents of the innovators are calculated as gross technology revenues. No research, marketing or administration costs are deducted, because such data are not easily available. If these costs were deducted, the general rule of thumb could rather become 'one quarter upstream versus three quarters downstream'. For an example of a study incorporating such data, see Phillips (2003).

[2] We are grateful to Brent Borrell (CIE, Canberra) for pointing this out.

[3] According to Gohin and Bureau (2006), various world sugar market liberalisation studies produce inconsistent results because of the incorrect modelling of EU supply response. Therefore, using an aggregate function that summarizes heterogeneous individual behaviours is one way to deal with the problem.

[4] Ivan Roberts correctly points out that this is so as long as the aid is maintained. But if it were to be discontinued, it would raise world prices, influencing C-sugar and B-sugar returns.

[5] In the short run, producers could stock surpluses generated by the innovation, but this 'hold-up' of R&D benefits is temporal as the stocks are limited to 20% of the A quota (European Commission 1996).

[6] Our *ceteris paribus* assumption implies that transgenic technology is only adopted in the beet sector.

[7] We assume that the conditions for the CAPM (capital asset pricing model) do hold. The risk adjusted rate of return is the sum of the risk premium and the risk-free rate of return (ROR). We assume a risk premium of 8%, based on the New York Stock Exchange (see Dixit and Pindyck 1994) and added a 2.5% risk-free ROR from the European Central Bank in 1995, getting a 10.5% risk adjusted ROR.

[8] We assume complete market clearance, i.e. stock decisions are not affected by the new technology.

[9] After an extensive sensitivity analysis it appears that this is just an inconsequential scaling parameter, which is in line with the observations of Moschini, Lapan, and Sobolevsky (2000, p. 46).

[10] We believe that the US case of HT Roundup Ready® soybeans is comparable with the EU case of HT sugar beet, because of (i) the common embedded technology of herbicide tolerance, (ii) the ubiquitous importance of each crop on both continents, and (iii) the importance of exports of the refined products.

[11] Supply elasticities of sugar cane are inelastic in the short run since several annual crops can be harvested from one planting of cane whereas beet is an annual crop.

[12] The elasticities from the ESIM-model are behavioral elasicities while the others are econometric elasticities.

[13] In the new CMO, prices can be assumed to be fixed due to the intervention mechanism in the policy in case of long term price declines.

[14] The Netherlands and Ireland are excluded from the analysis due to there mixed price system. Ireland stopped producing under the new CMO. The regression on the Netherlands showed policy has a significant positive effect on the farmers rent (1.8) bigger than for other B-producers. The reason can be found in the lower price they were paid due to the mixed price before the reform.

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Table 1: Competitiveness of sugar beet production for each Member State

	Frandsen,2003	Frandsen, revisited[a]	Poonyth,1998	Gohin,2006	Buy-out in first 2 year
Belgium + Luxembourg			Include	Include	No
Danmark		Include			No
Germany	Include	Include	Include	Include	No
Greece					Yes
Spain					Yes
France	Include		Include	Include	No
Ireland			wrong[b]		Yes
Italy					Yes
the Netherlands				Include	No
Austria	Include		Include		No
Portugal					Yes
Finland					Yes
Sweden		Include			Yes
United Kingdom	Include	Include	wrong[b]	Include	No
Czech republic		Include			Yes
Hungary		Include			Yes
Poland		Include			No

[a] The criteria used by Frandsen on an extended data set (1996-2006)

[b] The mixed price used is wrong (Frandsen et al. 2003;Gohin and Bureau 2006;Poonyth 1998)

Table 2: Regional specification of incentive prices and elasticities

Region	φ_i		Incentive price		Area elasticity	Yield elasticity
	former	new	former	new		
ROW cane	6	6	world price	world price	0.290	0
ROW beet	5	5	world price	world price	0.202	0
Belgium	4	8	world price (C)	world price (ind)	0.055	0.08
Denmark	3	7	B sugar price	instit. price	0.034	0.08
Germany	4	8	world price (C)	world price (ind)	0.074	0.08
Greece	0	7	A sugar price	instit. price	0.228	0
Spain	3	7	B sugar price	instit. price	0.226	0.08
France	4	8	world price (C)	world price (ind)	0.172	0.08
Ireland	2	7	mixed price (A, B and C sugar)	instit. price	0.034	0.08
Italy	1	7	A sugar price	instit. price	0.712	0.08
Netherlands	2	7	mixed price (A, B and a fixed quantity of C sugar)	instit. price	0.041	0.08
Austria	4	8	world price (C)	world price (ind)	0.154	0.08
Portugal	0	7	A sugar price	instit. price	0.228	0
Finland	1	7	A sugar price	instit. price	0.064	0.08
Sweden	2	7	B sugar price	instit. price	0.030	0.08
United Kingdom	4	8	world price (C)	world price (ind)	0.176	0.08
Czech Republic	4	7	world price (C)	instit. price	0.569	0.08
Hungary	3	7	B sugar price	instit. price	0.5686	0.08
Poland	3	7	B sugar price	instit. price	0.5667	0.08

Sources: Devadoss and Kropf (1996), Poonyth *et al.* (2000), Confédération des Betteraviers Belges (2002) and Frandsen *et al.* (2003), Banse, Grethe, and Nolte (2005)

Table 3:Heterogeneity among farmers, technology fee and maximal adoption following Dillen, Demont and Tollens (2007)

	Loglogistic(0, γ, δ)				μ		$\rho_{max,i,j}$	
	γ		δ					
	1996	2004	1996	2004	1996	2004	1996	2004
Belgium	163.74	206.59	8.3785	4.2293	98	88	89%	91%
Denmark	165.51	165.51	4.3522	4.3522	98	88	88%	92%
Germany	202.04	160.33	4.9939	3.9367	98	88	90%	69%
Greece	223.55	121.06	9.067	10.519	98	88	99%	63%
Spain	265.37	222.94	5.5183	6.0868	98	88	100%	100%
France	124.76	135.78	4.7872	9.7149	98	88	43%	89%
Ireland	196.52	84.422	9.9645	9.68	98	88	93%	1%
Italy	184.83	145.32	5.7751	6.3659	98	88	74%	53%
The Netherlands	123.5	164.32	3.2706	13.483	98	88	69%	100%
Austria	229.12	260.8	4.729	5.4323	98	88	87%	96%
Portugal	265.37	265.37	5.5183	5.5183	98	88	99%	100%
Finland	266.13	200.67	6.514	10.044	98	88	99%	100%
Sweden	139	148.56	3.4986	4.2881	98	88	47%	60%
United Kingdom	124.05	124.05	5.9299	5.9299	98	88	66%	73%
Czech Republic		180.12		9.9884		88		92%
Hungary		132.28		2.7296		88		46%
Poland		184.91		6.3962		88		87%

Table 4:Price and welfare effects (in million euros) of the adoption of herbicide tolerant sugar beet in the world

Year	Benchmark 1996/97	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06
Price effects											
World sugar price (%)	100%	99.65%	99.59%	99.35%	99.09%	98.92%	98.73%	98.65%	98.49%	98.58%	98.66%
A sugar price (%)	100%	99.99%	99.99%	99.99%	99.99%	99.97%	99.98%	99.97%	99.98%	99.99%	99.98%
B sugar price (%)	100%	99.77%	99.77%	99.73%	99.70%	99.17%	99.48%	99.16%	99.26%	99.56%	99.37%
Welfare effects											
Belgium	0.00	2.46	3.61	4.13	5.70	6.72	8.67	8.67	9.02	15.21	18.53
Denmark	0.00	1.90	3.23	4.59	6.28	7.75	9.56	9.91	11.04	12.61	12.23
Germany	0.00	12.70	18.53	24.46	31.12	39.79	48.13	48.17	49.08	44.21	53.55
Greece	0.00	1.82	3.17	3.44	5.47	7.84	8.87	9.51	8.33	5.38	5.68
Spain	0.00	9.10	15.47	22.04	30.27	38.07	44.49	44.88	50.76	45.90	44.06
France	0.00	5.10	7.40	9.71	11.74	11.50	19.09	15.78	16.84	44.74	61.10
Ireland	0.00	1.32	2.09	3.20	4.45	5.08	5.98	6.45	7.13	0.21	0.35
Italy	0.00	5.67	9.21	13.64	18.61	22.74	27.09	28.66	34.37	21.91	21.75
The Netherlands	0.00	3.71	6.60	10.50	13.88	15.83	20.00	20.27	22.47	34.09	33.65
Austria	0.00	1.42	2.09	2.74	3.39	3.93	5.34	5.24	5.15	8.22	10.81
Portugal	0.00	0.03	0.83	1.17	1.75	1.90	2.54	2.36	2.96	3.00	2.88
Finland	0.00	1.02	1.48	2.57	3.24	4.11	4.83	5.13	5.78	4.94	4.98
Sweden	0.00	0.64	1.09	1.58	2.32	2.93	3.45	3.97	4.19	4.88	5.32
United Kingdom	0.00	2.62	3.97	4.93	6.03	6.50	9.51	8.56	8.98	13.25	16.42
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.44	14.85
Hungary	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.12	8.56
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.17	56.21
EU-15 producers	0.00	49.51	78.77	108.69	144.25	174.68	217.53	217.54	236.09	341.29	370.93
EU-15 consumers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ROW cane	0.00	-116.46	-115.22	-148.77	-164.49	-238.67	-289.76	-300.04	-296.12	-310.02	-420.16
ROW beet	0.00	39.56	67.42	89.95	115.36	154.36	161.54	187.03	181.99	175.09	207.94
Net ROW producers	0.00	-76.90	-47.80	-58.83	-49.12	-84.31	-128.22	-113.00	-114.14	-134.93	-212.22
ROW consumers	0.00	148.80	147.01	184.16	202.99	295.45	341.47	335.27	349.94	373.88	491.50
Net ROW	0.00	71.90	99.21	125.33	153.86	211.14	213.25	222.27	235.80	238.95	279.28
Input suppliers	0.00	75.33	113.68	169.04	233.93	277.06	307.68	352.17	363.58	359.78	355.16
Total	0.00	196.75	291.66	403.06	532.05	662.89	738.46	791.98	835.48	940.02	1005.36
Welfare distribution											
EU-15 producers (%)	.	25%	27%	27%	27%	26%	30%	28%	28%	36%	37%
EU-15 consumers (%)	.	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Net ROW (%)	.	36%	34%	31%	29%	32%	29%	28%	28%	25%	28%
Input suppliers (%)	.	38%	39%	42%	44%	42%	42%	45%	44%	38%	35%
Total (%)	.	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Year	2006/07	2007/08	2008/09	2009/10	2010/11	2011/2012	2012/2013	2013/2014	2014/2015	AGGR	Land supply response
Price effects											
World sugar price (%)	98.33%	98.36%	98.40%	98.40%	98.40%	98.40%	98.40%	98.40%	98.40%		
Welfare effects											
Belgium	16.50	14.30	14.92	15.26	15.29	15.37	15.50	15.58	15.70	222.73	0.18%
Denmark	10.87	8.75	8.32	7.97	7.97	7.96	7.95	7.93	7.92	177.93	-3.11%
Germany	45.45	43.54	45.56	46.63	46.76	47.04	47.47	47.73	48.15	887.94	0.20%
Greece	5.12	2.35	2.21	2.10	2.11	2.11	2.11	2.11	2.11	115.02	-2.77%
Spain	27.00	22.18	21.18	20.35	20.33	20.30	20.26	20.23	20.19	691.01	-3.26%
France	56.81	43.62	46.29	47.78	48.02	48.45	49.09	49.51	50.14	603.32	0.29%
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	63.75	-1.99%
Italy	10.83	9.69	9.17	8.75	8.74	8.73	8.72	8.70	8.69	389.45	-2.23%
The Netherlands	22.57	18.07	17.14	16.37	16.36	16.35	16.34	16.32	16.30	389.05	-3.17%
Austria	9.40	7.84	8.15	8.31	8.33	8.36	8.42	8.45	8.51	127.25	0.63%
Portugal	1.60	0.85	0.81	0.78	0.78	0.78	0.78	0.78	0.77	36.01	-3.64%
Finland	4.78	2.68	2.56	2.46	2.45	2.44	2.43	2.42	2.40	78.91	-3.58%
Sweden	5.35	4.46	4.23	4.05	4.04	4.04	4.03	4.03	4.02	74.06	-1.99%
United Kingdom	14.59	12.10	12.79	13.17	13.22	13.33	13.49	13.60	13.75	209.75	0.30%
Czech Republic	10.68	7.09	6.71	6.40	6.39	6.39	6.38	6.37	6.37	80.30	-4.29%
Hungary	5.90	3.79	3.62	3.48	3.48	3.47	3.46	3.45	3.44	45.07	-2.19%
Poland	40.36	32.45	30.84	29.51	29.47	29.41	29.35	29.29	29.23	331.44	-4.06%
EU-15 producers	287.81	233.76	234.52	233.37	233.74	234.53	235.78	236.49	237.70	4523.00	-1.20%
EU-15 consumers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.
ROW cane	-520.77	-478.29	-508.50	-537.68	-548.45	-561.27	-576.74	-589.95	-606.16	-7222.11	-0.37%
ROW beet	199.78	190.78	197.62	199.85	198.69	199.95	201.69	202.84	204.53	3460.72	-2.75%
Net ROW producers	-320.99	-287.51	-310.88	-337.83	-349.76	-361.32	-375.04	-387.11	-401.63	-3761.38	-0.70%
ROW consumers	601.25	569.38	597.32	629.07	644.44	661.78	682.95	701.22	723.31	8609.72	.
Net ROW	280.26	281.87	286.44	291.24	294.67	300.46	307.91	314.11	321.68	4848.33	.
Input suppliers	321.29	306.54	302.39	298.31	294.13	293.57	292.94	292.28	291.61	6068.94	.
Total	889.36	822.17	823.34	822.93	822.55	828.55	836.63	842.88	850.99	15440.27	-0.73%
Welfare distribution											
EU-15 producers (%)	32%	29%	29%	28%	29%	28%	28%	28%	28%	29%	
EU-15 consumers (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Net ROW (%)	31%	34%	35%	35%	36%	36%	37%	37%	38%	31%	
Input suppliers (%)	36%	37%	37%	36%	36%	35%	35%	35%	34%	39%	
Total (%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	

Table 5:Descriptive statistics of the distribution of the aggregated impact of HT sugar beet on EU-25 agriculture, the seed industry and the ROW, 1996/97-2014/15

	Minimum	2.5% confidence limit[a]	Mean	97.5% confidence limit[a]	Maximum
EU-25 producers	3,245.4	3,750.6	4,523.0	5,346.9	5,997.8
EU-25 consumers	0.0	0.0	0.0	0.0	0.0
Net ROW	2,563.1	3,365.5	4,848.3	6,333.0	7,414.9
Input suppliers	4,310.1	4,777.4	6,068.9	7,354.9	7,837.6
Total	10,998.6	12,511.7	15,440.3	18,462.3	20,160.7

[a] Lower limits are rounded up while lower limits are rounded down.

Table 6:Regression coefficient of the impact of yield, world price, tech fee and policy on the benefits acruing to EU-25 farmers

	Variable	BETA	St. Err. of BETA	p-level
A-producers	Intercept			0.10
	World price	0.14	0.07	0.09
	Tech fee	0.39**	0.13	0.01
	Policy	-0.87**	0.12	0.00
	Yield	0.30**	0.11	0.02
	R^2	0.935		
B-producers	Intercept			0.03
	World price	-0.02	0.20	0.90
	Tech fee	1.37**	0.25	0.00
	Policy	0.96**	0.28	0.00
	Yield	0.15	0.20	0.46
	R^2	0.694		
Exporters	Intercept			0.47
	World price	-0.24	0.22	0.31
	Tech fee	1.26**	0.42	0.01
	Policy	1.06**	0.27	0.00
	Yield	0.00	0.38	0.99
	R^2	0.699		

**significant on the 5% level

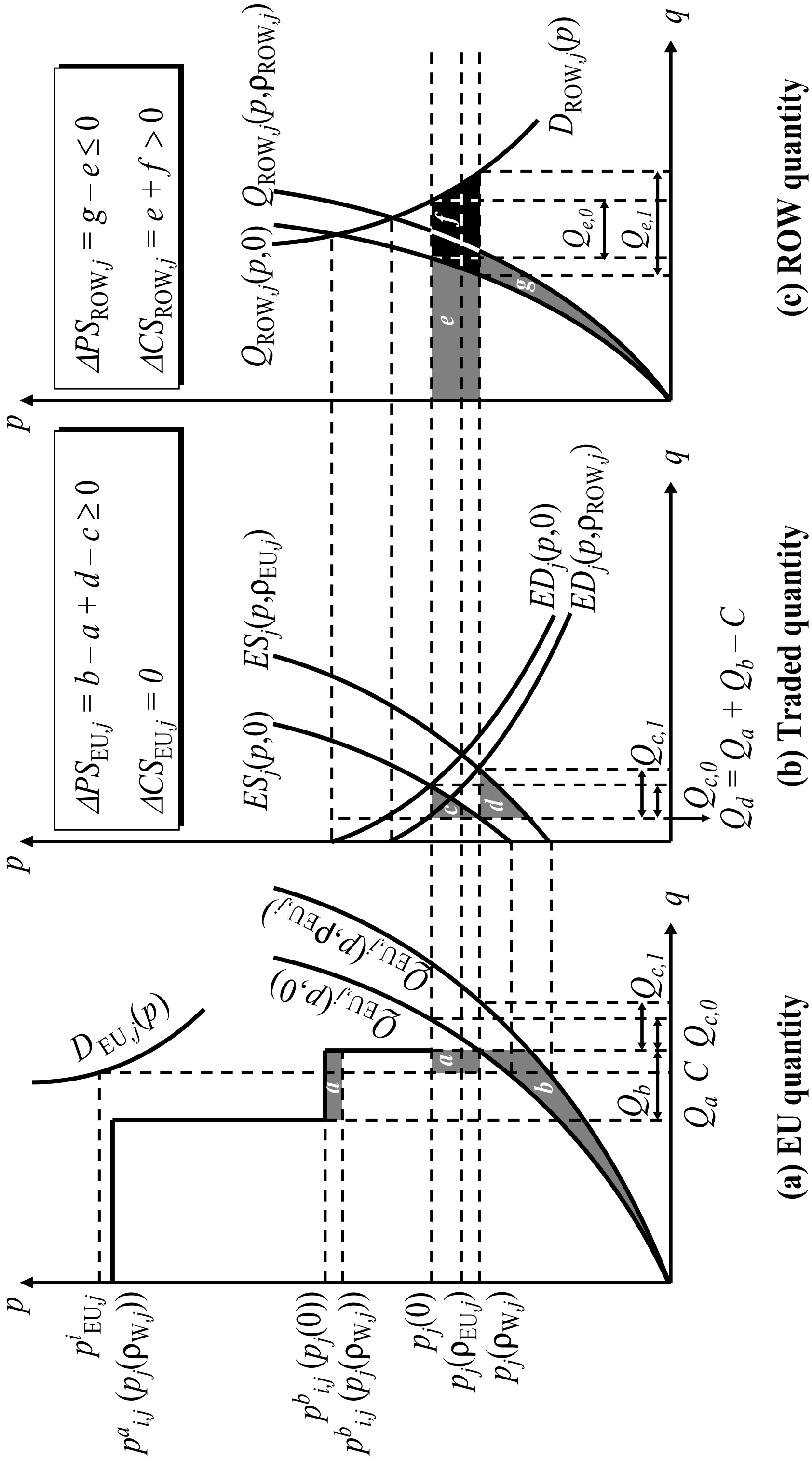

Figure 1: Distribution of R&D benefits in the EU's sugar sector with technology spillovers to the rest of the world (ROW)