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International diffusion of gains from biotechnology and the European Union's Common Agricultural Policy

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Abstract

This paper analyses the impact of adopting or rejecting genetically modified (GM) crops in the European Union, taking into account the EU Common Agricultural Policy (CAP). In this paper the productivity impact of genetically modified organisms (GMOs) differs across crops, taking factor biased technology change into account. The transfer of knowledge across countries is modelled as a process of endogenous knowledge spill-overs. Analysis with a multi-region applied general equilibrium model shows that the CAP protects farm income and production despite non-adoption of the more productive GM crops in the EU. The EU will forgo substantial benefits in terms of economic welfare if it bans GM imports.

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1. Introduction

This paper analyses the impact of adopting or rejecting genetically modified (GM) crops in the European Union, taking into account the EU Common Agricultural Policy (CAP). The adoption of GM crops implies productivity growth, through improved crop

varieties and through improved farming knowledge. In this paper the productivity impact of genetically modified organisms (GMOs) differs across crops, taking factor biased technology change into account. The transfer of knowledge across countries is modelled as a process of endogenous knowledge spill-overs.

This paper concentrates on the two most important GM crops: HT Soybeans and Bt corn. Almost all GM soybeans are herbicide tolerant (HT). The crop contains a modified growth-regulating enzyme that is immune to the active ingredient. This allows the

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herbicide to be applied directly on the crops, while it kills all the plants not processing this gene. Two thirds of GM corn is insect resistant. By inserting genetic material from the *Bacillus thuringiensis* (Bt) into seeds, these crops produce their own insecticides, making the corn resistant to the European corn borer. Less widely spread GM crops are cotton, rapeseed, tobacco and potatoes. Commercially grown GM crops are concentrated in a few countries, mainly USA and Argentina (see Table 1).

GM crops have increased productivity. Unlike other papers we take into account that GMOs might imply factor biased technical change. For example, in corn the productivity impact is mainly yield increasing, and in soybeans the GM technology allows saving on inputs of chemicals and labour. Furthermore, we assume that the international diffusion of these technologies is not perfect but dependent on trade linkages, absorption capacity, size of farms and whether a technology is socially acceptable.

Since 1999 the EU has had a de facto moratorium on the approval of new GM crops. This policy is inspired by consumer concerns about the environmental effects and human health effects. Recently, the European Commission and Member states have reached an agreement on the regulation and labelling of GM food products.¹ This is a very stringent set of rules, requiring the labelling of food products if the GM content exceeds a 0.9% threshold. It remains to be seen whether the labelling approach will make GM products more socially acceptable in the EU.

The trade and production impact of banning GM technologies by the EU are dependent on the current CAP policy. The EU market is partially insulated from price movements on world markets. As a consequence, productivity gains in other regions are found to hardly affect agricultural production in the EU. This stands in contrast to analyses that do not take proper account of the CAP, where productivity gains outside the EU would typically lead to a loss of market position of EU farmers. See Nielsen and Anderson (2001), for example, for such an approach.

¹ See Directive 2001/18/EC and press release IP/03/1056 on <http://www.europa.eu.int>.

Table 1
GM soybean and corn area, 1999

	Soybean		Corn	
	Mio (ha)	GM (%)	Mio (ha)	GM (%)
USA	15	51	10.3	36
Argentina	5.5	75	0.31	11
Canada	0.1	10	0.5	44
Brazil	1.18	10		
Romania	0.001	NR		
South Africa			0.16	5
Spain			0.01	0.2
Portugal			0.001	0.4

Source: European Commission, 2000.

2. Issues

2.1. Knowledge spill-overs are not perfect

The degree to which farmers can realise the potential productivity gains that come along with genetically modified corn and soybeans differs across countries. New technologies are always developed in a given technological, economic, social and cultural context. Transfer of new technologies to other countries is generally most successful if a close match between the circumstances exists.

In their synthesis report on the economic impacts of GMOs on the Agri-Food Sector, the European Commission (2000) supports the findings from a study by the US Department of Agriculture (USDA, 1999) that concludes amongst other things that: 'larger operations and more educated operators are more likely to use herbicide tolerant soybean seeds'. It is very likely that the same applies to Bt Corn. The decision to plant Bt corn is complex and implies assumptions as to the expected degree of infestation and adjustments in planting planning to foresee refuges. Next to knowledge, farm size matters. The adoption of biotechnology is not size-neutral. (European Commission, 2000, p. 19)

It appears that the effectiveness of received knowledge is dependent on:

- A country's absorption capacity: education is needed, and countries with low educational levels can only adopt the new technology to a limited extent, if it can be introduced at all.
- Structural similarity between the innovating and the adopting country: USDA (1999) research shows that

adoption is more frequent in large operations. One can, therefore, expect that soybean and maize GM technology will be more easily adopted in countries with large farms.

Consumer resistance to GM foods has slowed the introduction of GMOs in the farming sector. In the EU, food processors and retailers are taking steps to avoid these products. On the other hand, in the US, Canada and Argentina, producers have been quick to embrace the advantages of the GM technology. Evidently, social acceptance plays a role in effecting knowledge spill-overs.

2.2. Knowledge is embodied in traded goods

An important issue is also how knowledge ‘travels’ between countries. Coe et al. (1995) discuss various channels along which technology spill-overs work. Most important are contacts in export markets and knowledge exchange through imports of new technologies and through foreign direct investment. Timmer (1988) and Hayami and Ruttan (1985) argue that knowledge in agri-technology is embodied in traded inputs, such as machines, and agri-chemicals. The largest part of current biotechnology research is generated in life science companies, which have arisen from diversified pharmaceutical and chemical multinationals. This raises the issue of measuring biotechnology trade and associated knowledge flows. As the companies involved in GM crops are typically classified under the chemical sector in the National Accounts, which is a major source for the empirical modelling in this paper, we assume that knowledge about producing GMOs is embodied in international trade of chemical inputs.

2.3. Productivity effects differ across GMO crops

The effects of GMOs on productivity and on farmers’ income are still somewhat unclear (see European Commission, 2000). There is a consensus, though, that the productivity impact of GM technologies differs across crops, and that one cannot simply assume that these technologies imply a Hicks-neutral productivity boost. The productivity change brought by GM technology is factor biased, and this differs between soybeans and corn.

Herbicide tolerant (HT) soybeans lead to two factor specific productivity changes: a) they save on the inputs of chemicals, and b) they save on labour inputs in the longer run. Based on a survey of numerous available studies, the European Commission (2000) finds that HT soybeans allow for cost savings, due to reduced use and reduced costs of herbicides. However, the yield of GM soybeans is still lower than for conventional soybeans. When comparing returns per area (ha) or returns per labour unit, no significant differences appear between GM and non-GM varieties. It is expected that the ‘convenience effect’ will imply increased ‘labour productivity and saving in crop-specific labour costs’ (European Commission, 2000, p. 49) in the longer run. In contrast, for Bt corn, significant yield gains have been observed. However, the cost effectiveness of Bt corn depends heavily on growing conditions, in particular on the degree of infestation in corn borers.

3. Modelling endogenous technology spill-overs and the CAP

The starting point for our empirical assessment is the database and model formulation of the global trade analysis project (GTAP) multi-sector multi-region applied general equilibrium model; see Hertel (1997) for a comprehensive discussion. The choice of a multi-sector model is motivated by inter-sectoral effects that are induced by technology change, such as resource movements between activities. Accounting for differences in input intensities, as captured by the input–output system and differences in primary factor shares, is an essential element for the assessment of endogenous technology spill-overs. The choice of a multi-region model is motivated by likely inter-country effects, since productivity changes have an impact on the comparative advantage of regions, and hence will affect trade flows and welfare.

The well-known GTAP model is a multi-regional, static, applied general equilibrium model based on neo-classical micro-economic theory. All sectors produce under constant returns to scale and perfect competition on factor markets and output markets is assumed. Firms combine intermediate inputs and primary factors (land, labour and capital). Intermediate inputs are used in fixed proportions, but are

themselves CES composites of domestic and foreign components. In addition, the foreign component is differentiated by region of origin (Armington assumption), which permits the modelling of bilateral (intra-industry) trade flows, depending on the ease of substitution between products from different regions. Primary factors are combined according to a CES function. Regional endowments of land, labour and capital are fixed. Labour and capital are perfectly mobile across domestic sectors. Land, on the other hand, is imperfectly mobile across alternative agricultural uses, thus sustaining rent differentials.

We modify the standard GTAP model to take endogenous international technology spill-overs and the CAP into account. The spill-over mechanism is extensively described in [van Meijl and van Tongeren \(1998\)](#). We extend this formulation to allow for social acceptance as an additional factor that influences the effectiveness of spill-overs. Furthermore, we use a common feature of adoption models, and include a threshold value for the absorption and structural similarity index (see [Geroski, 2000](#)) for an overview of technology adoption models). The spill-over hypothesis is summarised in an equation that relates productivity growth rates between two regions. Productivity growth in the receiving region is determined by the following transmission equation:

$$a_s = \gamma(E_{rs}, H_s, D_s, S_s)a_r = S_s E_{rs}^{(1-H_s D_s)} a_r \quad (1)$$

where r denotes the region of origin of the productivity growth, s denotes the destination region, a_r and a_s denote productivity growth rates in the two regions. The initial productivity growth in the source region a_r results from the application of GM technology. E_{rs} is an index of the amount of knowledge that is embodied in trade linkages between the two regions. In this paper, we assume that the amount of knowledge is measured by the bilateral trade flows of the innovative input. The indices H and D measure the absorption capacity and structural similarity in the host country. These indices are constructed such that $0 \leq HD \leq 1$. The social acceptance index S_s is a dummy variable that takes the value zero if the GM technology is not accepted in the destination country, and takes the value 1 otherwise.

The index E_{rs} is taken to be a function of the domestic use in region s , which is satisfied by imports

from region r . We assume that technological progress in sector i comes along with the traded innovative inputs produced by sector j . The embodied knowledge index becomes the import share in production:

$$E_{irs} = \frac{M_{jirs}/Y_{is}}{X_{jirr}/Y_{ir}}, \quad (2)$$

where M_{jirs} represents the imports of input j used in sector i that are shipped to the destination country s from the source country r , Y_{is} is production of sector i in country s , and X_{jirr} are domestic inputs of sector j delivered to sector i in country r . The denominator represents the input–output coefficient of domestic inputs from the innovating sector j in production of activity i in the country of origin. The numerator is an input–output coefficient of foreign-sourced inputs from the innovating sector j in production of activity i in the destination country. Recall that we assume the knowledge of biotechnology to be originating in the broad sector, Chemicals; hence our embodied knowledge index will reflect the relative importance of imported chemicals in domestic production.

The absorption capacity index (H_s) relates the average years of schooling in the destination region (h_s) to the threshold level of the average years of schooling needed to adopt GM technologies. We use the following specification for the absorption capacity index:

$$H_s = \min \left[1, \frac{\log h_s}{\log h_{\text{threshold}}} \right]. \quad (3)$$

This particular form of the H -measure incorporates the notion that there are no obstacles to absorbing GM technology if the destination region has a larger amount of human capital than the threshold level, while absorption is more difficult if the absorption capacity in the destination region lags behind. The threshold value is dependent on the technology under consideration. The absorption capacity has been quantified by using information on schooling years from the well-known [Barro and Lee \(1993\)](#) data set. Values are given in [Appendix A](#).

We proxy structural similarity by land/labour ratios, using the equation:

$$D_s = \exp \left[- \left| \frac{l_{\text{threshold}} - l_s}{d_{\text{max}}} \right| \right], \quad (4)$$

where l and $l_{\text{threshold}}$ denote land/labour ratios in activity i in the two regions, and d_{max} is the largest structural dissimilarity found in the data, i.e. the observation for the country, which is farthest away from the threshold. This formulation scales the differences in the indicators on the unit interval. The threshold value captures the notion that up to a certain level the size of farms limits adoption, but beyond the threshold level, size is no longer a barrier to adoption, as noted by the European Commission (2000). The index of structural similarity has been quantified using FAO data to calculate land and labour intensities. Values are given in Appendix A.

To incorporate the main features of the CAP in the cereals sector we include three interrelated policy instruments. First, the domestic market is insulated from world price changes through a variable import tariff. Second, a variable export subsidy is introduced to dispose excess supply on the world market. Third, an endogenous price transmission mechanism between intervention price and market price is introduced. The price transmission from intervention to market prices is dependent on the net-export position, extra-EU trade position, in a varying-parameter model. For an application and detailed discussion in the context of the EU's Uruguay Round commitments on export subsidies, see van Meijl and van Tongeren (2002).

4. Numerical results

Our simulations use version 5 of the GTAP database. This dataset is benchmarked to the year 1997 and comprises 57 sectors and 66 countries and regions (see Dimaranan and McDougall, 2002). We construct an aggregation that divides the world into nine regions, each with 12 sectors. The regional detail highlights the attention to be given to the main participants in the GMO debate (e.g. North America, Argentina and EU), while the sectoral detail focuses on the primary agricultural sectors involved in the GMO debate and the commodities which can be considered as carriers for GM technologies (coarse grains, oilseeds and chemicals).

In the scenarios it is assumed that GMO-driven productivity growth occurs only in the coarse grains and oilseeds sectors, since we focus on maize and

soybeans as the most important commercially grown GM crops. We assume that productivity impacts of GM technologies differ across GM crops. We assume Hicks-neutral productivity growth in coarse grains (maize) to capture the yield effect, and model chemicals cum labour augmenting technical change in soybeans. Available estimates of economic benefits to producers from cultivating GM crops are very scattered and highly diverse (see, e.g. European Commission, 2000 for an overview of available estimates). Nelson et al. (1999) indicate that glyphosate-tolerant soybeans may generate a cost reduction of 5% and that the yield increases of Bt corn range from 1.8 to 8.1%. Therefore, we follow Nielsen and Anderson (2001) in assuming a productivity gain of 5%. Fig. 1 describes the five scenarios. These are designed to assess (1) endogenous international knowledge spill-overs, (2) the effect of the CAP, (3) the effect of social acceptance of GM technologies, and eventually (4) a GMO ban in the European Union with CAP.²

4.1. Endogenous international knowledge spill-overs

Fig. 2 shows the received potential spill-overs in all regions, following a GMO-induced 5% productivity increase in North America, which is Hicks-neutral for corn and factor biased for soybeans. The received potential spill-overs are dependent on the amount of knowledge that is embodied in bilateral trade in chemicals and on the effectiveness of this amount of knowledge. That is, Eq. (1) has the binary parameter S set to one. The received spill-overs are endogenous but also 'potential', in the sense that these spill-overs could be obtained if the GMO production technology is socially accepted. The

² Our scenarios 0, 2 and 4 are rather similar to the scenarios performed by Nielsen and Anderson (2001), and a discussion of the principal mechanisms can be found there. They assume in their base scenario: 5% Hicks neutral productivity growth in North America in both coarse grains and oilseeds, in their SpiCapSa (3) scenario that some countries (Southern Cone (e.g. Argentina, Brazil), China, the Rest of East Asia, India, Mexico and South Africa) get the same productivity benefits as the innovating country, and in their EUBAN scenario that the EU bans GMOs altogether. Although these scenarios are quite similar to ours, the results differ because the values of the spill-overs differ, we assume labour cum chemical saving technical change in oilseeds, we use a more recent version of the database, and the regional and sectoral aggregation differs.

Name	Description of scenario	
0 Base	Base scenario: 5% Hicks neutral productivity growth in Maize and 5% chemicals cum labour augmenting tech change in soybeans in North America	
1 Spill-over	Spill-over scenario: Base scenario with endogenous international knowledge spill-overs	Scenario 0 + Spill-overs
2 Spill-over & CAP	Spill-over scenario with CAP implementation	Scenario 1 + CAP
3 Spill-over & CAP & Social acceptance	Spill-over scenario with CAP implementation that includes social acceptability of GMO production technology.	Scenario 2 + social acceptability of technology
4 EU Ban	In addition to non-acceptance in production, GM crops are not accepted in consumption. This is obtained by deterring imports from countries that produce with GMO technology.	Scenario 3 + EU ban on GMO imports

Fig. 1. Description of scenarios.

difference between oilseeds and coarse grains is due to the ‘amount’ of knowledge embodied in chemicals, since effectiveness ($H_s \times D_s$) is not commodity specific. It is clear from Fig. 2 that the differences in spill-overs across commodities are much smaller than the differences across regions. The region-specific effectiveness of the amount of knowledge is clearly important for the productivity gains of GMO technologies. Australia–New Zealand potentially receives full spill-overs because the farm size and education levels for this region exceed the threshold

levels. Argentina and Europe potentially receive about 70 or 60% of the total productivity growth. Argentina and Europe both have relatively high farmer education levels, but average farm size in Europe is smaller. Potential spill-overs to the other countries, especially to developing countries, are smaller because they trade less chemicals with North America, their farm size is too small and/or their education level is too low to adopt the new GM technologies profitably. Assumptions about exogenous international spill-overs made in other studies

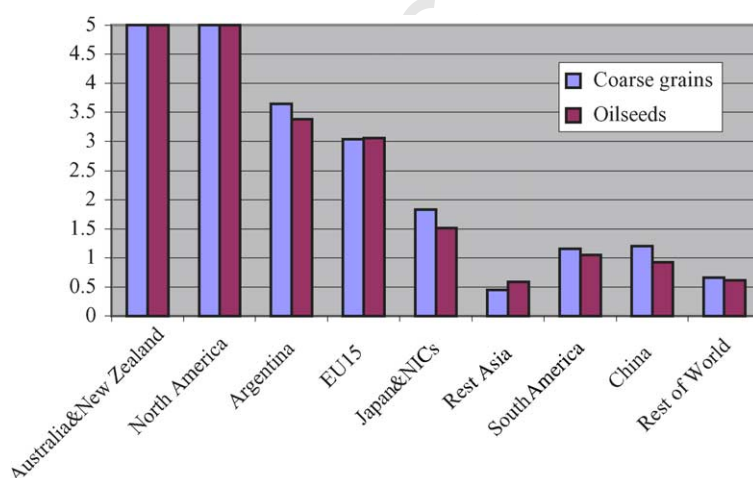


Fig. 2. Received potential spill-overs in all regions following 5% productivity increase in North America (‘potential’ because social acceptance is not taken into account).

will overstate the productivity impact in some countries because farm size and education level matter.

Comparing the endogenously generated potential spill-overs with actual adoption figures, we observe that countries with large farms in terms of area per person and a rather high education level indeed tend to adopt the GM technologies. For example, Fig. 2 shows that Argentina's potential spill-overs are high, while this country's adoption is also high in reality (see Table 1). The simulated spill-over coefficients in a large part of the world are small and we also see little or no actual adoption of these new technologies. There is a mismatch between potential knowledge spill-overs and actual knowledge spill-overs in the regions Australia–New Zealand, Europe and to a lesser extent Japan.

The question is, of course, why these countries did not adopt the new technologies, since there is great potential according to the model simulations. Our social acceptance variable helps to explain the non-adoption. In scenario 2 we move from potential spill-overs to actual spill-overs, and in this case the regions Australia–New Zealand, the EU15, Japan and the Newly Industrializing Countries (NICs), and the Rest of World receive zero knowledge spill-overs because they do not accept the technologies. When we combine potential and actual spill-overs, our results of received knowledge are broadly in line with the actual adoption figures.

Simulation results show that without spill-overs, the production of both coarse grains and oilseeds expand in the innovating country and declines in all other countries. The decline in production is highest in countries for which international trade is important and which compete with the cheaper GM commodities from Northern America. This is true for large importers, such as Japan for both oilseeds and coarse grains, and large exporters, such as Argentina for coarse grains and Australia–New Zealand for oilseeds. With spill-overs, other countries also get a part of the productivity increase. In this case the increase in production in the innovating country is less pronounced and the decline in production in the knowledge receiving countries is less severe, or may even turn positive. The change in domestic production due to spill-overs is dependent on the value of the spill-overs a country receives (these are depicted

in Fig. 2), in combination with the importance of international trade in that commodity for the particular country. The large exporter, Argentina, which has also a high spill-over coefficient, realizes a steep increase in coarse grain production. Regions with low spill-over coefficients tend to see shrinking output, because they now also lose market share to other more successful adopters.

For oilseeds, the factor bias effect is also important. The GM technology in oilseeds saves on labour and chemicals; therefore, countries for which labour and chemical cost shares are high will benefit from this technology. For example, European oilseeds benefit substantially from these spill-overs, because the labour and chemical cost shares are high, their spill-over coefficient is rather high and the EU is relatively open to international trade in oilseeds.

Fig. 3 shows that the EU's production decrease of coarse grains is smaller, but farm income deteriorates, if international knowledge spill-overs are included. Declining farm income is a typical effect of productivity improvements that lead to lower prices. Because all countries witness productivity increases, these lower prices imply almost no substitution effects in the domestic and international market. This, together with an inelastic demand for coarse grains, implies that the increase in output falls short of the decrease in prices.

4.2. *The impact of EU's Common Agricultural Policy and alternative EU responses to GMOs*

Fig. 3 shows the impacts on production and farm income of alternative EU policy responses to GMOs. We focus on coarse grains because in this sector the CAP price insulation policy is still in place. The CAP changes the EU's production response from -0.2 to 2.9% and farm income from -3.6 to -0.2% . This clearly indicates that isolation from price movements on world markets matters. The EU is isolated from the downward pressure on world prices brought about by the global productivity boost. At the same time, the EU can transmit its own productivity increase to the rest of the world. First, productivity increases and corresponding lower world prices are mitigated through higher import tariffs due to flexible import tariffs in the EU. Second, the price transmission of productivity increases in the EU itself is dampened

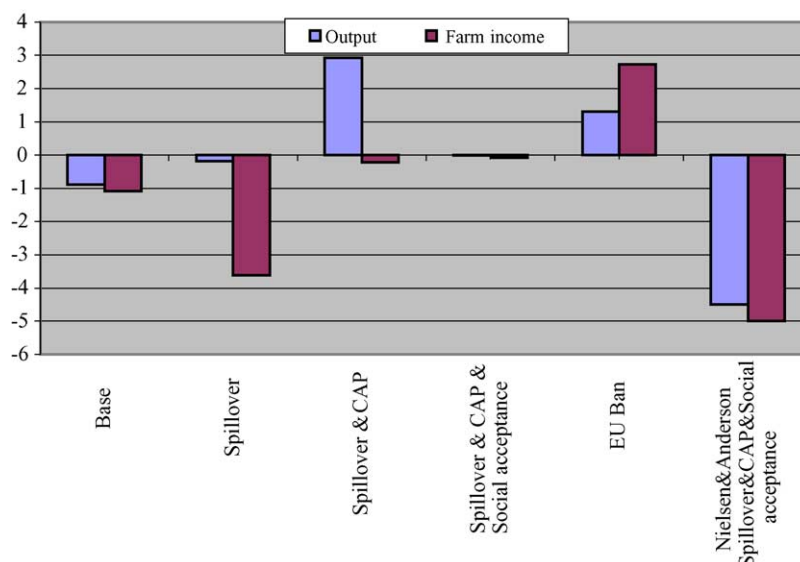


Fig. 3. Percentage change in production and farm income of coarse grains sector in EU.

because of the intervention price. Third, increased productivity and lower price transmission lead to excess supply in the EU market, which can be disposed of on world markets through a flexible export subsidy.

Not accepting the GMO production technologies in the EU implies that this region receives no productivity increases (no shock inside the EU); similarly there are no shocks in Japan, Australia–New Zealand and in the Rest of World. Fig. 3 shows that both production and farm income are unchanged as a result of the CAP, which shields EU farmers from productivity improvements in other regions. This is in sharp contrast to results of Nielsen and Anderson (2001), who found a sharp reduction in coarse grains output in the EU.

Because these authors do not include a good representation of CAP they overstate the negative production and farm income impact of not adopting GMO production technologies.

If the EU completely rejects consumption of products that are produced with GMO technologies it will have to ban GM product imports in addition to not allowing own-production of these crops. In this situation, conventional coarse grain production in the EU increases to replace the imports of GMO producing regions. Market prices will also rise in the EU due to increased demand for domestic products.

Table 2 gives an overview of core simulation results. In the oilseed sector the price insulation

Table 2
Core simulation results (percentage change from 1997 base)

	Output (EU)		Market price (EU)		Farm income (EU)		Equivalent variation (million USD, 1997)	
	Oilseeds	Coarse grains	Oilseeds	Coarse grains	Oilseeds	Coarse grains	EU	North America
Base	−0.65	−0.90	−0.20	−0.18	−0.85	−1.08	249	2250
Spill-over	0.45	−0.18	−1.86	−3.43	−1.41	−3.61	1283	2173
Spill-over and CAP	0.25	2.93	−1.71	−3.14	−1.46	−0.21	666	2172
Spill-over, CAP and social acceptance	−0.86	−0.02	−0.18	−0.06	−1.04	−0.08	152	2205
EU ban	19.75	1.3	4.48	1.42	24.23	2.72	−1426	1767

Source: authors' calculations.

mechanism is not present and therefore the general direction of the results is similar to results of other studies that have been cited earlier. In terms of economic welfare, measured as equivalent variation (EV), the EU would forego substantial benefits if it banned GM imports. The total cost of banning amounts to US\$ 1.6 billion (bUS\$). Even under the current policy environment of the CAP and low social acceptance, the EU could realize a welfare gain of US\$ 152 million, whereas an import ban by the EU would result in a loss of US\$ 1.4 billion. The latter is mainly due to a negative allocative effect because resources move into the distorted coarse grains sector. At the same time, a ban imposes a cost of US\$ 0.4 billion on North America due to negative terms of trade effects. Possible welfare effects are highest for the EU if it adopts GM technologies without the CAP. The welfare gain is US\$ 1.3 billion, due to received knowledge spill-overs (US\$ 0.8 billion), allocative effects (US\$ 0.4 billion) and terms of trade effects (US\$ 0.1 billion). Notice that the CAP halves the welfare gains of GM technologies, as it shifts resources into the distorted coarse grains sector and reduces the benefits of lower world prices that result from global productivity improvements.

5. Conclusions

Our simulation results show that imperfect international knowledge spill-overs, factor biased technology change and an improved representation of CAP policies are crucial in estimating production, trade and welfare effects of adopting GMOs in the EU and other regions. In particular, the inclusion of endogenous technology spill-overs brings the simulated patterns of adoption close to observed adoption rates. Without taking the price-insulating characteristic of the CAP into account, a global GM-induced productivity boost would imply a very slight displacement of coarse grain production for EU farmers. However, as the CAP shields domestic maize producers from world markets, they can fully benefit from productivity gains, while farm income is not negatively affected at all. Consumer concerns about GM technologies are of little concern to EU farmers, as long as the CAP shields them from world

markets, as is the case in the grains sector. A complete ban of GM production and consumption would even lead to increased domestic output and rising farm incomes in the EU. However, the EU would forego substantial benefits in terms of welfare through its CAP policies, the social unacceptability of GMO technologies and, especially, if it bans GMOs completely.

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Appendix A. Human capital data

Population weighted average years of schooling from the Barro and Lee (1993) data are used as a proxy for the absorption capacity (see Table A.1). These data have been downloaded from World Banks Internet site, URL: <http://www.worldbank.org/html/prdmg/grthweb/dataset.htm>. Threshold value is set to 9.3 years, which equals the observation for Japan and the NICs.

Table A.1
Average years of schooling in the nine model regions

Australia and New Zealand	10.5
North America	11.6
Argentina	8.13
EU15	8.2
Japan and NICs	9.3
Rest Asia	4.2
South America	4.7
China	5.9
Rest of world	6.6

Source: Barro and Lee (1993) database, authors’ calculations.

Table A.2

Land/labour ratios in grain crops (hectares per person)

Australia and New Zealand	123.6
North America	87.1
Argentina	17.1
EU15	9.18
Japan and NICs	1.4
Rest Asia	1.3
South America	2.0
China	0.7
Rest of world	1.1

Source: FAOSTAT and GTAP database, authors' calculation.

Appendix B. Land/labour ratios

Grain acreage and the total number of persons employed in agricultural production are taken from FAOSTAT (URL: http://app.fao.org/lm500/agri_db.pl). The latter have been adjusted with GTAP (version 3) labour shares to obtain an estimate of persons employed in grain production only. Threshold value is set to 17.1, which equals the observation for Argentina (Table A.2).

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