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

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1. Introduction

This paper analyses the impact of adopting or rejecting genetically modified GM crops in the EU, taking into account the European Union's 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 GMs differs across crops, as it takes factor biased technology change into account. The transfer of knowledge across countries is modelled as a process of endogenous knowledge spillovers.

Commercially grown GM crops are concentrated in a few countries, mainly USA and Argentina. The two most important crops are soybeans and maize.[2] Almost all GM soybeans are herbicide tolerant (HT). Herbicide tolerance is achieved by inserting a herbicide tolerant gene into the plant, such that the plant is tolerant to a wide spectrum of herbicides. The crop contains a modified growth-regulating enzyme that is immune to the active ingredient. This allows the herbicide to be applied directly on the crops, while it kills all the plants not processing this gene. In 1999, GM soybean sowings accounted for nearly 22 Mio ha or more than 52% of total GM sowings. It is equal to one third of world total soybean area. The USA (63%) and Argentina (23%) have 94% of the total GM soybean area.

Two thirds of GM maize is insect resistant. By inserting genetic material from the *Bacillus thuringiensis* (Bt) into seeds, these crops produce their own insecticides. Bt corn is resistant against the European corn borer. Bt cotton combats bollworms. In 1999, GM maize sowings accounted for nearly 11 Mio ha. This is equal to 8% of world total corn area, and 27% of total GM sowings. The USA has 91% of the total GM corn. In Canada and Argentina, respectively, 44% and 11% of total corn production is GM corn.

Less widely spread GM crops are cotton, rapeseed, tobacco and potatoes, representing respectively 9.4%, 8.4%, 2.4% and 0.1% of total GM sowings. In this paper we concentrate on two most the most important GM crops: Ht Soybeans and Bt maize.

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[2] In this papers the terms 'maize' and 'corn' are used interchangeably.

Table 1 GM soybean and maize area, 1999

	Soybean		Maize	
	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: Commission of European Union, 2001.

GMs increase productivity. Unlike other papers we take into account that GMs might imply factor biased technical change. For example, in maize the productivity impact is mainly yield increasing, and in soybeans saving on inputs of chemicals and labour. 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. If a production technology is not socially acceptable than a country is excluded from these potential productivity gains that are already less than perfect. If in addition a GM product is also banned from consumption in a country, then imports from GMO producing countries will be zero.

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 be hardly negative for agricultural production in the EU. This contrasts with an analysis that does 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 for example Nielsen and Anderson (2001) for such an approach.

2. Issues

Knowledge spillovers are not perfect

The degree to which farmers can realize the potential productivity gains that come along with genetically modified maize 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. If the circumstances in the adopting country differ widely from those in the inventing country, the potential productivity gains will be smaller.

In their synthesis report on ‘the economic impacts of GMOs on the Agri-Food Sector the European Commission concludes: “For example, USDA (1999) has examined different factors affecting the adoption of HT soybeans and concluded that "***larger*** operations and

more educated operators are more likely to use the technology" It is very likely that the same applies to Bt Corn. The decision to plant Bt corn is a complex one, it implies assumptions as to the expected degree of infestation, adjustments in planting planning to foresee refuges. Such differences between adopters and non-adopters of biotechnology have to be taken into account when comparing yields and returns obtained on both types of farms. The higher degree of education might echo the skills required for changes in growing and management (e.g. contracting) practices. The farm size of adopters might be a factor explaining, amongst others, the dramatic increase in areas sown to GM crops. The adoption of biotechnology is not size-neutral (European Commission, 2001, p.19)".

This illustrates that the effectiveness of received knowledge is dependent on:

- A country's <u>absorption capacity</u>: 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.
- <u>Structural similarity</u> between the innovating and the adopting country: the USDA (1999) research shows that adaptation is more frequent in large operations. One can therefore expect that soybean and maize GMO technology will be more easily adopted in countries with large farms. Countries were production occurs mainly on small land holdings can be expected to be less effective in adoption.

Consumer resistance to GM foods has slowed down the introduction of GMOs in the farming sector. In the EU, food processors and retailers are taking steps to avoid these products. Food suppliers are extremely careful with the introduction of new products that are developed with modern biotechnology. This is also stimulated by the precautionary principle that governs the EU policies towards such products. On the other hand, in the US, Canada and Argentina producers have been quick to embrace the advantages of the GM technology. Technology adoption has not been hampered by low social acceptance in these countries. Evidently, <u>social acceptance</u> plays a role in the effectuation of knowledge spillovers. If the new technology is not socially acceptable, and consumers and citizens object to their introduction, then the farmers in the adopting country have limited scope to fully realize productivity gains.

Knowledge is embodied in traded goods

An important issue is also how the knowledge 'travels' between countries. Coe et al. (1995) discuss various channels along which technology spillovers work. The most important ones are contacts in the export markets, knowledge exchange through imports of new technologies and through foreign direct investment. Timmer (1988) and Hayami and Ruttan (1985) argue that knowledge in agri-technolgy is embodied in traded inputs, such as machines, and agri-chemicals. See, Van Meijl and Van Tongeren (1998) for a more elaborate discussion. The largest part of current biotechnology research is generated in life science companies. Such companies have arisen from diversified pharmaceutical and chemical multinationals. Bijman (2001) shows that the pharmaceutical industries are recently withdrawing from agricultural biotechnology. Eaton and van Tongeren (2002) provide data on industry concentration and vertical linkages in the biotechnology industry. As the companies involved in GM crops are typically classified under the chemical sector in the National Accounts, and we assume in this paper that knowledge about producing GMOs is embodied in international trade of chemical inputs.

Productivity effects differ across GMO crops

The effects of GMOs on productivity and on farmer's income are still somewhat unclear. (see European Commission, 2001). There is a consensus, though, that the productivity impact of GMO 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 EU commission finds that HT soybeans allow for cost savings thanks to reduced use and costs of herbicides. However, the yield of GM soybeans is still lower than for conventional ones. When comparing returns per ha or per labour unit no significant differences appear between GM and non-GM varieties. In this context the **convenience effect** appears to be the main driving force. In the longer run, it should imply increased **labour productivity and saving in crop-specific labour costs** (p. 49). However, this effect is not always assessed in profitability studies. One author (Duffy 1999) concludes that HT soybeans provide the same returns on ha or on labour as conventional crops. But if they allow for reduced labour costs, the same return on less labour means increased profitability. This convenience effect has to be further assessed in particular, the valuation of the labour effect.

In contrast, for Bt corn significant **yield gains** have been observed. However, the cost effectiveness of Bt corn depends on growing conditions, in particular on the degree of infestation in corn borers. Applications of insecticides have increased globally. Some, studies show some increased costs for Bt technology, first, for seeds but also for weed control and fertiliser. Results regarding profitability are contrasted, none can be considered as significant.

The Common Agricultural Policy is a factor in technology spillovers

The adoption of GM crops is not invariant to the agricultural policies in place. The market intervention policies of the EU's CAP, shield EU farmers from world market developments. Even after the successive rounds of CAP reforms in the years 1992 (Mac Sharry) and 2000 (Agenda 2000), world prices are only partially transmitted to domestic markets. While the ceilings installed by the Uruguay Round Agreement on Agriculture (URAA) implied some constraints, the question remains to what extent these ceilings will drive away the prime characteristic of the CAP, its insulation of domestic price levels from world market price developments. On the import side two tariff arrangements can be distinguished. In accordance with the 1993 Blair House agreement variable tariffs can be applied for cereals and rice up to a given percentage above EU intervention prices.[3] Therefore, imports either enter the EU under a variable tariff or under a current or minimum market access arrangement (TRQ). In the latter case it is the variable quota rent rather than the tariff that plays the buffering role against volatile world market prices. The external supporting mechanism for the CAP's price insulation policy is still there, though -admittedly- the variable import levies are replaced by variable tariffs and variable rents on the tariff rate quota and the variable export subsidies.

This implies that in the grains sectors a system of flexible import tariffs and variable export subsidies exists to support the institutional price arrangements, although the flexibility of this system is somewhat constrained by the URAA commitments. Hence, if world prices for grains crops decline as a result of adoption of GM technology in the mayor exporting countries, the lower world prices do not necessarily trigger a substitution of EU demand towards imported varieties.

3. A model of endogenous technology spillovers

To model the impact of a GM ban in the EU, we modify the multi-country trade focused general equilibrium model GTAP to take endogenous international technology spillovers and the CAP into account. The spillover mechanism is extensively described in Van Meijl and Van Tongeren (1998). We modify this formulation to allow for social acceptance as an additional factor that influences the effectiveness of spillovers. Furthermore, in line with adoption models, we include a threshold value for the absorption and structural similarity index (see, Geroski (2000) for an overview of technology adoption models).

The spillover hypothesis is summarized in an equation that relates productivity growth rates between two regions. Productivity growth in the receiving region, is determined by the following transmission equation:

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

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 biotechnology. E_{rs} is an index of the amount of knowledge that is embodied in trade linkages between the two regions. The indices H and D measure the absorption capacity and structural similarity in the host country. These indices are constructed such that $0 \leq H \cdot D \leq 1$. 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.

[3] The entry price system for fruits and vegetables also establishes a fixed price floor below which imports cannot occur. Moreover, if some of the bound rates for other agricultural commodities turn out not to be prohibitive they can often be made prohibitive by invoking the price-triggered variant of the Special Safety Clause (e.g. sugar, poultry).

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 innovative inputs produced by sector *j* that are exported. The embodied knowledge index becomes the import share in production:

$$E_{irs} = \frac{M_{jirs} / Y_{is}}{X_{jirr} / Y_{ir}}$$

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*, 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.

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 tot adopt GM-technologies. We use the following specification for the absorption capacity index:

$$H_s = \min\left[1, \frac{LOG(h_s)}{LOG(h_{threshold})} \right]$$

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 & Lee (1993) data set. Values are given in appendix 1.

We calculate an index of structural similarity using the equation:

$$D_s = \exp[-\left| (l_{threshold} - l_s)/d \max \right|]$$

Where *l* and $l_{threshold}$ denote land/labor ratios in activity *i* in the two regions, and d_i^{max} is the difference in the indicator found between the threshold value and the country with the smallest land/labor ratio: $d_{\max} = l_{threshold} - \min_i [l_i]$. This formulation scales the differences in the indicators on the unit interval. We include a threshold value that captures the notion that up to the threshold level the size of the farms limits adoption but after the threshold level size is no barrier to adoption any more, as noted by the EU Commission

(2001). The index of structural similarity in equation has been quantified using FAO data to calculate land and labor intensities. Values are given in appendix 1.

4. Modelling CAP essentials

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 price is dependent on the net-export position (extra-EU trade position) in a varying parameter model. This approach has also been used by Guyomard et al. (1993) in the MISS partial equilibrium model to assess the 1992 CAP reforms. Our implementation extends this approach to a general equilibrium setting. See van Meijl and van Tongeren (2001) for a discussion of this approach.

We assume that the cereals market price *pm* is a weighted average of the intervention price and the threshold price *pt*:

$pm = \alpha\, pi + (1-\alpha)\, pt$, with $0 \leq \alpha \leq 1$

The threshold price equals 1.55 x the intervention price in the Agenda 2000:

$pt = 1.55 \cdot pi$

The key idea of the varying-parameter model is that α is a function of net exports (or excess domestic supply), *Nexp*. Surry (1992) has proposed the logistic function:

$$\alpha(\text{Nexp}) := \frac{1}{1 + \exp\left[-(\phi 0 + \phi 1 \cdot \text{Nexp})\right]}$$

This function bounds α between 0 and 1, and it implies that full price transmission ($pm = pi$) is a special case. This will occur in a situation of massive excess domestic supply (such that $\alpha=1$). The parameters ϕ_0 and ϕ_1 are estimated econometrically using time series data, and they determine the slope of the curve, and hence the degree to which market prices are responding to a reduction of intervention prices. An increasing net export position pushes the market price towards the intervention price ($\alpha \rightarrow 1$), while a net import position pulls the market price towards the threshold price ($\alpha \rightarrow 0$).

4. Numerical Results

Global modelling framework

The starting point for our empirical assessment is the database and model formulation of the GTAP multi-sector multi-region applied general equilibrium model (Global Trade

Analyses Project).[4] 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 spillovers. 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 most recent database available for the model is benchmarked to 1997, and it comprises 57 sectors and 66 countries and regions (Version 5, see McDougall et al. 2001). Our implementation of the GTAP model uses an aggregation that divides the world into nine regions, each with twelve sectors (shown in Fgure 1). The regional detail highlights the attention to be given to the main participants in the GMO debate, 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.

Figure 1: Regions and sectors in the empirical model analysis

Regions		Sectors
1. AUS	Australia-New Zealand	1. Wheat
2. NAM	North America	2. Coarse grains
3. ARG	Argentina	3. Oilseeds
4. EU	European Union	4. Other crops
5. JAN	Japan and the NICs	5. Livestock
6. RAS	Rest of Asia	6. Mining, forestry and fishing
7. SAM	South America	7. Processed food
8. CHN	China	8. Textiles
9. ROW	Rest of World	9. Chemicals
		10 Transport and machinery
		11 Other manufacturing
		12 Services and activities NES

In the scenarios it is assumed that GM-driven productivity growth occurs only in the sectors coarse grains and oilseeds. This follows from our focus on maize and soybeans as the most important commercially grown GM crops. In contrast to Nielsen and Anderson (2001) we assume that productivity impacts of GM technologies differ across GM crops.

[4] The GTAP model is multi-regional, static, applied general equilibrium model based on neo-classical micro economic theory. All sectors are producing 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 (Armington, 1969). 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, hence sustaining rent differentials.

We assume Hicks-neutral productivity growth in coarse grains (maize) to capture the yield effect. We 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. EU 2000 for an overview of available estimates). Nelson et al. (1999) indicate that Ht soybeans (glyphosphate tolerant) may generate a cost reduction of 5% and the yield increases of Bt corn fall in the range of 1.8% to 8.1%. Therefore, we follow Nielsen and Anderson (2001) in assuming a productivity gain of 5%. Figure 2describes the five scenarios. These are designed to assess (1) endogenous international knowledge spillovers, (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.

Figure 2: Description of scenarios

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 Northern America	
1 Spi	Spillover scenario: Base scenario with endogenous international knowledge spillovers	Scenario 0 + Spillovers
2 SpiCap	Spillover scenario with CAP implementation	Scenario 1 + CAP
3 SpiCapSa	Spillover scenario with CAP implementation that includes social acceptability of GMO production technology.	Scenario 2 + social acceptability technology
4 EUBan	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

5. Empirical results

The discussion of results focuses on the new elements of this paper in the GMO debate: endogenous international knowledge spillovers and the Common Agricultural Policy of the EU. Scenario 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.[5] Here we focus on the new elements introduced.

[5] Nielsen and Anderson assume in their base scenario: 5% Hicks neutral productivity growth in NAM in both coarse grains and oilseeds, in their SpiCapSa (3) scenario that the some countries (Southern Cone (e.g. Argentina, Brazil), China, the Rest of East Asia, India, Mexico and South Africa) get the same productivity

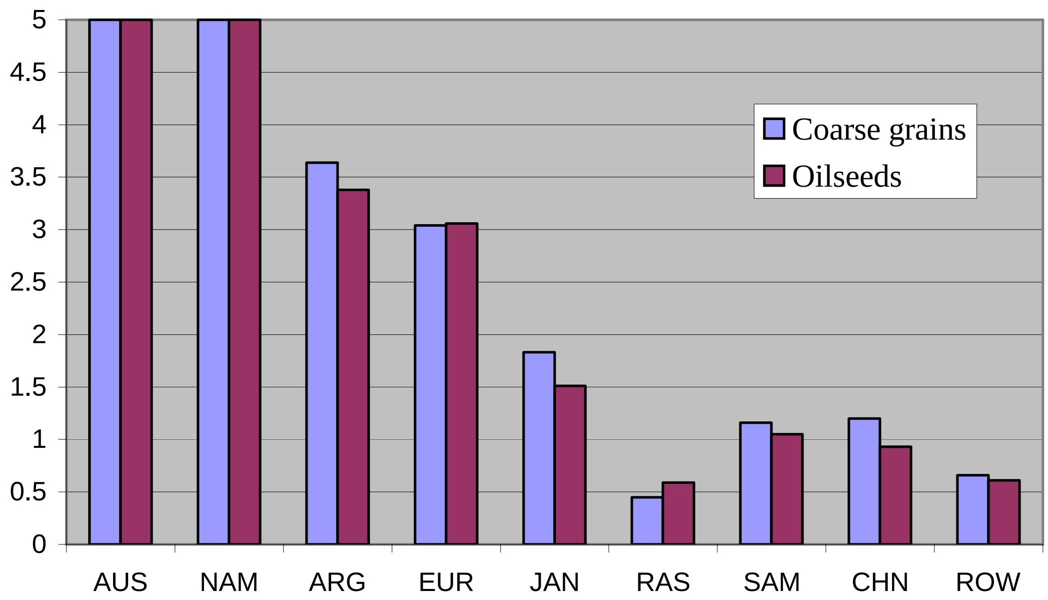

Figure 3.: Received potential spillovers in all regions by 5% productivity increase in NAM: 'potential' because social acceptance is not taken into account

Endogenous international knowledge spillovers:
Figure 3 shows the received potential spillovers in all regions, following a GMO-induced 5% productivity increase in North America (NAM), which is Hicks-neutral for maize and factor biased for soybeans. The received potential spillovers are dependent on *the amount of knowledge* that is embodied in bilateral trade in chemicals and on the *effectivenes*s of this amount of knowledge. The latter is dependent on absorption capacity and structural similarity. The received spillovers are endogenous but also ‘’potential’’, in the sense that these spillovers could be obtained if the GMO production technology is socially accepted. The difference between oilseeds and coarse grains is due to "amount" of knowledge embodied in chemicals, since the effectiveness is the same for both commodities within a region. It is clear from figure … that the difference in spillovers across commodities is 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 (AUS) potentially receive full spillovers because their farm size and education level exceeds the threshold levels. Argentina and Europe potentially receive about 70% or 60% of the total productivity growth. Argentina and Europe have both a relatively high education level of their farmers, but average farm size in Europe is smaller. Potential spillovers to the other countries, and especially developing countries, are smaller because they trade less chemical with Northern America, their farm size is too small and/or the education level is too low to adopt the new GM-technologies profitably. Assumptions about exogenous

benefits as the innovating country, and in their EUBAN scenario that the EU bans GMO's altogether. Although some of the scenario's are quite similar to our scenario's the results differ because
the value of the spillovers differ, we assume labour cum chemical saving tech change in oilseeds, we use a more recent version of the database, and, the regional and sectoral aggregation differs.

international spillovers made in other studies will therefore overstate the productivity impact in some countries because farm size an education level matter. For example, Nielsen and Anderson (2001) assume that a country will receive full spillovers if a technique is socially acceptable. This leads to exaggerated estimates of the potential productivity gains. In particular, this maybe the case for China, Rest of Asia and India.

If we compare the endogenously generated potential spillovers with these actual adoption figures, we observe that indeed countries with large farms in terms of area per person and a rather high education level tend to adopt these GM technologies. Figure 3 shows that Argentina's potential spillovers are high and in reality the adoption is also high (see Table 1). The coefficients in a large part of the world are small and we see also that the actual adoption of these new technologies is not existent. There is a mismatch between potential knowledge spillovers and actual knowledge spillovers in Australia-New Zealand, Europe and to a lesser extent Japan. The question is of course why these countries did not adopt these new technologies? This is where the social acceptance kicks in. In scenario 2 we are going from potential spillovers to actual spillovers and in this case AUS, EU, JAN and ROW receive no knowledge spillovers because they do not accept these technologies. If we combine the potential and the actual spillovers than our results of the received knowledge are broadly in line with the actual adoption figures.

Table 2 shows the production impact of potential knowledge spillovers when innovation takes place in Northern America. Without spillovers 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 therefore compete with the cheaper GM-commodities from Northern America. This is true for big importers such as Japan for both oilseeds and coarse grains and exporters such as Argentina for coarse grains and Australia-New Zealand for oilseeds (see import and export shares in Table 2). With spillovers other countries get also a part of the productivity increase. As expected 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 production due to spillovers is dependent on the value of the spillovers a country receives (these are depicted in figure 1) in combination with the importance of international trade for a country. Therefore, big exporter Argentina who has also a high spillover coefficient gets a high increase in coarse grain production. The production in some regions (e.g. ROW) declines even further which is due to their low spillover coefficients because now they also lose relative to other more successful adopters. For oilseeds the factor bias effect is also important. The GM-technology in oilseeds saves on labour and chemicals and therefore countries will profit from this technology whose labour and chemical cost shares are high (cost shares are given in Table 2). For example, European oilseeds benefit substantially from these spillovers, because the labour and chemical cost share are high, spillover coefficient is rather high and it is very open to international trade.

Table 2: Production impact of potential spillovers and key figures

	AUS	NAM	ARG	EU	JAN	RAS	SAM	CHN	ROW
				Coarse grains					
Production 0 Base	-0.81	1.92	-2.04	-0.9	-4.14	-0.1	-1.07	-0.71	-0.8
1 Spi	0.43	1.32	1.38	-0.18	-2.15	-0.18	-0.89	-0.69	-1.07
World Export share	0.02	0.52	0.10	0.23	0.00	0.00	0.01	0.06	0.06
Share of exports	0.14	0.17	0.38	0.17	0.00	0.00	0.01	0.07	0.04
Share of imports	0.00	0.02	0.03	0.18	0.88	0.05	0.13	0.06	0.16
				Oilseeds					
Production 0 Base	-2.25	1.61	-0.13	-0.65	-1.23	-0.16	-0.98	-0.54	-0.51
1 Spi	-0.6	1.12	0.26	0.45	-0.75	-0.14	-1.12	-0.37	-0.67
Labour share	0.17	0.21	0.42	0.43	0.32	0.28	0.19	0.42	0.37
IO coeff. Of chemicals	0.05	0.09	0.03	0.10	0.06	0.06	0.07	0.10	0.05
Labour + chemical share	0.23	0.29	0.45	0.52	0.38	0.35	0.26	0.52	0.42
World Export share	0.01	0.59	0.02	0.10	0.00	0.02	0.17	0.02	0.08
Share of exports	0.49	0.40	0.05	0.13	0.04	0.02	0.19	0.03	0.13
Share of imports	0.18	0.05	0.04	0.40	0.94	0.05	0.19	0.19	0.17

Figure 4 shows that including international knowledge spillovers implies that the EU's production decreases of coarse grains is smaller, but farm income deteriorates. The latter is a typical effect of the productivity improvements that lead to lower prices, and, because all countries get 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.

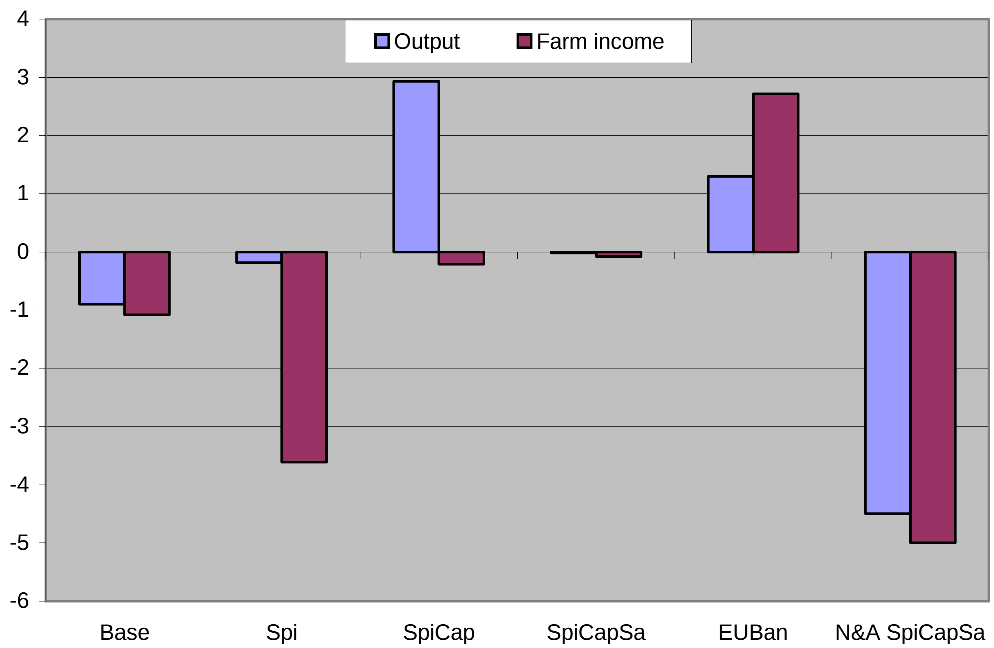

Figure 4.: Percentage change in production and farm income of coarse grains sector in EU.

The impact of EU's Common Agricultural Policy by alternative EU responses to GMOs

Figure 4 shows the production and farm income impact of alternative EU policy responses to GMOs. We focus on coarse grains because in this sector the CAP price insulation policy still in place. A comparison of 'Spi' with 'SpiCap', highlights the impact of the CAP policy alone, i.e. without taking social acceptance into account. The CAP changes the EU's production response from –0.2% to 2.9% and farm income from -3.6% to –0.2%. Clearly this indicates that isolating 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 and can transmit its own productivity increase to the rest of the world. First, productivity increases and corresponding lower export prices of other regions 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 because of the intervention price dependent price transmission mechanism. Third, increased productivity and lower price transmission lead to excess supply in the EU market, which can be disposed on world markets through a flexible export subsidy.

Comparing 'SpiCap' with 'SpiCapSa' shows impact of not accepting the GMO production technologies in the EU (also for JAN, AUS, ROW). This implies that the EU receives no productivity increases (No shock inside the EU). In addition the CAP isolates EU from productivity increases in GMO adopting regions through flexible import tariffs. Figure 4 shows that both production and farm income do not change and are therefore isolated from productivity improvements in other regions. This is in sharp contrast with results of N&A, who found a sharp reduction in coarse grains output in the EU (see, N&A SpiCapSa in figure 4). Because N&A do not include a good representation of CAP they overstate the negative production and farm income impact of not adopting GMO production technologies in the EU.

If the EU completely rejects consumption of products that are produced with GMO technologies it will ban GM product imports. Now the production in the EU increases because it has to replace the imports of GMO producing regions. Market prices will also rise in the EU due to increased demand.

Table 3: 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	NAM
Base	-0.65	-0.90	-0.20	-0.18	-0.85	-1.08	249	2250
Spi	0.45	-0.18	-1.86	-3.43	-1.41	-3.61	1283	2173
SpiCap	0.25	2.93	-1.71	-3.14	-1.46	-0.21	666	2172
SpiCapSa	-0.86	-0.02	-0.18	-0.06	-1.04	-0.08	152	2205
EUBan	19.75	1.3	4.48	1.42	24.23	2.72	-1426	1767

Table 3 gives an overview of core simulation results. In the oilseed sector the price insulation mechanism is not present and therefore the general direction of the results is similar results of other studies that have been cited earlier.

5 Conclusions

Our simulation results show that imperfect international knowledge spillovers, factor biased technology change and an improved representation of CAP policies are crucial for production, trade and welfare effects of adopting GMOs in the EU and other regions.
In particular, the inclusion of endogenous technology spillovers 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.

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Appendix 1:

Human capital data
Population weighted average years of schooling from the Barro & Lee data (1993) are used as a proxy for the absorption capacity (see table A.3). These data have been downloaded from World Banks Internet site; URL: http://www.worldbank.org/html/prdmg/grthweb/dataset.htm. Threshold value is 9.3 years.

Table A.1: Average years of schooling in the 9 model regions

AUS	NAM	ARG	EUR	JAN	SAS	SAM	CHN	ROW
10.5	11.6	8.13	8.2	9.3	4.2	4.7	5.9	6.6

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

Land/labour ratios (Table A.2)
Grain acreage and the total number of persons employed in agricultural production are taken from FAOSTAT (URL: http://app.fao.org/lim500/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 17.1.

Table A.2: Land/labour ratios in grain crops (hectares per person)

AUS	NAM	ARG	EUR	JAN	SAS	SAM	CHN	ROW
123.6	87.1	17.1	9.18	1.4	1.3	2.0	0.7	1.1

Source: FAOSTAT and GTAP database, authors calculation.