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 EU, taking into account the European Union's Common Agricultural Policy (CAP). 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. Analyses with a multi-region applied general equilibrium model shows that the CAP protects farm income and production from not adopting GM crops in the EU but has costs in terms of welfare. The EU will forgo substantial benefits if it banned GM imports.

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.

This paper concentrates on the two most the most important GM crops: Ht Soybeans and Bt corn. Almost all GM soybeans are herbicide tolerant (HT). 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. Commercially grown GM crops are concentrated in a few countries, mainly USA and Argentina (see table 1).

[Insert table 1]

GMs increase productivity. Unlike other papers we take into account that GMs might imply factor biased technical change. For example, in corn the productivity impact is mainly yield increasing, and in soybeans 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. If a production technology is not socially acceptable than a country is excluded from these potential productivity gains that are already below the gains obtained in the innovating country, due to imperfect spillovers. If in addition a GM product is also completely 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 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 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. Next knowledge, farm size matters. 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 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: the USDA (1999) research shows that adaptation 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 down 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. Technology adoption has not been hampered by low social acceptance in these countries. Evidently, social acceptance plays a role in the effectuation of knowledge spillovers.

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. As the companies involved in GM crops are typically classified under the chemical sector in the National Accounts, the modelling in this paper assumes 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 area (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). 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.

3. Modelling endogenous technology spillovers and the CAP

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, 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 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:

$$\begin{aligned} a_s &= \gamma(E_{rs}, H_s, D_s, S_s).a_r \\ &= \mathrm{S_s} \cdot E_{rs}^{(1-H_s \cdot D_s)}.a_r \end{aligned} \qquad (1)$$

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 biotechnology. 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 $0 \leq H \cdot D \leq 1$. 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 (quantified by using information on schooling years from the well-known Barro & Lee (1993) data set, see appendix 1). The structural similarity index (D) is proxied by differences in land/labour ratio's relative to a threshold value needed for adoption (see appendix 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.

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.

4. Numerical Results

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 Analysis

Project). 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. 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 GM-driven productivity growth occurs only in the sectors coarse grains and oilseeds.[2] 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. 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 1 describes 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.

[Insert figure 1]

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.[3]

[Insert Figure 2]

Endogenous international knowledge spillovers:

Figure 2 shows the received potential spillovers in all regions, following a GMO-induced 5% productivity increase in North America (NAM), which is Hicks-neutral for corn 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 the "amount" of knowledge embodied in chemicals, since the effectiveness is the same for both commodities within a region. It is clear

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[2] The GTAP database is not detailed enough to split out maize from other coarse grains.
[3] 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 benefits as the innovating country, and in their EUBAN scenario that the EU bans GMO's altogether. Although some of the scenarios are quite similar to ours the results differ because

from figure 2 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 international spillovers made in other studies will therefore overstate the productivity impact in some countries because farm size and 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.

Comparing the endogenously generated potential spillovers with the 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. For example, 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

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.

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 zero 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.

Simulation results show that 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 which 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. With spillovers other countries also get 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 2) 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. This is due to their low spillover coefficients, because they now also lose compared 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. For example, European oilseeds benefit substantially from these spillovers, because the labour and chemical cost share are high, their spillover coefficient is rather high and the EU is very open to international trade.

Figure 3 shows that including international knowledge spillovers implies that the EU's production decrease of coarse grains is smaller, but farm income deteriorates (compare SPI and Base). The latter 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.

[Insert Figure 3]

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

Figure 3 shows the impact of alternative EU policy responses to GMOs on production and farm income. 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%. This clearly 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 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 the 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 the EU from productivity increases in GMO adopting regions through flexible import tariffs. Figure 3 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 3). 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 have to ban GM product imports. In this situation, 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 for domestic produce.

[Insert Table 2]

Table 2 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 to results of other studies that have been cited earlier. In terms of economic welfare, measured as Equivalent variation (EV), table 2 shows that the EU would forego substantial benefits if it banned GM imports. The total cost of banning amounts to 1.6 billion USD. Even under the current policy environment of the CAP and the low social acceptance, the EU could realize a welfare gain of 152 million USD, whereas an import ban by the EU would result in a loss of 1.4 billion USD. The latter is mainly due to a negative allocative effect because resources move into the distorted coarse grains sector. At the same time, the ban imposes a cost of 0.4

billion USD on North America due to negative terms of terms of trade effects. Possible welfare effects are highest for the EU if the adopt GM technologies without CAP. The welfare gain is 1.3 billion USD and due to received knowledge spillovers (0.8 billion USD), allocative effects (0.4 billion) and terms of trade effects (0.1 billion USD). 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 prices that would prevail if EU grains farmers were not isolated from world markets, and the lower world prices that result from global productivity improvements were transmitted to EU markets.

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. On the other side the EU would forego substantial benefits in terms of welfare through its CAP policies, the social unacceptability of GMO technologies, or especially if it bans GMOs at all.

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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.

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: Commission of European Union, 2001.

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	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

Figure 1: 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 of 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

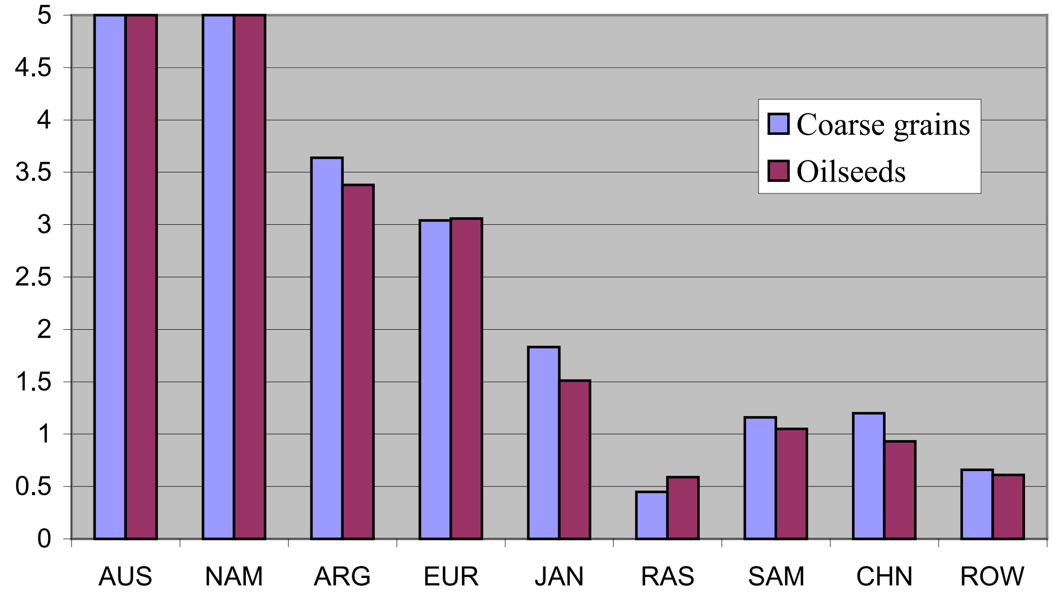

Figure 2.: Received potential spillovers in all regions by 5% productivity increase in NAM: 'potential' because social acceptance is not taken into account

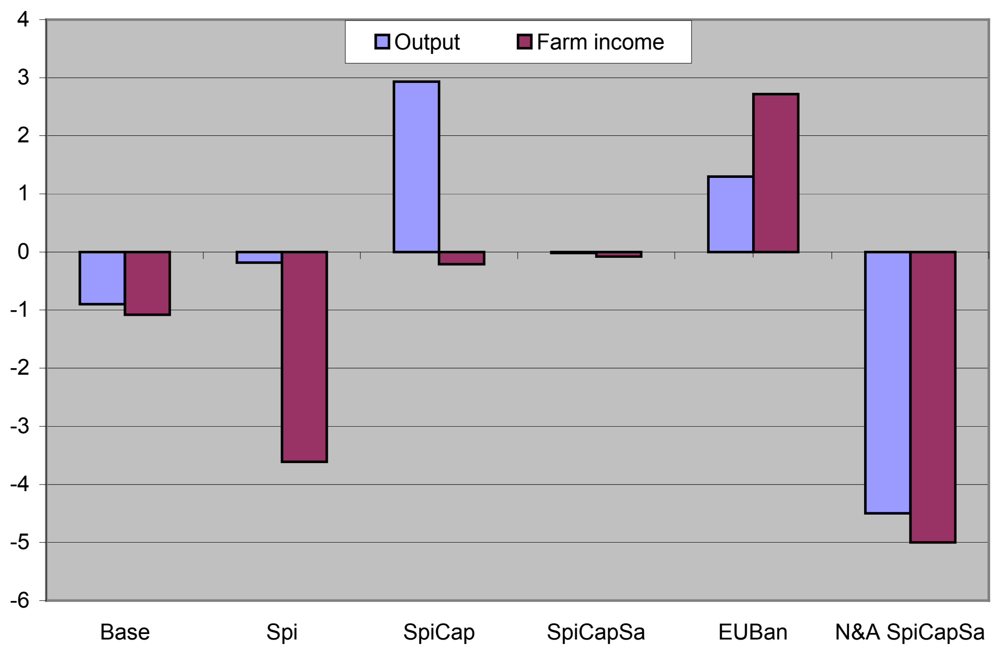

Figure 3: Percentage change in production and farm income of coarse grains sector in EU.