The Global Welfare Effects of GM Sugar Beet under Changing Sugar Policies

Dillen, K. [1], Demont M. [1, 2] and Tollens E. [1]

[1] Centre for Agricultural and Food Economics, Katholieke Universiteit Leuven (K.U.Leuven), Leuven, Belgium
[2] Africa Rice Center (WARDA), Saint-Louis, Senegal

Abstract—**Since most of the recent agricultural biotechnology innovations have been developed by private companies, the central focus of societal interest is on the distribution of the gains from these technologies among all stakeholders. In a partial equilibrium model, assuming perfect corporate pricing strategies given the heterogeneous population of potential adopters, we model the worldwide introduction of GM sugar beet. The introduction is modelled under both the old and new CMO for sugar in the EU. We see GM sugar beet could bring great benefits to both consumers in the world and sugar beet producers even when the innovation is protected by intellectual property rights and the innovator uses his restricted monopoly to the full extend.**

Keywords— **GM, sugar beet, partial equilibrium**

I. INTRODUCTION

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. The first *ex post* impact studies of agricultural biotechnology indicate that farmers are clearly capturing sizeable gains of the new technology [1].

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 [2,3] and herbicide tolerant soybeans in Romania [4]. Some *ex ante* EU distributional impact studies on transgenic sugar beet are documented as well [5-7], 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%).

Despite the official end of the moratorium and new approvals of GE 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.

However, with the recent trends in world food and bio-energy markets it seems like the tide is changing and the demand for introduction from GM crops increases in the European Union. In this study we assess the potential introduction of herbicide tolerant (HT) sugar beet under changing sugar policies.

II. MODEL

The case of 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 [8], which makes the HT trait very attractive to farmers. The case of sugar beet is very current. It seems the sugar industry opened its doors towards HT sugar beet which is commercialized in the USA in 2008. Furthermore, sugar beet is a potential input commodity for the growing bio-energy sector and the biochemistry sector. Dillen, Demont and Tollens [9] develop a framework to model heterogeneity among potential adopters in *ex ante* welfare assessments which allows determining the marginal adopter, endogenizing the technology fee and adoption rate in the case of monopolistic price setting. They also calculate farmer rents and the revenue for the innovator. However, Frisvold, Sullivan, and Raneses [10] argue distributional effects cannot be assessed adequately without aggregating results and incorporating market effects. Therefore we use the EUWABSIM model to assess the distributional effects [5,11,12]. The model covers 19 agricultural seasons (1996-2014) and as such takes into account the introduction of 10 New Member States in 2004 and the change in the sugar policy in 2006 (cfr.infra). EUWABSIM is based on the large open-economy framework of Alston *et al.* [13], but explicitly recognises that research protected by intellectual property rights generates monopoly profits [14]. It is framed to the policy and market features of the EU Common Market Organization (CMO) for sugar as modelled by [15,16]. The model starts from non-linear constant-elasticity (NLCE) supply functions, developed by Moschini *et al.* [17], incorporating technology-specific parameters, which enable the detailed parameterisation of the herbicide tolerance technology. Seventeen regions are included, each of them modelled by a NLCE supply function: fourteen EU regions before 2004 and 17 thereafter (resembling 92% of EU 27 sugar production), the Rest of the World (ROW) beet region, and the ROW cane region. This specification allows technology spillovers to be included for the ROW sugar beet region. The seventeen EU and two ROW supply functions are aggregated, respectively into an EU and a ROW aggregate supply function. The model is non-spatial, since intra-EU trade flows are not modelled; only aggregate EU and ROW demand for sugar are taken into account. The differentials between aggregate supply and demand functions result in an EU export supply function and a ROW export demand function, since the EU is a net exporter and the ROW a net importer of sugar. By imputing a hypothetical adoption curve for HT sugar beet into the model, the technology-specific parameters engender a pivotal shift of the regional NLCE supply functions and hence of the export supply and demand functions. The world price is modelled as the intersection of both functions on the world market. For the former sugar policy, changes in the world price are transmitted to domestic EU prices through the auto-financing constraint of the CMO for sugar [16]. Finally, the welfare changes (producer and consumer surplus) are calculated via standard procedures [18]. In the next paragraphs we highlight some of the features of the model the EUWABSIM model.

A. The former Common Market Organisation for sugar

The technology induced world price change can be transmitted to EU domestic prices using the principles of the EU's CMO for sugar, which came into full effect in 1968. The key features include a minimum price and the creation of production quotas. Anticipating an increase in consumption, the quotas are set at a higher level than internal consumption. This overproduction, 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. Both the levies on A and B quota 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 [16]. 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. For each Member State, A and B quota prices can be deducted from the institutional price and the levies. 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 African Caribian Pacific (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. The same argument holds for the EU's stocking and carrying-over policy, at least in the medium- and long-run.

To calculate the producer surplus, which strongly depends on the competitiveness of the different countries a categorical parameter to denote the region's production efficiency is introduced. Depending on the value this parameter takes, the model automatically selects the appropriate formula for the calculation of the welfare effects, depending on their incentive for production. For detailed formulas see [7].

B. New Common Market Organisation for sugar (2006/2014)

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, 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 in order to reach the goals of the reform.

For the model this has several structural effects. The older differentiated quota are replaced by one quota with a price independent from the world market price, the reference price. The characterisation of production competitiveness changes for all countries. Producers not filling their assigned quota before, will sell excess quota and fill their new quota. Producers filling their quota before will keep on doing this 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 are affected the most. Due to a complaint by the WTO, export of out of quota sugar (former C-sugar) is severely constraint. 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 the EU still influence the world market to some extent. In 2009 the Everything but Arms agreement will grant free access to the European sugar market for the least developed countries (LDC). However, the combination of lower prices for ACP countries with the free access for LDC will keep the European import only slightly changed [19] so it can be assumed exogenously.

III. 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, 'incentive prices' (see below), London n°5 world sugar prices, quantities and quota are taken from various sources [20-24]. 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, produce industrial sugar and this up to an amount of 1.5 million ton [25] shared weighted on their quota. The other Member States are assumed to just fill their new quota. 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[26]. Therefore, we first transform the logistic adoption curve [27] into its log-linear form:

$$\ln\left(\frac{\rho_i(t)}{\rho_{\max,i} - \rho_i(t)}\right) = a_{\rho,i} + b_{\rho,i}t \cdot \qquad (1)$$

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. By assuming a adoption ceiling of $\rho_{\max,\mathrm{US}} = 0.9$, the estimated OLS parameters using linear regression are $a_{\rho,\mathrm{US}} = 2.49$, and $b_{\rho,\mathrm{US}} = 0.61$. We assume a uniform pricing strategy [9] in which the innovating firm sets their technology fee in 1996 upon introduction of the technology and in 2004 with the introduction of 10 New Member States since production structure. $\rho_{\max,\mathrm{I}}$ then represents the maximal adoption under the restricted monopoly held by the innovator. Distribution were created based on herbicide and application costs from Hermann [28,29] (Table 1).

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) are not yet available. Moreover, the estimation of certain parameters, such as elasticities, is surrounded by uncertainty. Therefore, using the computer program @Risk 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 [9] 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-27 Member States' efficiency gains.

To calibrate the model, we need to define regional 'incentive prices' for all regions depending on the categorical parameter introduced earlier. For the ROW the world price is used. For EU regions, the incentive price depends on the region's production efficiency and the national pricing system applied to pay beet growers and processors.

Table 1 Densities of herbicide expenditures and the the calculated technology fee and adoption rates

	Shape parameter of the logistic PDF on herbicide expenditures γ		δ		tech fee (€/ha)		*Maximal adoption* $\rho_{\max,i,j}$	
	1996	2004	1996	2004	1996	2004	1996	2004
Belgium	163.74	206.59	8.39	4.23	98	88	89%	91%
Denmark	165.51	165.51	4.40	4.35	98	88	88%	92%
Germany	202.04	160.33	5.00	3.94	98	88	90%	69%
Greece	223.55	121.06	9.06	10.52	98	88	99%	63%
Spain	265.37	222.94	5.52	6.09	98	88	100%	100%
France	124.76	135.78	4.81	9.71	98	88	43%	89%
Ireland	196.52	84.422	9.97	9.68	98	88	93%	1%
Italy	184.83	145.32	5.78	6.37	98	88	74%	53%
The Netherlands	123.5	164.32	3.27	13.48	98	88	69%	100%
Austria	229.12	260.8	4.73	5.43	98	88	87%	96%
Portugal	265.37	265.37	5.52	5.52	98	88	99%	100%
Finland	266.13	200.67	6.51	10.04	98	88	99%	100%
Sweden	139	148.56	3.50	4.29	98	88	47%	60%
United Kingdom	124.05	124.05	5.93	5.93	98	88	66%	73%
Czech Republic		180.12		9.99		88		92%
Hungary		132.28		2.73		88		46%
Poland		184.91		6.40		88		87%

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, B sugar prices, a region-specific mixed price, or the world price. For the new CMO for sugar the incentive price for in quota sugar is fixed (although decreasing in time) and the out of quota incentive price is the world price. Dillen et al. [12] introduce a multicriteria decion tool to assign the right incentive price to different Member States.

Since our model features disaggregated area response and yield response to prices, 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.* [30] report short- and long-run area elasticity estimates for all EU-15 Member States, except Portugal and Greece. As Poonyth *et al.* [30] do not include any standard deviations for the elasticities, 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, we construct symmetric triangular distributions, centred on the base value and ranging from zero to twice the base value. Devadoss and Kropf [31] 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 of -0.034. For Greece and Portugal we use Devadoss and Kropf's [31] supply elasticity estimate of 0.228 for A quota sugar. As supply elasticities already incorporate yield response to prices, we set yield elasticities to zero for these regions. For EU-27 regions we use the yield response to prices from the ESIM-model [32], 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.

IV. RESULTS AND DISCUSSION

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 accrues 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-27 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' [33], 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 [34] and 0.88% [17] and 0.97% [35] 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, 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 [36], processors will gain as the processing costs are approximately the same per ton of beets regardless of sugar content [37]. Moreover, if the EU government endogenised public and private agricultural research expenditures [see e.g. 38] 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. The last column of Table 4 presents the average land supply response (LSR). Our model predicts that due to the adoption of HT sugar beet, the EU-27 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 2, we present some descriptive statistics of the generated welfare estimates. Given the assumed subjective distributions, reflecting the uncertainty in the data, EU-27 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.

Table 2 Descriptive statistics of the distribution of the aggregated impact of HT sugar beet on EU-27 agriculture, input suppliers and the ROW (1996-2014)

	Minimum	2.5% confidence limit[a]	Mean	97.5% confidence limit[a]	Maximum
EU-27 producers	3,245.4	3,750.6	4,523.0	5,346.9	5,997.8
EU-27 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 3 Normalised regression coefficients of the impact of HT sugar beet on the world sugar price, EU-27 agriuculture , input suppliers and the ROW in agricultural season 2006/2007

Parameter	World price	EU-15 producers	ROW cane	ROW beet	ROW consumers	Net ROW	Input Suppliers	Total
Short run supply elasticity	0.905	0.094	0.905	0.709	-0.905	-0.088	0.003	-0.020
Long run supply elasticity	0.375	0.039	0.375	0.293	-0.375	-0.037	0.000	-0.008
Area elasticity ROW cane	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.009
Area elasticity ROW beet	-0.004	0.000	-0.004	-0.003	0.004	0.000	0.000	0.000
Yield change ROW	0.000	0.000	0.000	0.534	0.000	0.861	-0.052	0.444
Yield change EU [a]	-0.018	0.133	-0.018	-0.014	0.018	0.002	-0.001	0.038
R^2	0.982	0.997	0.982	0.989	0.982	0.998	1.000	0.999

[a] The normalised regression coefficients are averaged over all EU regions.

Normalized regression coefficients in Table 3 reflect the robustness of the model to individual parameter values. The coefficient of determination R^2 is high in all regressions, which means the linear approximation explains the variation in the iterations. We investigate the coefficient for the most recent agricultural season, 2006/07, the sensitivity estimates for the other seasons being essentially the same. The short-run flexibility ≤ 0, which can be interpreted as the inverse of the ROW export demand elasticity, is the main driver of technology-induced world price movements. A higher short run flexibility implies a more elastic export demand curve, engendering (i) a smaller technology-induced world price decline, (ii) a smaller loss for all farmers (positive coefficient, columns 2, 3 and 4) and (iii) a smaller gain for ROW consumers (negative coefficient, column 5). For global welfare gains, the opposing effects are largely cancelling each other out. Sensitivities to the lagged sugar export supply expansion coefficient are smaller because of two reasons. First, we assumed a more narrow distribution for this parameter.

Secondly, as we assumed a monotonically increasing adoption curve, lagged technology-induced EU sugar export supply expansions are smaller than actual expansions such that it has a smaller effect on welfare gains, regardless of its stochastic distribution. Any yield increases have an important effect on global welfare. As the EU model is spatial, each region features a separate stochastic yield boost and the aggregate effect is partly cancelled out. However, for individual world price responsive EU regions the coefficients are larger, ranging from 0.011 for Hungary to 0.162 for Germany. The ROW cane area benefits from all factors that prevent the EU (i) to achieve large efficiency gains in adopting HT sugar beet, e.g. small yield boost, and (ii) to export its surplus on the world market, e.g. an elastic export demand and/or inelastic supply. As the ROW cane region does not innovate in our model, its welfare is essentially a function of the world sugar price. Therefore, the world price and the ROW cane region share the same regression coefficients. Table 3 reports a small but significantly negative effect of a yield increase on input suppliers' profits. In highly protected sectors, such as quota systems, yield-enhancing technologies negatively affect their own demand, as farmers who are irresponsive to world prices will decrease their land allocated to the crop, lowering the derived demand for enhanced seed. This phenomenon has long been observed in the EU market for sugar beet seed, which is gradually decreasing due to increasing productivity and to decreasing acreage [39]. Further research questions include the influence of the new sugar policy on the innovation incentive in the European sugar sector. Which farmers have the highest incentive to innovate their production process and how is the revenue of the seed developer affected by the new sugar policy. Including the market for biofuels or modeling the introduction of GM technologies in sugar cane production could also be included in further updates of the EUWAB model.

V. CONCLUSIONS

Despite the granted intellectual property rights granted to the private innovation of HT sugar beet, the introduction of

HT sugar beet could created significant benefits for different stakeholders; sugar beet farmers in Europe and the ROW, consumers in the ROW and the innovators. The innovation is modelled as priced perfectly by the innovator given a heterogeneous population of potential adoption. Even under this perfect corporate pricing strategy, 2/3 of the benefits accrue to farmers and consumers. The benefits are twofold, cost reduction for farmers and a price reduction for consumers. The same effect of price decreases on the world market creates losses for the sugar cane sector, who can not benefit from spillovers of the sugar beet sector. European consumers do not benefit from the innovation because of the regulated internal prices. The new sugar regime alters the benefits generated by the innovators An important side effect of HT sugar beet for European agriculture is the land contraction taking place due to the higher yielding HT sugar beet. This land could be used for the increasing demand for raw material and food in the coming years.

The change of the CMO for sugar and the accession of several new Member States alters the flow of innovation rents due to reduced production, lower prices and reduced export. However, the sharing-out between stakeholders stays at the 2/3 -1/3 level giving benefits to farmers and consumers worldwide.

Table 4 Welfare effects of introducing HT sugar beet worldwide

Year	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	99.6	99.6	99.4	99.1	98.9	98.7	98.7	98.5	98.6	98.7
A sugar price	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
B sugar price	99.8	99.8	99.7	99.7	99.2	99.5	99.2	99.3	99.6	99.4
Welfare effects (mill €)										
Belgium	2.5	3.6	4.1	5.7	6.7	8.7	8.7	9.0	15.2	18.5
Denmark	1.9	3.2	4.6	6.3	7.8	9.6	9.9	11.0	12.6	12.2
Germany	12.7	18.5	24.5	31.1	39.8	48.1	48.2	49.1	44.2	53.6
Greece	1.8	3.2	3.4	5.5	7.8	8.9	9.5	8.3	5.4	5.7
Spain	9.1	15.5	22.0	30.3	38.1	44.5	44.9	50.8	45.9	44.1
France	5.1	7.4	9.7	11.7	11.5	19.1	15.8	16.8	44.7	61.1
Ireland	1.3	2.1	3.2	4.5	5.1	6.0	6.5	7.1	0.2	0.4
Italy	5.7	9.2	13.6	18.6	22.7	27.1	28.7	34.4	21.9	21.8
The Netherlands	3.7	6.6	10.5	13.9	15.8	20.0	20.3	22.5	34.1	33.7
Austria	1.4	2.1	2.7	3.4	3.9	5.3	5.2	5.2	8.2	10.8
Portugal	0.0	0.8	1.2	1.8	1.9	2.5	2.4	3.0	3.0	2.9
Finland	1.0	1.5	2.6	3.2	4.1	4.8	5.1	5.8	4.9	5.0
Sweden	0.6	1.1	1.6	2.3	2.9	3.5	4.0	4.2	4.9	5.3
United Kingdom	2.6	4.0	4.9	6.0	6.5	9.5	8.6	9.0	13.3	16.4
Czech Republic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	14.9
Hungary	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	8.6
Poland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.2	56.2
EU-27 producers	49.5	78.8	108.7	144.3	174.7	217.5	217.5	236.1	341.3	370.9
EU-27 consumers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROW cane	-116.5	-115.2	-148.8	-164.5	-238.7	-289.8	-300.0	-296.1	-310.0	-420.2
ROW beet	39.6	67.4	90.0	115.4	154.4	161.5	187.0	182.0	175.1	207.9
Net ROW producers	-76.9	-47.8	-58.8	-49.1	-84.3	-128.2	-113.0	-114.1	-134.9	-212.2
ROW consumers	148.8	147.0	184.2	203.0	295.5	341.5	335.3	349.9	373.9	491.5
Net ROW	71.9	99.2	125.3	153.9	211.1	213.3	222.3	235.8	239.0	279.3
Input suppliers	75.3	113.7	169.0	233.9	277.1	307.7	352.2	363.6	359.8	355.2
Total	196.8	291.7	403.1	532.1	662.9	738.5	792.0	835.5	940.0	1005.4
Welfare distribution (%)										
EU-27 producers	25	27	27	27	26	30	28	28	36	37
EU-27 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	98.3	98.4	98.4	98.4	98.4	98.4	98.4	98.4	98.4		
Welfare effects (mill €)											
Belgium	16.5	14.3	14.9	15.3	15.3	15.4	15.5	15.6	15.7	222.7	0.2
Denmark	10.9	8.8	8.3	8.0	8.0	8.0	8.0	7.9	7.9	177.9	-3.1
Germany	45.5	43.5	45.6	46.6	46.8	47.0	47.5	47.7	48.2	887.9	0.2
Greece	5.1	2.4	2.2	2.1	2.1	2.1	2.1	2.1	2.1	115.0	-2.8
Spain	27.0	22.2	21.2	20.4	20.3	20.3	20.3	20.2	20.2	691.0	-3.3
France	56.8	43.6	46.3	47.8	48.0	48.5	49.1	49.5	50.1	603.3	0.3
Ireland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.8	-2.0
Italy	10.8	9.7	9.2	8.8	8.7	8.7	8.7	8.7	8.7	389.5	-2.2
The Netherlands	22.6	18.1	17.1	16.4	16.4	16.4	16.3	16.3	16.3	389.1	-3.2
Austria	9.4	7.8	8.2	8.3	8.3	8.4	8.4	8.5	8.5	127.3	0.6
Portugal	1.6	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	36.0	-3.6
Finland	4.8	2.7	2.6	2.5	2.5	2.4	2.4	2.4	2.4	78.9	-3.6
Sweden	5.4	4.5	4.2	4.1	4.0	4.0	4.0	4.0	4.0	74.1	-2.0
United Kingdom	14.6	12.1	12.8	13.2	13.2	13.3	13.5	13.6	13.8	209.8	0.3
Czech Republic	10.7	7.1	6.7	6.4	6.4	6.4	6.4	6.4	6.4	80.3	-4.3
Hungary	5.9	3.8	3.6	3.5	3.5	3.5	3.5	3.5	3.4	45.1	-2.2
Poland	40.4	32.5	30.8	29.5	29.5	29.4	29.4	29.3	29.2	331.4	-4.1
EU-15 producers	287.8	233.8	234.5	233.4	233.7	234.5	235.8	236.5	237.7	4523.0	-1.2
EU-15 consumers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.
ROW cane	-520.8	-478.3	-508.5	-537.7	-548.5	-561.3	-576.7	-590.0	-606.2	-7222.1	-0.4
ROW beet	199.8	190.8	197.6	199.9	198.7	200.0	201.7	202.8	204.5	3460.7	-2.8
Net ROW producers	-321.0	-287.5	-310.9	-337.8	-349.8	-361.3	-375.0	-387.1	-401.6	-3761.4	-0.7
ROW consumers	601.3	569.4	597.3	629.1	644.4	661.8	683.0	701.2	723.3	8609.7	.
Net ROW	280.3	281.9	286.4	291.2	294.7	300.5	307.9	314.1	321.7	4848.3	.
Input suppliers	321.3	306.5	302.4	298.3	294.1	293.6	292.9	292.3	291.6	6068.9	.
Total	889.4	822.2	823.3	822.9	822.6	828.6	836.6	842.9	851.0	15440.3	-0.7
Welfare distribution (%)											
EU-27 producers	32	29	29	28	29	28	28	28	28	29	
EU-27 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	

REFERENCES

1 Demont M, Dillen K, Mathijs E, Tollens E (2007) GM Crops in Europe: How Much Value and for Whom? Eurochoices 6:46-53
2 Demont M, Tollens E (2004) First impact of biotechnology in the EU: Bt maize adoption in Spain. Ann. Appl. Biol 145:197-207
3 Gomez-Barbero M, Berbel J, Rodriguez-Cerezo E (2008) Bt corn in Spain: the performance of the EU's first GM crop. Nat Biotech 26:384-386
4 Brookes G (2005) The farm-level impact of herbicide-tolerant soybeans in Romania. AgBioForum 8:235-241
5 Demont M, Tollens E (2004) *Ex ante* welfare effects of agricultural biotechnology in the European Union: The case of transgenic herbicide tolerant sugarbeet.In: Evenson RE, Santaniello V The regulation of agricultural biotechnology. CAB International, Wallingford, UK, pp. 239-255
6 Demont M, Wesseler J, Tollens E (2004) Biodiversity versus transgenic sugar beet: The one euro question. Eur Rev Agric Econ 31:1-18
7 Demont,M. (2006) Economic impact of agricultural biotechnology in the European Union pp. 1-138, Katholieke Universiteit Leuven
8 Demont M (2006) Economic impact of agricultural biotechnology in the European Union: Transgenic sugar beet and maize. Katholieke Universiteit Leuven, Leuven
9 Dillen,K. *et al.* (2008) Modelling heterogeneity to estimate the ex ante value of biotechnology innovations, EAAE proc. 12th congress of the European association of Agricultural Economists, Gent, 2008
10 Frisvold GB, Sullivan J, Raneses A (2003) Genetic improvements in major US crops: The size and distribution of benefits. Agr Econ 28:109-119
11 Demont M, Wesseler J, Tollens E (2004) Biodiversity versus transgenic sugar beet: The one Euro question. Eur Rev Agric Econ 31:1-18
12 Dillen K, Demont M, Tollens E (2008) European sugar policy reform and agricultural innovation. Can J Agr Econ in press
13 Alston JM, Norton GW, Pardey PG (1995) Science under scarcity: principles and practice of agricultural research evaluation and priority setting. Cornell University Press, Ithaca, NY
14 Moschini G, Lapan HE (1997) Intellectual property rights and the welfare effects of agricultural R&D. Am J Agr Econ 79:1229-1242
15 Bureau J-C, Guyomard H, Morin L, Réquillart V (1997) Quota mobility in the European sugar regime. Eur Rev Agric Econ 24:1-30
16 Combette P, Giraud-Heraud E, Réquillart V (1997) La politique sucrière européenne après les accords du GATT: Une analyse de quelques scénarios d'évolution. Economie et Prévision 127:1-13
17 Moschini G, Lapan HE, Sobolevsky A (2000) Roundup Ready soybeans and welfare effects in the soybean complex. Agribusiness 16:33-55
18 Just R, Hueth D, Smith A (2004) The welfare economics of public policy. Edward Elgar, Cheltenham,UK
19 Nolte S (2008) The future of the world sugar market- A spatial price equilibrium analysis. European Association of Agricultural Economists 107th Seminar - 2008
20 European Commission (1999) The agricultural situation in the European Union: 1998 report. Office for Official Publications of the European Communities, Luxembourg
21 F.O.Licht (2001) World sugar statistics 2002. F.O.Licht, Kent
22 FAO (2006) FAOSTAT agriculture data. FAO, Rome
23 F.O.Licht (2005) World sugar yearbook 2006. F.O.Licht, Kent
24 USDA (2006) EU25 sugar semi anual Gain report
25 SUBEL (2007)
26 USDA (2006) Adoption of Genetically Engineered Crops in the U.S. http://www.ers.usda.gov/Data/BiotechCrops/
27 Griliches Z (1957) Hybrid corn: An exploration in the economics of technological change. Econometrica 25:501-522
28 Hermann O. (2006) Survey on pests and diseases in sugar beet growing and the cost of plant protection products in Europe CIBE congress 2006, Cracow
29 Hermann O (1997) Enquête sur le coût de la lutte phytosanitaire dans la culture de la betterave sucrière en Europe IIRB 60th Congress Proceedings. IIRB, Brussels, pp. 469-475
30 Poonyth D, Westhoff P, Womack A, Adams G (2000) Impacts of WTO restrictions on subsidized EU sugar exports. Agr Econ 22:233-245
31 Devadoss S, Kropf J (1996) Impacts of trade liberalizations under the Uruguay Round on the world sugar market. Agr Econ 15:83-96
32 Banse M, Grethe H, Nolte S (2005) Documentation of the ESIM model structure, base data and parameters. University of Göttingen and Humboldt University, Göttingen and Berlin
33 Bhagwati JN (1958) Immiserizing growth: A geometrical note. Review of Economic Studies 25:201-205
34 Falck-Zepeda JB, Traxler G, Nelson RG (2000) Surplus distribution from the introduction of a biotechnology innovation. Am J Agr Econ 82:360-369
35 Qaim M, Traxler G (2005) Roundup Ready soybeans in Argentina: farm level, environmental, and welfare effects. Agr Econ 32:73-86
36 Kniss AR, Wilson RG, Martin AR, Burgener PA, Feuz DM (2004) Economic evaluation of glyphosate-resistant and conventional sugar beet. Weed Technology 18:388-396
37 DeVuyst CS, Wachenheim CJ (2005) American Crystal Sugar: Genetically enhanced sugarbeets? Rev Agr Econ 27:105-116
38 Swinnen JFM, De Gorter H (1998) Endogenous commodity policies and the social benefits from public research expenditures. Am J Agr Econ 80:107-115
39 Bijman J (2001) KWS: going beyond sugar beet. AgBioForum 4:46-51
40 Confédération des Betteraviers Belges (2002)
41 Frandsen SE, Jensen HG, Yu W, Walter-Jørgensen A (2003) Reform of EU sugar policy: Price cuts versus quota reductions. Eur Rev Agric Econ 30:1-26

Use macro [author address] to enter the address of the corresponding author:

- Author:Koen Dillen
- Institute:Centre for agricultural and food economics, KULeuven
- Street:de Croylaan 42 bus 2424
- City: 3001 Heverlee
- Country: Belgium
- Email: koen.dillen@ees.kuleuven.be