European Sugar Policy Reform and Agricultural Innovation

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In July 2006, the European Union's (EU) Common Market Organization (CMO) for sugar underwent the first radical reform since its establishment in 1968. In this article, we study the incentives for adoption of new technologies before and after the policy reform. We build a stochastic partial equilibrium model and use it to analyze the effect of the policy reform on the adoption incentives of genetically modified herbicide tolerant sugar beet. Our findings show that the adoption incentives of high-cost sugar beet farmers are significantly reduced under the new CMO. Medium-cost producers, in contrast, have greater incentives to adopt new technologies, while low-cost producers are largely left unaffected. The reduced adoption incentives of high-cost farmers lead to lower flexibility and competitiveness of these farmers and therefore coincides with the goals of the reform to crowd out high-cost producers and increase competitiveness of the European sugar market.

En juillet 2006, l'Organisation commune du marché (OCM) du sucre a subi sa première réforme radicale depuis sa mise en place par l'UE en 1968. Dans la présente étude, nous avons examiné les incitatifs offerts pour l'adoption de nouvelles technologies, avant et après la réforme. Nous avons élaboré un modèle stochastique d'équilibre partiel et l'avons utilisé pour analyser les répercussions de la réforme sur les incitatifs offerts pour l'adoption de variétés de betteraves sucrières génétiquement modifiées résistantes aux herbicides. Selon nos résultats, les incitatifs offerts aux producteurs de betterave sucrière ayant des coûts marginaux élevés ont significativement diminué depuis la réforme de l'OCM du sucre. Par contre, les incitatifs offerts aux producteurs ayant des coûts marginaux moyens se sont accrus, tandis que ceux offerts aux producteurs ayant de faibles coûts marginaux n'ont pas changé. La diminution des incitatifs offerts aux producteurs ayant des coûts marginaux élevés entraîne une diminution de la souplesse et de la capacité concurrentielle de ces producteurs et, par conséquent, coïncide avec les objectifs de la réforme qui visent à évincer les producteurs ayant des coûts marginaux élevés et à accroître la capacité concurrentielle du marché européen du sucre.

INTRODUCTION

In 2006, the European Union (EU) implemented the first radical reform of the Common Market Organization (CMO) for sugar since its establishment in 1968. Two key factors are said to have initiated this reform. First, there is the conviction of the EU sugar policy on April 28, 2005, when after a complaint from Brazil, Thailand and Australia, it was decided that the export of out-of-quota sugar did not comply with World Trade Organization (WTO) rules because of a cross-subsidy effect. This so-called C-sugar is supposed to be traded on the world market at low prices due to the high support for in-quota sugar and is therefore indirectly supported by the policy. The second constraint is the Everything But Arms (EBA) agreement which will offer free access on the European sugar market for the least developed countries (LDCs) starting in 2009. To cope with this anticipated increased competition from LDCs, a more competitive European sugar sector is a necessity.

Several studies have attempted to estimate the effects of alternative reform scenarios of the European sugar sector and the CMO itself, both at the farm level and at the aggregate level (Schmitz 2002; Frandsen et al 2003; de Bont et al 2006; Gohin and Bureau 2006; Bogetoft et al 2007; Buysse et al 2007; Nolte 2008). These studies have focused on the demand and supply side of the sugar market assuming unaltered incentives for innovation. In contrast, we explicitly model the incentives for innovation under changing sugar policies, while taking the observed reform-induced changes in production incentives and consumption as given.

Market interventions are a key determinant of innovation because they distort the flow of benefits from R&D and, hence, the incentives for innovation in the agricultural sector (Alston et al 1995). However, although agricultural innovation could assist the European sugar sector to become more competitive, so far no studies have modeled to which extent this new policy alters the incentives for the adoption of new technologies.[1] Our paper assesses whether the indirect effect of the policy reform, i.e., its impact on innovation incentives, is consistent with the objectives of the reform to increase the competiveness of the European sugar sector. Specifically, we test whether the null hypothesis, namely *the policy reform has no influence on the stream of benefits from innovation*, holds, or not. Our analysis shows that this test depends on the production costs of EU sugar beet producers. We find that technology adoption by high-cost producers is discouraged by the reform. In contrast, medium-cost producers have greater incentives to adopt new technologies. Low-cost producers are affected very little in terms of their incentives to adopt new technologies. Overall, these results suggest that, consistent with its goal, the new CMO will lead to a crowding out of high-cost producers and will increase the competiveness of the European sugar sector.

Our model is a stochastic partial equilibrium model and the specific innovative crop we analyze is genetically modified (GM) herbicide tolerant (HT) sugar beet. The case of herbicide tolerance in sugar beet growing is very appealing for EU agriculture as sugar beet is grown in most of its member states and weed control is crucial to economic beet production. Previous research has forecast that EU beet growers could substantially gain from HT technologies (Demont and Tollens 2004; Demont et al 2004; Demont 2006). Most European countries have sufficient research experience in GM sugar beet, but for the time being their processing industries remain largely reluctant to accept this technology due to the fear of losing domestic and export markets (DeVuyst and Wachenheim 2005). In the United States, in contrast, many processors have cleared their growers to plant GM HT sugar beet in the spring of 2008, developed by the gene developer Monsanto and seed company Betaseed (part of the KWS Group).[2]

A key factor in modeling the European CMO for sugar is the specification of responsiveness of out-of-quota supply to world prices in the distorted world market. Beet growers may overshoot their quotas for two reasons, namely (i) as a precautionary measure to ensure quota fulfillment, or (ii) to speculate on the world market. In the literature, alternative argumentations on the incentives behind observed out-of-quota production have been presented (see Buysse et al 2007 for a review). In this article we propose a balanced multi-criteria system to identify member states that consistently supply out-of-quota sugar in response to world prices.

The paper is organized as follows. In the next section, we introduce the stochastic partial equilibrium model which explicitly models the old and the new EU sugar regimes. It simulates the impact of the introduction of GM sugar beet in the EU with spillovers to the sugar beet sector in the rest of the world (Row). In the following two sections we calibrate the model with data borrowed from various sources and report the outcomes of a Monte Carlo simulation. The final section concludes.

MODEL

The Framework

The focus in our framework lies at the level of the farmers, who are the main actors in the adoption process of new varieties of crops. The incentive to innovate and adopt is assessed in a rational choice model (see Scot 2000, for a review and common critiques), that is, a farmer makes his decision purely based on the per-hectare profit of adoption. For suppliers of the innovative input, HT sugar beet in this example, only the revenue is estimated here.[3] To analyze the potential benefits of the introduction of HT sugar beet in the sugar sector, we set up a spatial model that differentiates between sugar cane and sugar beet. The sugar beet region is further subdivided into the EU-27[4] and the ROW. We believe that a three-region model captures well the essence of production and trade in the global sugar market.

Moschini and Lapan (1997) argue that impact assessments of new technologies should account for the relevant institutional and industry structures responsible for the actual development of these technologies. Most of the recent agricultural biotechnology innovations are patented by private firms. Prices for such patented inputs are of course higher than they would be in a perfectly competitive market. Our model draws on the impact assessment framework of Moschini et al (2000), which assumes monopoly power in the input market. They develop a profit function for farmers operating in the output market which explicitly accommodates the characteristics of the HT technology. By introducing the simplifying assumption of exogenous monopolistic pricing of the technology in the profit function, they separate the incentives for innovation from the incentives for the adoption of the proprietary technology:

$$\bar{\pi}_{i,j}(p,\rho) = A_{i,j} + \rho\alpha_i + \frac{(1+\rho\beta_i)G_{i,j}}{1+\eta_i} p^{1+\eta_i} - \mu_i\rho \tag{1}$$

where the HT technology is parameterized through four parameters, i.e., the adoption rate ρ, the technology-induced per-hectare profit gain α_i, the yield boost β_i in percentage and the per-hectare licensing premium or "technology fee" μ_i. Furthermore, $A_{i,j}$ and $G_{i,j}$ represent scale parameters (i represents the region and j the year), p the sugar price, and η_i the elasticity of yield with respect to sugar prices (as defined by Moschini et al 2000).

Applying Hotelling's lemma, the yield function (i.e., supply-per-hectare function) can be shown to be $(1+\rho\beta)G_{i,j}p^{\eta_i}$. Next, the supply of the scarce factor to the industry, i.e., land, is represented by an upward-sloping non-linear constant-elasticity function of the average per-hectare profit:

$$L_{i,j} = \lambda_{i,j}\bar{\pi}_{i,j}(p,\rho)^{\theta_{i,j}} \tag{2}$$

Multiplying the land supply function with the yield function results in a region- and year-specific supply function:

$$Q_{i,j}(p,\rho) = \lambda_{i,j}[\bar{\pi}_{i,j}(p,\rho)]^{\theta_{i,j}}\,(1+\rho\beta_i)G_{i,j}\,p^{\eta_i} \tag{3}$$

where $\lambda_{i,j}$ is a scale parameter and $\theta_{i,j}$ the land supply elasticity (area elasticity) with respect to sugar beet profit per hectare. As far as the supply function is concerned we distinguish 18 regions, i.e., the ROW cane region ($i = 0$), the ROW beet region ($i = 1$), 16 EU-27 member states ($i = 2, 3, \ldots, 17$) (see Table 1); and nine agricultural seasons (2006–14).[5]

Aggregation of 18 supply functions allows for a sophisticated analysis of the impact on world sugar prices of the introduction of the HT technology. While all regions respond to certain region-specific prices, in reality only the producers in most competitive regions respond to world market prices. Uncompetitive regions are isolated from world market incentives due to the combination of high production costs and domestic price regulations. Their supply is inelastic and, instead of exporting on the world market, any surplus generated through enhanced yields will be absorbed by their domestic quotas and will free up land allocated to sugar beet. Hence, we distinguish between world price responsive (WPR) and world price nonresponsive (WPN) member states, which will be identified through a multi-criteria framework at a later stage in this paper. The aggregate EU sugar supply function in year j is given by

$$Q_{\mathrm{EU},j}(p,\boldsymbol{\rho}_{\mathrm{EU}}) = \sum_{i=2}^{17} Q_{i,j}(p,\rho_i) = \sum_{i=WPN} \bar{Q}_{i,j} + \sum_{i=WPR} Q_{i,j}(p,\rho_i) \tag{4}$$

In Equation (4), $\boldsymbol{\rho}_{\mathrm{EU}}$ represents the 16×1 adoption vector of the new technology in the EU with elements ρ_i ($i = 2, 3, \ldots, 17$). This aggregate sugar supply function is very detailed in that it contains 10 parameters per member state totaling 160 parameters, of which 64 are related to the new technology.

Next, we model the adoption of new technologies. The adoption occurs in a large, open economy with technology spillovers, where we shape the two-region framework of Alston et al (1995, p. 219) to the specific features of the EUs CMO for sugar. For each beet growing region i, the four technology-specific parameters (ρ_i, α_i, β_i, μ_i) engender a pivotal, divergent shift of the supply curve (Equations (1)–(3)). At the center of the analysis is the calculation of a counterfactual world price p_j in year j to isolate the effect of the technology-induced supply shift from other exogenous changes in supply and demand. It represents what the world price would be if all supply and demand conditions are identical except for the introduction of the new technology. Hence, in our analysis we represent the world price as a function of the worldwide adoption vector: $p_j(\boldsymbol{\rho}_{\mathrm{W}})$.

Table 1. Regional specification of incentive prices and elasticities

Region	$\varphi^*_{i,j}$ Former	$\varphi^*_{i,j}$ New	Incentive price Former	Incentive price New	Area elasticity	Elasticity of yield
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 (industrial)	0.055	0.08
Denmark	3	7	B-sugar price	instit. price	0.034	0.08
Germany	4	8	world price (C)	world price (industrial)	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 (industrial)	0.172	0.08
Italy	1	7	A-sugar price	instit. price	0.712	0.08
The 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 (industrial)	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 (industrial)	0.176	0.08
Czech Rep.	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 (1998), Confédération des Betteraviers Belges (2002), Frandsen et al (2003), and Banse et al (2005).
*Legend for $\varphi_{i,j}$: 0 = A-quota not fulfilled; 1 = A-quota fulfilled; 2 = A-quota fulfilled and significant part of B-quota; 3 = A-quota and B-quota fulfilled but world price nonresponsive (WPN) sugar production; 4 = A-quota and B-quota fulfilled but world price responsive (WPR) sugar production; 5 = ROW but WPN sugar production; 6 = ROW and world price responsive (WPR) sugar production; 7 = post-reform quota fulfilled; 8 = post-reform quota fulfilled and world price responsive (WPR) sugar production.

The EUs export supply curve in year j is given by

$$ES_j(p, \boldsymbol{\rho}_{\mathrm{EU}}) = Q_{\mathrm{EU},j}(p, \boldsymbol{\rho}_{\mathrm{EU}}) - C_j \tag{5}$$

where C_j is EU sugar demand in year j, assumed exogenous and independent of the price due the inelastic response to sugar prices in the EU (FAO 2003). The EUs export supply expansion, generated by a technology-induced pivotal shift of the EUs aggregate supply function, would cause the world price to decline from $p_j(0)$ to $p_j(\boldsymbol{\rho}_{\mathrm{EU}})$. This price decrease is determined using a reduced-form equation, extracted from the University of Missouri's 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).[6] For each year j the reduced-form equation transforms the observed world price into the price that would result from the EUs technology-induced export expansion in year j and j–1:

$$p_j(\rho_{\mathrm{EU},j}) = p_j(0)\left[1 + \sigma_1 \frac{ES_j(p_j(0), \rho_{\mathrm{EU},j}) - ES_j(p_j(0), 0)}{ES_j(p_j(0), 0)} + \sigma_2 \frac{ES_{j-1}(p_{j-1}(0), \rho_{\mathrm{EU},j-1}) - ES_{j-1}(p_{j-1}(0), 0)}{ES_{j-1}(p_{j-1}(0), 0)}\right] \quad (6)$$

with $\sigma_1 = -1.0$ and $\sigma_2 = 0.46$. The variables σ_1 and σ_2 are the short- and long-run flexibility, respectively, and they reflect 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 $p_j(\boldsymbol{\rho}_{\mathrm{EU}})$. The reaction stems mainly from the ROW cane sector. The ROW beet region supplies less than 2% of globally traded sugar (World Sugar Yearbook 2006) and can therefore be considered "small," i.e., facing an infinitely elastic export demand function and not able to influence world prices significantly through innovation in the beet sector solely. ROW sugar policies further weaken the link between world prices and domestic prices and supply. Therefore, we model the ROW beet region as WPN and, as a result, in our model world prices are not affected by technology spillovers to this region. In addition, if we assume no spillovers of biotechnology in sugar beet breeding to the ROW cane sector, the following equality holds: $p_j(\boldsymbol{\rho}_{\mathrm{W}}) = p_j(\boldsymbol{\rho}_{\mathrm{EU}})$, i.e., the world price is independent of $\boldsymbol{\rho}_0 = 0$ and $\boldsymbol{\rho}_1$.

The Old Common Market Organization for Sugar

The overall world price change can be transmitted to EU domestic prices using the principles of the EUs former CMO for sugar, which came into full effect in 1968 and ended on June 30, 2006. At the start of each year j, the Council of the European Union fixed an *intervention price* ($p^i_{\mathrm{EU},j}$) for sugar and *minimum prices* for beet. The quotas, consisting of A- and B-sugar ($\bar{Q}_{a,j}$ and $\bar{Q}_{b,j}$), filled under the high price support system, were set at a higher level than internal consumption C_j, at the intervention price $p^i_{\mathrm{EU},j}$. This overproduction $\bar{Q}_{d,j}(=\bar{Q}_{a,j} + \bar{Q}_{b,j} - C_j)$ was exported on the world market and hence subsidized. This export subsidy system was completely auto-financed by levies on A- and B-quota production. Consumers, who paid a high internal intervention price, subsidized the internal within-quota production. A levy τ^a_j of maximum 2% of the intervention price applied to the entire quota. Moreover, B-quota production received an additional, more variable, levy τ^b_j of maximum 37.5% of the intervention price. Both levies were chosen to satisfy the auto-financing constraint, AFC_j, which was a function of the world price (Combette et al 1997):

$$p^i_{\mathrm{EU},j}\,\tau^a_j\,(p_j(\boldsymbol{\rho}_{\mathrm{W}}))(\bar{Q}_{a,j} + \bar{Q}_{b,j}) + p^i_{\mathrm{EU},j}\tau^b_j(p_j(\boldsymbol{\rho}_W))\bar{Q}_{b,j} - (\bar{Q}_{a,j} + \bar{Q}_{b,j} - C_j)\big(p^i_{\mathrm{EU},j} - p_j(\boldsymbol{\rho}_{\mathrm{W}})\big) = 0 \quad (7)$$

The levies had to fill the gap between the world price and the high internal price for quota production which was in excess of consumption and exported on the world market. If AFC_j did not solve by combining Equations (7) and (8), the system of Equations (7) and (9) was solved. Finally, when the latter neither yielded a solution, a multiplicator ν_j was defined solving the system 7 and 10:

$$\begin{cases} \tau_j^a(p_j(\boldsymbol{\rho}_{\mathrm{W}})) \in [0, 0.02] \\ \tau_j^b(p_j(\boldsymbol{\rho}_{\mathrm{W}})) = 0 \end{cases} \tag{8}$$

$$\begin{cases} \tau_j^a(p_j(\boldsymbol{\rho}_{\mathrm{W}})) = 0.02 \\ \tau_j^b(p_j(\boldsymbol{\rho}_{\mathrm{W}})) \in [0, 0.375] \end{cases} \tag{9}$$

$$\begin{cases} \tau_j^a(p_j(\boldsymbol{\rho}_{\mathrm{W}})) = 0.02(1 + \upsilon_j) \\ \tau_j^b(p_j(\boldsymbol{\rho}_{\mathrm{W}})) = 0.375(1 + \upsilon_j) \end{cases} \tag{10}$$

By feeding the technology-induced world price $p_j(\boldsymbol{\rho}_{\mathrm{W}})$ into Equation (7), the system of Equations (7)–(10) yielded an estimate of the levies that had to be imposed on quota-production to satisfy AFC_j. This specification clearly visualizes how the levies were a function of the world price, while the world price on its turn was a function of worldwide adoption. World prices were transmitted to levy changes through solving AFC_j. For each member state, A- and B-quota prices could be deducted from the State's intervention price $p_{i,j}^i$ and the levies:

$$p_{i,j}^a(p_j(\boldsymbol{\rho}_{\mathrm{W}})) = p_{i,j}^i\left[1 - \tau_j^a(p_j(\boldsymbol{\rho}_{\mathrm{W}}))\right] \tag{11}$$

$$p_{i,j}^b(p_j(\boldsymbol{\rho}_{\mathrm{W}})) = p_{i,j}^i\left[1 - \tau_j^a(p_j(\boldsymbol{\rho}_{\mathrm{W}})) - \tau_j^b(p_j(\boldsymbol{\rho}_{\mathrm{W}}))\right] \tag{12}$$

By substituting $p_j(\boldsymbol{\rho}_{\mathrm{W}})$ into Equations (11) and (12), the model allows us to transform world price changes into domestic quota price changes. Thus, under the former CMO the farm-gate price was endogenous since it depended on sugar production, internal demand and the gap between the intervention and the world price. All out-of-quota production could 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.

The opposite effects of technology-induced cost-reduction and depression of world and domestic prices are transmitted to the average profit functions by imputing the corresponding prices and adoption rates (Equation (1)). Note that the profit functions are a function of (i) region-specific and (ii) worldwide adoption rates, the latter through the world price: $\bar{\pi}_{i,j}[p_{i,j}^a(p_j(\boldsymbol{\rho}_{\mathrm{W}})), \rho_i]$ for A-quotas, $\bar{\pi}_{i,j}[p_{i,j}^b(p_j(\boldsymbol{\rho}_{\mathrm{W}})), \rho_i]$ for B-quotas, and $\bar{\pi}_{i,j}[p_j(\boldsymbol{\rho}_{\mathrm{W}}), \rho_i]$ for C-sugar beet. If $L_{i,j}(\bar{\pi})$ denotes the optimal allocation of land to sugar beet in member state i in year j, the variation in producer surplus (relative to the benchmark without adoption) due to the innovation can be measured in the market of land supplied to the industry (Moschini et al 2000).

Table 2. Multi-criteria framework for identifying WPR sugar producers in the EU

	Frandsen (2003)	Frandsen (2003) revisited[a]	Poonyth (1998)	Gohin and Bureau (2006)	Buy-out in first 2 year[c]	Score
Belgium			WPR		No	WPR (3/5)
Denmark		WPR			No	
Germany	WPR	WPR	WPR	WPR	No	WPR (5/5)
Greece					Yes	
Spain					Yes	
France	WPR		WPR	WPR	No	WPR (4/5)
Italy					Yes	
The Netherlands				WPR	No	
Austria	WPR		WPR		No	WPR (3/5)
Portugal					Yes	
Finland					Yes	
Sweden		WPR			Yes	
United Kingdom	WPR	WPR	wrong[b]	WPR	No	WPR (4/5)
Czech Republic		WPR			Yes	
Hungary		WPR			Yes	
Poland		WPR			No	

Sources: Poonyth (1998), Frandsen et al (2003), Gohin and Bureau (2006).
[a]We extend the criterion of Frandsen et al (2003) to the period 1996–2006 (World Sugar Yearbook 2006).
[b]The authors did not use the correct mixed price in their econometric model.
[c]The fact that countries decide not to sell any quota despite this incentive means they are able to produce at the lower internal price, hence being competitive.

The producer surplus change strongly depends on the position of the supply curve and, hence, the member state's competitiveness in sugar production. Therefore, we introduce the categorical parameter $\varphi_{i,j}$ (Table 2). Depending on the value we attribute to this parameter, the model automatically selects the appropriate formula for the calculation of the welfare effects. Detailed information about the formulas can be found in Dillen et al (2007a). For a high-cost EU member not fulfilling its A-quota we set $\varphi_{i,j} = 0$. Portugal and Greece are the only examples. A high-cost EU member state, fulfilling its A- but not its B-quota is assigned $\varphi_{i,j} = 1$. The beet growers 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 EU countries fulfilling their A-quota and a significant part of its B-quota, we set $\varphi_{i,j} = 2$.

As mentioned previously, the estimation of world price effects crucially hinges on the specification of world price responsiveness of sugar supply. Particular attention needs to be given to the distinction between WPR and WPN member states.[7] Buysse et al (2007) summarize the literature on the specification of the sugar supply curve and the incentive to produce C-sugar. The first approach they discuss is developed by Gohin and Bureau (2006) who show that, in contrast to the WTO decision on C-sugar, cross-subsidization from the high price quota to the fixed costs of C-sugar production cannot be sustained in the long run. The second motivation for the production of C-sugar discussed is an insurance strategy against losses due to not filling the quota. However, Adenäuer and Heckelei (2005) show that this insurance strategy is only one factor in the decision, temporal variability being at least as important. Therefore, Buysse et al (2007) define a precautionary sugar beet supply as a function of the quota endowment and rent, taking into account farm-specific characteristics that play a role in this variability. Unfortunately, their analysis is based on farm level modeling and cannot be easily extrapolated to the aggregate level. Frandsen et al (2003) define WPN member states as those that overshoot their quota by less than twice the standard deviation of total production. They argue that WPN member states would normally not supply C-sugar, since the rents of the latter are not sufficient to cover production costs. Since quota fulfillment is the primary objective of WPN member states, we assume that risk premiums and stock decisions are exogenous.

In order to get a more balanced distinction between WPN and WPR member states we extend the single-criterion framework of Frandsen et al (2003) and present a multi-criteria framework in Table 2, by adding four additional criteria based on the literature and the success of the buy-out scheme. In our multi-criteria framework, we define WPR member states as those that satisfy more than half, i.e., at least three out of five, of the criteria in Table 2. We revisit the criterion proposed by Frandsen et al (2003) and apply it on a longer time series of data, i.e., 1996–2006. Further, we base our third and fourth criteria on econometric evidence provided by Poonyth (1998) and Gohin and Bureau (2006). Finally, we use observed post-reform behavior of member states as a fifth indicator. Application of the buy-out scheme in the post-reform period indicates the inability of a member state to produce at reduced post-reform internal prices and, hence, the inability to respond to world prices, which are even lower than internal prices. Our enhanced framework suggests adding Belgium to Frandsen et al's (2003) original list of WPR member states, i.e., Austria, France, Germany, and the United Kingdom.

The New Common Market Organization for Sugar

On the first of July 2006 a new CMO for sugar was introduced. The key features of the reform were (i) a progressive cut of the EU institutional 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 new institutional sugar price is not fixed in the short-run but in the long-run it is. In order to facilitate the desired reduction in production, a buy-out scheme was established. In the four-year period following the reform, sugar producers can sell their quota to the EU for an annually declining compensatory payment, which evolves from €730/ton in the first two years to, respectively, €625/ton and €520/ton in the third and fourth year. This should stimulate less competitive producers to reduce or abandon production. If the reduction were to be insufficient in 2010 to reach the goals set by the EU (12.5 million tons), the EU could decide on a linear quota cut for all European producers (European Parliament 2006).

For our model, the introduction of the new CMO has several structural implications. Supply and quota decisions depend to a large extent on the prices for sugar. Furthermore, this decision is influenced by a restructuring amount to be paid for each quota held which creates an incentive to sell excess quota as soon as possible. Therefore, we introduce two new post-reform categories of competitiveness (for an overview of all categories, see the legend of the categorical parameter $\varphi_{i,j}$ below Table 2). Producers not filling their quota under the old regime ($\varphi_{i,j} = 0, 2$), will sell their excess quota under the new institutional price and join the group of post-reform quota-fillers ($\varphi_{i,j} = 7$), together with pre-reform quota-fillers ($\varphi_{i,j} = 1, 3$) although the latter might sell some of the initially allocated quota due to the reduced sugar prices. WPR member states ($\varphi_{i,j} = 4$) are affected the most, since they have to give up all sugar production supplied to the world market but we assume that they remain WPR after the reform ($\varphi_{i,j} = 8$).

Due to WTO obligations, export of sugar is limited to 1.4 million tons white sugar per year. As a rule, this amount is filled with excess quota sugar. Only if the budget is not sufficient to fill the gap between the institutional price and the world price or the excess supply of quota sugar is smaller than 1.4 million tons there is a possibility to export out of quota sugar. Therefore, EU sugar production targeted to the world market is marginal. Low-cost producers can supply their excess out-of-quota sugar only to the small European industrial market. On this market European sugar producers are price takers since they have to compete with imported sugar and the limited size of this market. They get some rents through reduced costs but cannot influence world prices. The ROW cane industry is assumed to respond to the world price, but since no technology spillovers are assumed between beet and cane industries, cane producer surplus is only affected through world prices.

The innovation rents of A- and B-quota producers are estimated taking into account member state-specific pricing systems, quota and price responsiveness (see Demont 2006, pp. 115–118 for detailed formulas). The innovation rents of the European sugar beet producers post-reform are calculated following the same formulas depending on the categorical variable $\varphi_{i,j}$. The innovation rents of WPR member states under the old regime are measured along the supply curve of land to the sugar beet industry (Moschini et al 2000):

$$\Delta PS_{i,j}(p_j(\boldsymbol{\rho}_{\mathrm{W}}), \rho_i) = \int_{\bar{\pi}_{i,j}(p_j(0),0)}^{\bar{\pi}_{i,j}(p_j(\boldsymbol{\rho}_{\mathrm{W}}),\rho_i)} L_{i,j}(\bar{\pi})\, d\bar{\pi} \tag{13}$$

For WPN member states we assume inelastic land supply; instead of allocating more land, they respond to yield-enhancing technologies by freeing up land allocated to sugar beet. Hence, their innovation rents are measured as follows:

$$\Delta PS_{i,j}(p_j(\boldsymbol{\rho}_{\mathrm{W}}), \rho_i) = \frac{\bar{Q}_{i,j}}{y\left(p_j(\boldsymbol{\rho}_{\mathrm{W}}), \rho_i\right)} \left[\bar{\pi}_{i,j}\left(p_j(\boldsymbol{\rho}_{\mathrm{W}}), \rho_i\right) - \bar{\pi}_{i,j}\left(p_j(0), 0\right)\right] \tag{14}$$

Finally, to calculate the profit of the input suppliers in the case of GM sugar beet, we can reasonably assume that they will apply uniform monopolistic pricing at the EU-27 level (Dillen et al 2007b). Therefore, the gross revenue captured by the input suppliers can be modeled as the accumulation of monopolistic technology fees (μ_i) on the entire area of land supplied to the sugar beet industry in equilibrium and planted with GM crops (Moschini et al 2000):

$$\Pi_j(p_j(\boldsymbol{\rho}_{\mathrm{W}}), \boldsymbol{\rho}_{\mathrm{W}}) = \sum_{i=0}^{18} \rho_{i,j} L_{i,j}(p_j(\boldsymbol{\rho}_{\mathrm{W}}), \rho_i)\mu_i \tag{15}$$

Table 3. Global production of sugar beet and profits from HT technologies in 2006

	Area (ha)	Production (t white sugar)	Yield (t/ha)	Profit from HT sugar beet (€/ha)
Belgium	86,078	960,248	11.2	174
Denmark	48,595	475,047	9.8	145
Germany	405,136	4,090,902	10.1	108
Greece	37,490	294,897	7.9	63
Spain	114,334	1,207,097	10.6	192
France	349,906	4,328,332	12.4	131
Italy	26,375	185,281	7.0	45
The Netherlands	92,373	991,380	10.7	151
Austria	48,348	499,314	10.3	188
Portugal	7,091	65,467	9.2	223
Finland	32,316	158,930	4.9	102
Sweden	53,278	420,344	7.9	71
United Kingdom	118,737	1,257,945	10.6	99
Czech Republic	69,621	568,496	8.2	101
Hungary	63,519	497,047	7.8	78
Poland	292,579	2,047,234	7.0	96
EU-27	1,901,149	19,845,900	10.4	117[a]
ROW beet	3,088,900	14,826,720	4.8	117[a]
ROW cane	21,634,040	98,867,570	4.6	n.a.
World	26,624,089	133,540,190	5.0	n.a.

Sources: World Sugar Yearbook (2006), Dillen et al (2007b).
Notes: n.a.: not applicable; t: tons.
[a]EU area-weighted average.

DATA AND MODEL CALIBRATION

Our model is calibrated on the observed production data for the period 2004–06. Observed yields, world sugar prices on the London no. 5 exchange, quantities ($\bar{Q}_{i,j}$), and quota ($\bar{Q}^a_{i,j}$ and $\bar{Q}^b_{i,j}$) are taken from World Sugar Yearbook (2006), USDA (2006), and FAO (2007) (Table 3). Our counterfactual scenario projects the old regime up to 2014, assuming that production remains fixed at the pre-reform 2005 level. The factual scenario is based on observed post-reform 2006 data. Future price and consumption levels come from the World Sugar Outlook (2006) and future yields are derived through linear extrapolation of historical trends (World Sugar Yearbook 2000, 2006). The sugar prices, as forecast by FAPRI, account for the new CMO and could therefore affect our outcomes. However, the new regime, although eliminating a lot of the European export, is not the major factor influencing world sugar prices. For example right after the introduction of the new CMO, world prices went down due to record yields in Brazil and Thailand in 2007. Other major influences are the demand for bio-ethanol and decreasing stocks (as in India during 2007). We assume that only WPR producers supply industrial sugar after the reform and up to an amount of 1.5 million ton (SUBEL 2007), shared among producers and weighted according to their quota. The other member states are assumed to just fulfill their quota.

To calibrate the average profit function, we need an approximate estimate of the profit in all regions. Thelen (2004) compares per-hectare profits among four beet producers (Poland, Ukraine, the United States, and Germany) and six cane producers (Brazil, Australia, Thailand, South-Africa, India, and the United States). Since after an extensive sensitivity analysis it appears that this is just an inconsequential scaling parameter, we use the estimate of Germany for the EU-27 and calculate the area-weighted averages for the ROW cane and beet regions. All cost and price data are first deflated and actualized to the agricultural season 2006/07 using the GDP country deflators from the World Bank's World Development Indicators, and then converted to Euro using the Euro/USD exchange rate for 2006. We use the technology fee and adoption ceilings estimated by Dillen et al (2007b). We allow for technology spillovers to the ROW beet region but, as mentioned before, we assume no changes in the ROW cane region.

As we carry out the analysis before adoption has been observed, the relevant adoption data are not yet available. Moreover, the estimation of certain parameters, such as elasticities, is surrounded by uncertainty. Therefore, we construct subjective distributions for these parameters, using all prior information available. We generate stochastic distributions of the outcomes of the model using Monte Carlo simulations. For sugar beet, it is widely accepted that conventional herbicides harm the crop because of the low selectivity of the used herbicides (Märländer 2005). Field trials comparing HT sugar beet with conventional control practices suggest that yield boosts vary between 0% and 8% (Wevers 1998; Bückmann et al 2000; May 2003), due to greater weed control and reduced crop injury. We construct a triangular distribution for this parameter (minimum = 0%, most likely value = 4%, maximum = 8%) to capture this uncertainty. Dillen et al (2007b) extend the *ex ante* impact assessment framework of Demont et al (2008), and estimate per-hectare profit gains of HT sugar beet in all EU member states for the agricultural season 2004 (shown in the last column of Table 3). Their profit estimates are based on parametric modeling of heterogeneity of herbicide expenditures of beet growers and extrapolated to the entire period 2006–14 in our model.

To calibrate the model, we need to define incentive prices $\hat{p}_{i,j}$ for all regions i (Table 1). The incentive price for the ROW, $\hat{p}_{0,j}$ corresponds to the world price. For EU member states, the incentive price depends on the state's competitiveness and the national pricing system applied to pay beet growers and processors. The incentive prices under the former CMO for sugar are modeled in a dynamic way and depend on the world price, which, in turn, depends on world-wide adoption rates. Incentive prices can be A-sugar prices $p^a_{i,j}(p_j(\boldsymbol{\rho}_\mathrm{w}))$, B-sugar prices $p^b_{i,j}(p_j(\boldsymbol{\rho}_\mathrm{w}))$, a member state-specific mixed price $p^m_{i,j}[p^a_{i,j}(p_j(\boldsymbol{\rho}_\mathrm{w})), p^b_{i,j}(p_j(\boldsymbol{\rho}_\mathrm{w})), p_j(\boldsymbol{\rho}_\mathrm{w})]$ or the world price $p_j(\boldsymbol{\rho}_\mathrm{W})$ (see Demont 2006). For the new CMO, the incentive price for in-quota sugar ($p^o_{i,j}$) is set equal to the reference price level (which is decreasing in time) and the out-of-quota incentive price is the world price $p_j(\boldsymbol{\rho}_\mathrm{W})$. The model is calibrated on the pre-innovation equilibrium, i.e., we set $\boldsymbol{\rho}_\mathrm{W} = 0$.

In Table 1, we combine different literature sources and our categorical system mentioned above to calibrate supply curves with member state-specific incentive prices and area elasticities. 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 et al 2005):

$$\theta_{i,j} = \psi_i r_{i,j} = \psi_i \left[\frac{\hat{\pi}_i}{\hat{p}_{i,j} y_{i,j}} \right] \tag{16}$$

Since our model features disaggregated area response (ψ_i) and yield response (η_i) to prices we need to find elasticities that correctly represent farmers' behavior and incentives in the global sugar beet sector. In a quota system with fixed prices, the annual within-quota price variation is too small to obtain reliable estimates of the elasticities of supply. Quota rents of WPN member states are not significantly affected by supply response and therefore their supply elasticities do not influence the results. WPR member states, in contrast, significantly affect world prices and global welfare through technological innovation. Therefore for them, precise estimates of area response to world prices are needed. Poonyth et al (2000) report short- and long-run area elasticity estimates for 13 EU member states.[8] As they do not include any standard deviations for ψ_i, we construct symmetric triangular distributions with the short-run estimate as the minimum value, the long-run estimate as the maximum value, while we assume that the most likely value is the average of the short run and long run estimates. 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. For Greece and Portugal we use Devadoss and Kropf's (1996) supply elasticity estimate of 0.228 for A-quota sugar. As supply elasticities already incorporate yield response to prices, we set $\eta_i = 0$ for these member states. We borrow area elasticities for the new member states and yield elasticities from the ESIM-model of Banse et al (2005) and use the aggregate EU-27 elasticity of yield for all member states, $\eta_i = 0.08$. Unless otherwise stated, for all structural elasticities we construct symmetric triangular distributions centered on the average value and ranging from zero to twice the average value, based on strict positivity from theory.

RESULTS

We conduct a Monte Carlo simulation of 3,000 iterations to generate stochastic distributions for the results, using the software program @Risk from Palisade Corporation (Ithaca, NY). Given the assumed, estimated and retrieved parameters, in each random draw the model is calibrated on the pre-innovation structural parameters so as to retrieve pre-innovation acreage, quantity, yield, and price data for each year j. Two alternative scenarios have been assessed: first the observed factual introduction of the new regime in 2006, and second the counterfactual projection of the former CMO up to 2014. The basic question is whether the differences in innovation incentives among the two regimes are robust under a set of reasonable assumptions.

To analyze hypotheses of interest on transformed prior distributions of stochastic simulations, Davis and Espinoza (1998) use the distribution-free Chebychev inequality on the pairwise differences between alternative outcomes of the model. However, Griffiths and Zhao (2000) argue that this inequality is unnecessarily imprecise and recommend the use of ordinary probability intervals. If the null-hypothesis of this paper, H_0: *the policy reform has no influence on the stream of benefits from innovation*, is true, a probability interval of the pairwise differences of the alternative outcomes under both CMOs should contain the value zero. If it is rejected, the probability intervals show a significant deviation from zero, leading to higher or lower incentives after the reform.

Our results reveal that there are significant differences between the old and the new sugar regime for both farmers and input suppliers. Table 4 shows the 95% probability intervals of the reform-induced welfare gains of the new technology for the different member states. The reduction of institutional sugar prices in the EU implies a lower revenue for sugar beet producers. However not all producers are affected the same way as their supply responds to different incentive prices. High-cost sugar beet producers who responded to the high A-quota price face the steepest price drop. The latter implies a significant reduction of adoption incentives under the new regime. This effect is observed for Portugal, Italy, and Finland, where farmers gain on average €25/ha less from the innovation under the new CMO. For medium-cost producers, before adjusting supply according to B-quota prices, the situation is different. Although the average revenue (over the produced A- and B-quota) declines, their incentive price in fact increases. The new reference price for sugar is set between the old A- and B-quota prices. Therefore B-quota producers could gain from the reform. This gain is higher during the restructuring period due to the gradual reduction of the institutional price. Once the restructuring period is over in 2010, the institutional price is close to the old B-sugar price, reducing the additional incentives for innovation. This theoretical explanation is confirmed by the outcomes of the model. For medium-cost B-sugar producers, such as Spain, the Czech Republic, Hungary, Poland, Denmark, and Sweden, we observe significant positive effects on the incentives for innovation. The Netherlands, although also a B-sugar producer, has no significant outcome due to the use of the mixed pricing system in the former regime, which sets the incentive price a little above the B-sugar price, close to the new institutional price. Intuitively, we would have expected C-producers to have higher innovation incentives after the reform due to a smaller depressing effect of EU sugar exports on world prices. However, C-producers' innovation incentives seem to be largely unaffected by the reform. This holds for the highly competitive WPR member states Austria, Belgium, Germany, France, and the United Kingdom. These results suggest rejecting the null hypothesis of the paper, as the benefits stream of the innovation is indeed affected by the reform. The issue is whether this result interferes with the goals of the new CMO of increased competitiveness. Since the innovation incentive for high-cost producers is reduced, innovation is discouraged compared to the former CMO. On the other hand, producers with lower costs are encouraged to innovate or remain unaffected by the reform. They are stimulated to reduce production costs even further and are better prepared to cope with future changes in the market caused by biofuels or price changes. The reform increases the competitiveness of low-cost producers and potentially accelerates crowding out of high-cost producers. These results are in line with the predictions of Demont (2006, pp. 89–91).

The situation for the input suppliers is different. Under the new sugar regime, total production decreases following the abolishment of quota by high-cost producers. As a result, the total annual technology revenue for the supplier declines (Table 4). This might explain the observed lower priority that seed producers are currently attributing to the regulatory approval of HT sugar beet seed for cultivation in Europe (Monsanto 2007). *Ceteris paribus*, the decrease in revenue implies a decrease in profit and the incentive for innovation for the technology provider. The latter, however, might be partly offset by

Table 4. Ninety five percent probability intervals of farmers' profit differences (€/adopted hectare) and input suppliers' revenue (m€)

	2006	2007	2008	2009	2010
Belgium	(−21.9; 88.5)	(−20.2; 83.1)	(−22.1; 88.8)	(−23.1; 92.3)	(−23.3; 93.2)
Denmark	**(10.6; 137.8)**	**(2.2; 111.9)**	(−7.2; 102.0)	(−15.3; 93.8)	(−15.4; 94.8)
Germany	(−23.7; 97.0)	(−21.9; 91.7)	(−24.0; 97.5)	(−25.1; 101.2)	(−25.4; 102.3)
Greece	(−44.6; 3.9)	(−64.4; 1.4)	(−76.7; 0.93)	(−86.4; 0.31)	(−86.4; 0.34)
Spain	**(15.4; 94.1)**	**(9.6; 59.3)**	**(4.7; 41.4)**	(−0.19; 28.7)	(−0.19; 29.0)
France	(−27.7; 110.0)	(−25.6; 103.6)	(−28.1; 110.2)	(−29.3; 114.3)	(−29.6; 115.5)
Italy	(−35.0; 2.5)	(−48.5; 0.41)	**(−57.3; −0.24)**	**(−64.4; −0.79)**	**(−65.0; −0.77)**
The Netherlands	(−19.0; 94.5)	(−40.4; 70.8)	(−59.4; 65.4)	(−75.1; 62.3)	(−75.7; 62.9)
Austria	(−20.7; 87.0)	(−19.1; 81.9)	(−21.0; 87.3)	(−21.9; 90.8)	(−22.1; 91.9)
Portugal	**(−119.4; −5.9)**	**(−151.0; −10.8)**	**(−171.0; −13.0)**	**(−187.4; −14.5)**	**(−189.0; −14.9)**
Finland	**(−41.6; −1.1)**	**(−58.1; −3.7)**	**(−69.1; −5.0)**	**(−78.3; −6.0)**	**(−79.3; −6.0)**
Sweden	**(13.5; 81.1)**	**(10.5; 64.2)**	**(7.8; 55.2)**	**(5.4; 49.2)**	**(5.5; 49.6)**
United Kingdom	(−14.0; 54.6)	(−12.8; 51.0)	(−14.2; 54.8)	(−14.9; 57.0)	(−15.1; 57.7)
Czech Republic	**(10.0; 71.2)**	**(6.3; 46.7)**	**(3.9; 32.7)**	**(1.4; 22.7)**	**(1.5; 22.9)**
Hungary	**(2.8; 35.2)**	**(0.70; 22.7)**	(−1.4; 16.0)	(−3.8; 10.9)	(−3.8; 11.1)
Poland	**(9.8; 61.6)**	**(6.4; 41.9)**	**(3.6; 31.6)**	**(0.42; 24.2)**	**(0.40; 24.5)**
Input suppliers revenue	**(−4.3; −8.1)**	**(−10.9; −17.6)**	**(−10.6; −17.2)**	**(−10.4; −16.9)**	**(−10.6; −17.4)**

(*Continued*)

Table 4. *Continued*

	2011	2012	2013	2014
Belgium	(−23.7; 94.7)	(−24.3; 96.5)	(−24.7; 97.9)	(−25.3; 99.8)
Denmark	(−15.8; 96.1)	(−16.3; 97.7)	(−16.7; 99.0)	(−17.2; 100.6)
Germany	(−25.8; 103.8)	(−26.5; 105.8)	(−26.9; 107.3)	(−27.5; 109.3)
Greece	(−86.3; 0.40)	(−86.2; 0.51)	(−86.2; 0.59)	(−86.1; 0.70)
Spain	(−0.24; 29.3)	(−0.32; 29.8)	(−0.42; 30.1)	(−0.56; 30.6)
France	(−30.1; 117.1)	(−30.8; 119.2)	(−31.3; 120.8)	(−32.0; 123.0)
Italy	**(−65.7; −0.73)**	**(−66.3; −0.65)**	**(−67.0; −0.60)**	**(−67.7; −0.49)**
The Netherlands	(−76.5; 63.8)	(−77.4; 65.0)	(−78.2; 66.0)	(−79.4; 67.2)
Austria	(−22.6; 93.3)	(−23.1; 95.1)	(−23.5; 96.6)	(−24.0; 98.5)
Portugal	**(−190.2; −14.9)**	**(−191.3; −15.0)**	**(−192.6; −14.9)**	**(−193.8; −14.9)**
Finland	**(−80.4; −6.1)**	**(−81.4; −6.1)**	**(−82.5; −6.1)**	**(−83.5; −6.1)**
Sweden	**(5.5; 50.2)**	**(5.5; 50.8)**	**(5.5; 51.4)**	**(5.4; 52.1)**
United Kingdom	(−15.3; 58.7)	(−15.7; 59.9)	(−16.0; 60.8)	(−16.4; 62.1)
Czech Republic	**(1.5; 23.2)**	**(1.5; 23.6)**	**(1.5; 23.9)**	**(1.5; 24.3)**
Hungary	(−3.9; 11.2)	(−4.0; 11.4)	(−4.1; 11.5)	(−4.2; 11.7)
Poland	**(0.38; 24.8)**	**(0.34; 25.2)**	**(0.32; 25.6)**	**(0.29; 26.0)**
Input suppliers revenue	**(−10.2; −16.6)**	**(−10.1; −16.4)**	**(−10.1; −16.3)**	**(−10.0; −16.2)**

Note: Significant differences are identified by 95% probability intervals that do not contain zero and are indicated in bold.

the fact that higher farmer profits accelerate adoption and enable innovators to capture revenue in a shorter time interval. Moreover, other policy measures can significantly influence the profit of innovating firms. Kalaitzandonakes et al (2007) have shown that the regulatory costs for registering new GM varieties are very high. Creating an environment which favors innovation and research could lower the cost to introduce new technologies in the market. In this case lower revenue is not necessary correlated with lower profits.

The results also affect U.S. and Canadian sugar industries and consumers. There is of course a GM rent accruing to farmers due to reduced production costs. However, this GM rent does not change under the EU sugar reform because of the high domestic protection of the sugar market. The fact that innovation no longer affects world prices—the new CMO completely eliminates the risk of immiserizing growth (Bhagwati 1958)—represents perhaps the most dramatic change induced by the reform. For the North American government, this implies a reduction in tax expenses to protect beet and cane growers from world price declines. These savings accrue directly to taxpayers in these countries. In contrast with the former regime, world prices are not affected by the innovation, keeping sugar prices constant minimizing the welfare losses for sugar cane producers, mostly in developing countries. The increase of competitiveness in the European Union and North America also implies that trade barriers become less necessary to maintain domestic production. Therefore, endogenizing the innovation in trade policies would allow trade partners to reduce high trade barriers and the latter would perfectly fit in the ongoing WTO trade negotiations which spur free trade. On the other hand, in a world with rising agricultural commodity prices, a competitive European sugar sector could start exporting on the world market without subsidies and as such decrease the world price significantly after all.

CONCLUSION

The first historical radical reform of the European sugar regime has greatly affected the sector. Besides the direct goals of the reform to reduce production through exit from the industry of high-cost producers, our analysis has shown that the stream of benefits from an innovative technology are significantly altered due to the reform. Due to lower institutional prices of A-sugar, farmers in uncompetitive member states have weaker incentives to adopt new technologies under the new sugar regime. Former B-sugar producers, on the other hand, capture higher gains under the new regime because the new institutional price of B-sugar is slightly higher than the old institutional price. Hence, the new regime spurs innovation and adoption by leaving competitive producers unaffected, providing incentives for innovation for medium-competitive producers, while eroding incentives for uncompetitive producers and stimulating exit of this group.

One effect of the introduction of GM beet has not been considered in this study. The decrease in production costs in the European sugar industry could potentially open the door to cost-effective bio-ethanol production, as the attitude of consumers to biotechnology research in this area may well be sympathetic. Further research is needed to assess this scenario.

Market data show that total production under the new sugar regime has decreased due to the abolishment of quota by high-cost producers. This means that the market for

HT seed and the potential technology revenue for suppliers, such as Montsanto, also shrinks (see Table 4). This may explain the currently observed lack of interest of the European biotechnology sector in continuing GM sugar beet research. Targeted policy measures could offset the decrease in incentives to innovate because of declining sugar production in the EU.

NOTES

[1]It is important to make a distinction between the incentive to innovate for innovators (gene developers and seed suppliers) and the incentive to adopt innovations for farmers. The surplus of an innovation is the total value to the innovator and farmers of a cost-reducing innovation, while the incentive to adopt innovations is purely based on the share of the surplus accruing to farmers. As we are dealing with proprietary innovations in this paper, we make the assumption that the farmer who adopts the technology pays a license fee to the innovator.

[2]International consumer concerns seem to have subsided; there is a Feed and Food approval for HT Roundup Ready® sugar beet in Mexico, Japan, Australia, New Zealand, the EU, and other importers. The decision to adopt GM HT sugar beet in the United States cannot be explained by changes in the sugar market itself since no significant changes were made in U.S. legislation. Demand for this technology is important as farmers have extensive experience with GM crops in the United States since 1996.

[3]In Dillen et al (2007b) we provide a more detailed analysis of corporate pricing strategies of input suppliers as a function of farmer heterogeneity.

[4]However, the EU-27 is disaggregated further below to obtain a realistic supply response of the region.

[5]In the remainder of the text, the term "region" will be used both for aggregates (i.e., ROW beet, ROW cane, EU-27), as well as for individual EU-27 member states. In Tables 1 and 2 we distinguish 16, rather than 27 EU member states. We merged Belgium and Luxembourg in a single region "Belgium" and omitted nine remaining New Member States, who supply less than 4% of sugar in the EU-27. We also omitted Ireland which gave up production since the reform of the CMO, making a comparison between the two regimes impossible.

[6]If we assume EU imports to be exogenous, we can calculate the world price as a function of the EU's export supply expansion. Under the old CMO the import was fixed, due to fixed ACP (African, Caribbean, and Pacific) import agreements. Under the new CMO the EBA agreement will offer free access to the European sugar market for the LDCs in 2009. In a recent simulation, Nolte (2008) observes that the extra import under the EBA only has a marginal effect on the import and on the price level (−1%) in Europe due to the lower internal prices following the reform. Therefore, as the EBA will marginally affect our results we assume it to be exogenous under the new CMO.

[7]A reviewer pointed out that our exogeneity assumption imposed on the categorical parameter $\varphi_{i,j}$ is strong. We agree that the parameter $\varphi_{i,j}$ should be a function of prices (and adoption). This would imply that regions could move between categories due to the net effect of innovation and reducing prices. However, introducing endogeneity of $\varphi_{i,j}$ would make our model extremely complex. In this paper, we decided to develop a static multi-criteria framework to identify WPN and WPR regions, based on historical data (Table 2), due to the important influence of world price responsiveness on world prices. Ideally, we would need to apply this framework on all categories and make it dynamic, i.e., by endogenizing prices. These upgrades would unnecessarily complicate the present framework, because we would need to make strong assumptions on "when" regions upgrade from one category to a higher one, i.e., when regions become quota-fillers or when precautionary overproduction of quota-fillers becomes structural.

[8]Only the supply elasticities of WPR regions influence our results as in our model only these regions are able to influence world prices (see Demont 2006, p. 118 for more details). For the five WPR

countries, identified through our multi-criteria system (Table 2), Poonyth (1998) econometrically estimates area equations as functions of world price, exchange rates, wage index, allocated quota and sugar yield. He uses two-stage least square regressions and obtains highly significant t-values. Moreover, in none of the equations the Durbin H-test's null hypothesis of no autocorrelation was rejected. Therefore, we conclude that the supply elasticity estimates stemmed from well-behaved structural equations.

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