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The Economic Evaluation of a GM Free Country: an Irish Case Study

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Executive Summary

Presently, no GM crops are cultivated in Ireland. It is anticipated however that the introduction of co-existence guidelines could encourage the uptake of certain GM varieties (Flannery *et al.,* 2005). Hence, the objective of this research was to comparatively assess the costs and benefits of that uptake through the selection of hypothetical GM crops. In addition, the economic impact of a ban on GM feed materials for the livestock industry is also assessed. However, it should be noted that the imposition of a ban on the cultivation of GM crops or on the importation of GM feed is not open to any Member State, including Ireland; the GM free scenarios that are considered in the analysis can only be achieved on the basis of voluntary decisions made by the industry. The costs and benefits associated with the cultivation of these crops and the aforementioned ban on GM livestock feed ingredients was examined on a gross margin per hectare and per head basis for representative crop, dairy and beef farms.

The economic implications of a ban on imported livestock feed material, in particular soybean and maize, that contains GM products was assessed for specialist dairy and beef farms. Ensuring livestock products that are produced using identity preserved GM-free soybean and maize ingredients in livestock feed is a potentially complex and costly procedure. Such systems already exist for a number of products, including maize and soybeans. However, it is anticipated that in the short to medium term that supplies of IP GM free sources of soybean and maize will become scarce due to an increase in global plantings of GM material. Hence, it is assumed that the net effect will be a widening of the differential between GM and non GM product prices due to (i) the cost reducing effect of the new technology and (ii) IP costs associated with GM free crops.

The uptake of GM crop technology was assessed using two synthetic scenarios: (i) Adoption MAX where 100% of crop producers were assumed to adopt the new technology and (ii) Intermediate Adoption Scenario where 30% of the more progressive crop producers were assumed to adopt the new technology. For each of these scenarios five hypothetical crops were examined: (i) herbicide tolerant sugar beet (GMHT), (ii) *Septoria* resistant winter wheat (GMSR), (iii) *Fusarium* resistant winter wheat (GMFR), (iv) *Rhynchosporium* resistant spring barley (GMRR), and (v) *Phytophthora infestans* resistant potato. The costs and benefits of the new technology were assessed for representative crop and livestock farms. Furthermore, an exploratory analysis was conducted to determine the economic feasibility of the use of GM oilseed rape for the production of biofuel. However, the completion of a production cost impact analyses for this particular crop was deemed to be extremely sensitive to baseline data, hence, the methods employed in this analyses were not considered appropriate for this purpose.

The results show that the aggregate impact of a ban on non-cGMF livestock feed ingredients is estimated to reduce farm income earned by specialist dairy producers by between €2,8 million and €17,7 million when compared with the baseline position where no ban is imposed (the status quo ante); For specialist beef

farms in aggregate between €4,8 million and €18,6 million. At farm level, the results indicated that the 'less efficient' producers would lose more from a ban on the inclusion of non-cGMF feed ingredients. This is associated with relatively higher feed costs as a percentage of output on these farms.

Furthermore, as a result of 100% adoption rates of GM crop (Adoption MAX Scenario) technologies the aggregate impact was estimated to be between €336,737 and €1,701,963 for winter wheat and between €107,474 and €545,273 for spring barley producers. At farm level, the potential aggregate increase in profit associated with the two winter wheat GM traits was estimated at between 1.58% and 7.75% per hectare and between 0.29% and 1.48% for spring barley producers, compared to the baseline conventional crop. Furthermore, based on the assumption of 30% adoption rates of the new technology, the increase in costs for conventional producers associated with identify preservation could result in gross margin differentials of between 17.24% and 24.05% for winter wheat producers and between 14.89% and 16.25% for spring barley producers.

The aggregate impact for specialist dairy and beef producers of the introduction of the new crop technologies is estimated at between €248,000 and €445,000 for the Adoption MAX scenario and between €149,000 and €260,000 for the Intermediate Adoption scenario.

In summary, this analysis provides an assessment of the likely impact on profitability of a ban on the use and production of GM crops in Ireland, from which it is clear that the likely costs to the livestock industry in particular are significant, when a total ban on the import and cultivation of GM crops is considered. While the net benefit, for crop, livestock and dairy farms, resulting from the growing of GM cereal crops is quite minor compared to the benefits arising from the use of imported sources of GM soybean and maize, it is important not to consider these two scenarios in isolation from each other. If a ban on the presence of GM feed material is present in Ireland, it must be assumed that this ban will relate to the importation and the production within Ireland of GM crop material. Hence, the net economic benefit of the two GM free scenarios must be considered in aggregate (for cereal farms and specialist dairy and beef farms), which has been estimated with 90% confidence to be between €8,3 million and €38,9 million per annum.

It is important to note that this report does not attempt to forecast changes in market prices or demand due to increased levels of GM crop technology adoption by agriculture in Ireland and/or overseas. Hence, the results of the study cannot be used to forecast either future market prices or the demand for GM and non-GM crops. Nevertheless, the methods used in evaluating the impact of the scenarios outlined have a strong relative value (i.e. it is of most use in predicting the effect of a change in farming practices), however the absolute figures obtained should be used with care since the models have not yet fully been adjusted with field and market data.

Introduction

This report examines the possible national economic implications for the Agri-Food industry from the possible use of GMOs in crop and livestock production. The analysis contained in this report seeks to inform and contribute to the debate regarding the introduction of GM products into Ireland. However, it should be noted that the imposition of a ban on the cultivation of GM crops or on the importation of GM feed is not open to any Member State, including Ireland; the GM free scenarios that are considered in the analysis can only be achieved on the basis of voluntary decisions made by the industry. Also existing EU legislation does not provide for certification as 'GM free' but rather requires that feed containing greater than 0.9% GM material is labeled as containing GM.

In order to evaluate the economic impact in Ireland of restrictions on the adoption of GM technology and on the use of products derived from GMOs two separate scenarios were defined: (i) the economic implications of only allowing certified GM free (cGMF) imports of livestock feed ingredients versus the baseline position whereby it is probable that some, and possibly a large proportion, of feed ingredient imports are from genetically modified varieties of cereals and oilseed plants; and (ii) the economic implications for farm profitability of decreased feedstuff costs and output prices, ensuing from the introduction of GM crop varieties into Irish tillage crop systems, versus the baseline position of a continuation of the status quo whereby no GM crop varieties are grown in Ireland.

Results

Scenario 1: The Economic Implications of only allowing the importation into Ireland of certified GM Free (cGMF) Soybean and Maize Livestock Feed Ingredients in Ireland

Introduction

Currently a large proportion of purchased feed stuffs on Irish farms are imported. Of these feed stuff imports it is probable that some, and possibly a large proportion, are from genetically modified varieties of cereals and oilseed plants. As feed stuffs that cannot be certified as GMO free (cGMF) come to comprise the bulk of internationally traded cereal and oilseed commodities a policy that only allows cGMF crops as inputs into the livestock industry will imply increased feed costs for the Irish livestock industry.

It is possible that the increased livestock feeding costs implied by being a GM Free Country could be offset by the premia that might be earned from producing meat and dairy products that can be similarly certified as "GM Free". The nature (size and longevity) of such market premiums for meat and dairy products produced with the use of only cGMF feedstuffs is uncertain. Hence, this output price premium is not measured in this research, but the total extra cost ensuing from the use of cGMF inputs is considered as the minimum price premia that would have to be achieved, in order to cover the cost of a ban on GM products in Ireland.

In particular, soya and maize are major ingredients used in the Irish animal feed sector. The vast majority of the soya and maize gluten that contributes to the protein requirements in Irish animal feeds is imported from non-EU sources. Maize, which is used primarily as a non-protein animal feed ingredient, is mainly imported from other EU countries. For soya and maize gluten, the majority of imports currently ***may*** contain GM ingredients (see Appendix 1). Furthermore, given the high incorporation rates of these ingredients in compound animal feedstuffs, the imposition of a ban on the use of non-GM free feed ingredients has the potential to impact significantly on the economic situation of livestock producers. This scenario focuses on the potential economic implications (in Ireland) of a ban on the use in livestock feed rations of material that is not certified GM free, where non cGMF feeds are those that cannot be certified "free of genetically-modified (GM) ingredients".

For the purpose of this analysis, we have given priority to the assessment of the impact of a ban on the inclusion of non cGMF feed ingredients on the Irish dairy and beef livestock sectors. The priority was assigned due to the large share of Irish compound feed consumption accounted for by the dairy and beef sectors (see Table 1) and also because of their importance to the overall agricultural economy. The beef and dairy sectors alone accounted for 55% of Irish agricultural output in 2003 (CSO).

Table 1: Compound Feed Industry Consumption in Ireland (2001-2003)

	2001	**2002**	**2003**	
		('000 tonnes)		Share of total feed use (2001-2003)
Cattle	**1,963**	**2,144**	**2,101**	**55.7%**
Fattening	854	949	949	24.7%
Dairy cow	885	948	887	24.4%
Calves	171	179	170	4.7%
Others	53	68	95	1.9%
Pigs	**736**	**748**	**687**	19.5%
Piglets	108	95	96	2.7%
Pigs for fattening	481	498	441	12.8%
Breeding pigs	126	137	128	3.5%
Others	21	18	22	0.5%
Poultry	**479**	**493**	**485**	13.1%
Broilers	273	259	267	7.2%
Chicks & layers	108	119	128	3.2%
Others	98	115	90	2.7%
Milk replacers	**8**	**10**	**9**	**0.2%**
Pet food sec/Dry pet food	**14**	**13**	**45**	**0.6%**
Others	**375**	**413**	**413**	**10.8%**
TOTAL	**3,575**	**3,821**	**3,740**	

Source: FEFAC, 2004

Methods

The impact of likely price premia differences between cGMF and non cGMF compound feed on farm business profitability in the dairy and beef sectors, in terms of margins per cow and per head were examined. The impact on representative livestock farms was derived by applying (1) the estimated feed ingredient price effects, these were obtained from a comprehensive review of the literature on price differences for GM and non-GM free feed ingredients and (2) using information on average proportions of maize and soybean ingredients in livestock feed rations, defined from consultation with industry experts. The enterprise gross margin data for the representative livestock farms were based on National Farm Survey (NFS) data for the year 2003. Three specific representative specialist dairy, beef rearing and beef finishing farms were identified: (1) 'less efficient producers' (bottom 1/3 of producers in gross margin terms); (2) 'average producers' (middle 1/3 of producers in gross margin terms), and (3) 'more efficient producers' (top 1/3 of producers in gross margin terms).

Given the absence of data on the price and market impact of GM crops in an EU context, a broad range of price differentials between GM and non-GM free feed ingredients was analysed. The uncertain nature of the future price differential between non-GM free and GM free feed ingredients is unavoidable. The stochastic methods employed in evaluating the economic implications of a ban on the use of non-GM free feed ingredients are similar to those employed by Demont and Tollens (2004) and Davis and Espinoza (1998).

The main driver of the price differential between GM and non GM-free sources of feed ingredients is the interaction between supply and demand of these products. To date, supplies of non-GM-derived ingredients have been considered to be reasonably easy to obtain at limited additional cost relative to GM-derived alternatives. However, as supply of GM-free feed ingredients, in particular soya beans, is forecast to decline in the coming years and with demand likely to increase, the price differential between the two products is likely to widen. But, forecasting the likely level of this differential over the near future is extremely difficult due mainly to uncertainties about the relative levels of demand and supply. The European Federation of Biotechnology (2002) did however indicate that '*differential levels of up to 5%* [for soya]*…….may not survive for long. Higher differentials of 10% plus (possibly as high as 30%) are more likely. Differentials are only likely to remain at 5% if global demand for non-GM materials does not rise significantly and if illegal GM plantings of Brazilian soya do not exceed 2001 levels*'. Hence, given this indication that price differentials for GM and non-GM soya may widen in the future a probability distribution of the following form for the price differential between GM free and non-GM free soya was assumed: (i) 16.6 % probability of a 5% differential; (ii) 50% probability of a 10 % differential; (iii) 16.6% probability of a 20 % differential; and (iv) 16.6% probability of a 30 % differential.

In contrast to the situation for soya, the imports of maize to Ireland are mainly from EU sources. Although some GM varieties have been approved for planting in the EU, very little has been planted (mostly in Spain) and hence almost all the maize used in the EU feed sector is GM free. However, in addition to the imports into Ireland of maize for use as a non-protein feed ingredient, there are also imports of maize gluten for use as a protein source in feed compounds. These imports of maize gluten ***are mostly*** from the USA. The volume of imports of maize gluten into Ireland in 2003 and 2004 respectively were 441,989 and 625,903 tonnes respectively (see Appendix I). Hence, the economic implications of a ban on this product could also have significant consequences for the Irish livestock industry. In assessing the impact of a ban on the use of non cGMF feed ingredients on maize gluten prices similar price differentials to those assumed for cGMF and non cGMF free soya were assumed for maize gluten.

Results

The results in Table 2 show the estimated impact for livestock producers of a potential ban on the use of GM soya and maize feed ingredients in the compound feed industry in Ireland. This analysis is based on expert opinion regarding inclusion rates in feed rations i.e. a 30% inclusion rate for maize and an 10% inclusion rate for soya. The results show that for dairy farmers specializing in the production of manufacturing milk, gross margins per cow would drop by an average of 1.6% if a ban on the use of non CGMF feed ingredients were imposed. Furthermore, to capture the uncertainty surrounding the impact of a ban on the use of non-GM free feed ingredients, a 90% confidence interval was computed for the change in gross margin for the average producer. This 90% confidence interval ranged from -0.5% to -2.9%. Similar analyses were also conducted for the 'more efficient' and 'less efficient' specialist dairy producers. These showed that on a percentage of total gross margin basis and in absolute terms the 'less efficient' producers lose more from a ban on the inclusion of non-GM free feed ingredients. This is due to the fact that feed costs as a percentage of output were higher on these farms.

In addition, the aggregate impact for specialist dairy producers is estimated with 90% confidence to be between €2,8 million and €17,7 million, with an average estimated aggregate impact of €8,1 million. This figure compares with an estimated aggregate impact for the UK dairy industry of between €4,4 million and €33,2 million in 2001 for a similar ban on imported genetically-modified soybean and maize livestock feed ingredients (Bennett and Kitching, 2001). However, it is important to note that incorporation rates of maize and soya in the UK study were based on 1995 feed composition rates, hence were assumed to be considerably lower than the Irish case, due to subsequent substitution of soya and maize for meat and bone meal products.

A similar analysis was conducted for specialist 'beef rearing' and 'finishing farms', the results of which are also outlined in Table 2 below. These results again show that the 'less efficient' producers stand to lose more on a percentage and actual gross margin basis from a ban on non-GM free feed ingredients. The aggregate impact for specialist 'beef rearing' and 'finishing farms' combined is estimated with 90% confidence to be between €4,9 million and €18,6 million per annum. No similar results for beef farms were available from the UK study conducted in 2001.

Table 2: Descriptive statistics of the stochastic estimate of the impact of a ban on the import of GM feed ingredients in Ireland

	Minimum (% Difference) Actual Difference	**Mean** (% Difference) Actual Difference	**Maximum** (% Difference) Actual Difference
'Dairy Farm – average efficiency' (per cow)	(-0.48%) -4.99	(-1.36%) -14.15	(-2.88%) -29.98
'Dairy Farm – less efficient' (per cow)	(-0.89%) -6.97	(-2.53%) -19.73	(5.36%) -41.78
'Dairy Farm – more efficient' (per cow)	(-0.49%) -6.35	(-1.40%) -18.01	(-2.97%) 38.14
Aggregate Impact for Specialist Dairy Producers	**2.9E + 06**	**8.1E + 06**	**1.7E + 07**
'Specialist beef rearing – average efficiency' (per LU)	(-1.31%) -1.46	(-3.77%) -4.18	(-8.00%) -8.86
'Specialist beef rearing– less efficient' (per LU)	(-1.27%) 1.76	(-23.46%) -4.98	(-49.68%) -10.54
'Specialist beef rearing– more efficient' (per LU)	(-0351%) 1.21	(-1.45%) -3.20	(-3.07%) -6.79
Aggregate Impact for 'Specialist Beef Rearing'	**1.3E + 06**	**3.6E + 06**	**7.6E + 06**
'Specialist beef finishing – average efficiency' (per LU)	(-5.76%) -1.55	(-16.32%) -4.39	(-34.56%) -9.31
'Specialist beef finishing– less efficient' (per LU)	(-1.89%) -2.77	(-5.38%) -7.86	(-11.38%) -16.64
'Specialist beef finishing– more efficient' (per LU)	(-0.71%) -1.16	(-2.01%) – 3.68	(-4.26%) -6.93
Aggregate Impact for 'Specialist Beef Finishing'	**-1.8E + 06**	**-5.0E + 06**	**-1.1E + 07**
Aggregate Impact for Specialist Dairy & Beef Farms	**-6.0E + 06**	**1.7E + 07**	**3.6E + 07**

The stochastic nature of the results presented in Table 2 highlight the critical influence of the increase in livestock feed prices for Irish producers when they are required to use cGMF feed ingredients. The large variation in the estimated aggregate impact for dairy and cattle farms can be directly associated with the estimated range in price differentials between non cGMF and cGMF feed ingredients. Hence, as highlighted by Bennett and Kitching (2001) the cost associated with Identity Preservation (IP) of feed ingredients is likely to have a substantially large effect on the profitability of livestock farming in the future.

Scenario 2: The Economic Implications of GM Free Crop Cultivation in Ireland

Introduction

Presently, no GM crops are cultivated in Ireland. It is anticipated however that the introduction of co-existence guidelines could encourage the uptake of certain GM varieties (Flannery *et al.,* 2005). The objective of this research was to comparatively assess the costs and benefits of that uptake through the selection of five hypothetical GM crops: (i) herbicide tolerant sugar beet (GMHT), (ii) *Septoria* resistant winter wheat (GMSR), (iii) *Fusarium r*esistant winter wheat (GMFR), (iv) *Rhynchosporium* resistant spring barley (GMRR), and (v) *Phytophthora infestans* resistant potato.[i] The costs and benefits associated with the cultivation of these crops were examined on a gross margin per hectare basis for representative crop, dairy and beef farms. The representative crop farms used in the analysis were constructed based on Farm Management Protocol data. This approach was adopted due to (i) the lack of itemised data from NFS sources and (ii) the need to acknowledge the 'typical early adopters' in a technology cycle (Fernandez-Cornejo *et al.* 2001), for whom the farm management protocol data was deemed representative. However, data from the NFS were used to define representative dairy and beef farms, in order to determine the costs and benefits to dairy and beef farms that would be associated with GM barley and wheat production in Ireland. Barley and wheat are estimated to currently account for 15% of feed ingredient composition in the Irish cattle sector.

For the crop producer, the provision of an economic incentive is a highly significant factor in their decision to adopt/reject a new technology (e.g. GM crops). For this research, it is assumed that producers will base their decision on the relative prices of conventional and GM seeds, synthetic pesticides, labour, capital and other relevant inputs and choose a system which will minimise these costs (Kalaitzandonakes, 2003). If producers are to be motivated to adopt GM technology, production costs will have to decrease or remain static (Kalaitzandonakes, 2003). In parallel to the anticipated cost savings associated with the adoption of GM technology, the GM producer will also bear additional costs. A technology cost will typically be passed onto farmers in the form of a seed premium (PG Economics, 2003) as demonstrated in the US and Argentina (GAO, 2000), Spain (Demont and Tollens, 2004) and the UK (May, 2003). Further compliance-associated costs (cleaning of machinery, drying and storage facilities; separate transport and storage) will also arise at the harvest and post-harvest stage. Notably, these costs will vary and it can be expected that they will be lower on farms where 'only GM' or 'only non-GM' production is carried out and machinery is segregated for GM/non-GM cultivation purposes (Tolstrup *et al*., 2003).

Taking account of these aforementioned issues, the scenario described below provides an initial assessment of the economic cost/benefit of cultivating five hypothetical GM crops in Ireland. As noted above the crops (winter wheat, spring barley, sugar beet and potato) were selected based on their economic importance to Irish agriculture and the described traits (disease resistance/herbicide tolerance) were selected because of the difficulties these issues impose upon present crop management regimes. In the case of GM sugar beet, the availability of specific crop output data permitted a more detailed analysis, which was in contrast to winter wheat, spring barley and potato where the analysis was restricted to the benefit associated with reduced chemical input. All of the aforementioned hypothetical GM crops were examined relative to a conventional cropping system. While it is acknowledged by the authors and evident in the literature that the economic implications of the introduction of GM crops into a country would have alternative impacts on organic producers, compared to conventional producers, this impact assessment was conducted in this research. Organic farming is still a relatively unimportant sector of the Irish agricultural sector in terms of the value of output produced, employment and its contribution to overall agricultural sector income. Hence, the focus on conventional farming operations was considered a priority in this research. .

Furthermore, an exploratory analysis was conducted to determine the economic feasibility of the use of GM oilseed rape for the production of biofuel. However, as outlined by PG Economics (2003) the completion of a production cost impact analyses for this particular crop was deemed to be extremely sensitive to baseline data, hence, the methods employed in this analyses were not considered appropriate for this purpose. A more detailed methodology to include an analysis of the distribution of gross margin data for conventional oilseed rape producers versus the impact of a conversion to GM oilseed rape would be necessary, and beyond the scope of this project.

Methods

To examine the economic cost benefit analysis of GM crop cultivation in Ireland, the cropping regimes of the four listed crops were compared with equivalent, hypothetical GM scenarios. All figures used were based on crop production data for Ireland and include variable and some element of fixed costs: materials (seed, fertilisers, herbicides, fungicides, insecticides, growth regulators), machinery hire (ploughing, tilling, sowing, spraying, fertiliser spreading, harvesting) and miscellaneous costs (interest @ 7% and transport), (O' Mahony, 2002; Teagasc, 2002; O' Mahony, 2003; Teagasc, 2003).

The sugar beet analysis included data for seed cost, herbicide spray and application costs in conjunction with data from England (May, 2003). As yield data has been reported in regard to GMHT sugar beet, the impact of the technology on yield was examined. However, the treatment of the yield effect was carefully constructed in the economic analysis, as prescribed by Mitchell (2000) and Kniss *et al*., (2004). The overall economic implications of the introduction of the new technology were outlined both including and excluding the yield effect. The model including the yield effect was predicted by adopting a stochastic distribution of the reported yield affect from several European trials (Moll, 1997; Brants and Harms, 1998; Tenning, 1998; Wevers, 1998a; Wevers, 1998b; May, 2000; Mitchell, 2000; Richard-Molard, 2001). This approach was adopted given the problems associated with accurately predicting yield effects that have been highlighted by Mitchell (2000) and Kniss *et al.,* (2004). The inclusion of yield as a stochastic distribution captures the uncertainty surrounding the yield enhancing benefits of GM technologies.

In contrast, yield estimates for GM wheat/barley/potato were not available; hence the likely cost benefits gained from increased yields associated with these GM crops could not be represented. For winter wheat and spring barley, the cost of cultivating GMSR/GMFR winter wheat and GMRR spring barley was compared with conventional cropping regimes in terms of the impact the technology would have on fungicide sprays and their application. In the main-crop potato sector, the cost effect of decreasing the number of spray applications through the use of a GMLBR potato variety was examined. Note to safeguard the durability of host resistance a two-spray regime was included in the model.

Taking into account proposed co-existence guidelines, it was assumed that Irish GM producers will incur an additional administration fee to cover costs associated with crop co-existence and GM crop research. For the purpose of this research it has been assumed that the levy will be in the region of €25 per hectare. In addition, conventional crop producers could also incur additional costs arising from GM crop cultivation. Following the approach outlined by Bock *et al.,* (2002) it was assumed that these additional costs associated with Identity Preservation (IP) for conventional producers of non GM crops would be absorbed at farm level.

Following from evidence reported in Bock *et al.,* (2002) whereby the IP costs[ii] for conventional crop producers were shown to differ according to the crop produced, the identification of crop specific IP costs was considered important. Huygen *et al.,* (2004) outlined an estimate of IP costs for conventional non GM wheat (€29 per hectare) which were used in the estimation of the extra costs which would be borne by conventional producers in the production of winter wheat. This estimate was based on the incremental time and associated costs toe undertake IP protocols, such as time spent cleaning items of machinery and equipment or the costs of applying GM-content tests. This cost was assumed to be similar to those which would be evident in the production of spring barley and was thus used in the spring barley budgets. Data from Bock *et al.,* (2002) was used in the estimation of IP costs for conventional potato production (€41.50 per hectare, of which initial planning of the monitoring system was estimated to cost €12.90per hectare, implementation: €1,90 per hectare, on-line monitoring: €0.3 per hectare, sampling: €2.40 per hectare, GMO analysis: €9.0 per hectare, Review: €6.7 per hectare, External Audit: €8.20 per hectare). These costs are slightly higher than those used for cereal production because it is assumed that sampling of the potato crop must be conducted pre-harvest using in-field sampling, i.e. by taking leaves of the potato plants. Sampling potatoes post harvest was not considered feasible due to the large weight such a potato sample would represent. Following a similar rationale, monitoring costs for conventional sugar beet production were assumed to be similar to the costs for potatoes.

While GM seed will be more expensive than its conventional equivalent, predicting the cost is difficult as there is no precedent in Ireland and the cost of GM seed varies greatly between country, crop and variety. For the purposes of this study, crop specific seed premium prices have been used (as proposed by Alston *et al.*, 2002) when suitable data were available from the literature. However, based on the crops examined in this analysis, a relevant crop specific seed premium for Ireland was only available for sugar beet (€30 from May, 2000). For the remaining crops, a tentative premium of 15% was assumed. Alternative seed premium assumptions were considered for the remaining crops, such as that proposed by Alston *et al.*, (2002) where '*the variable costs per acre would be the same as for a representative conventional…..control technology*'. However, due to data limitations, in particular the absence of data on yield for the remaining crops, it was not possible to follow the Alston *et al*. approach of static average variable costs.

Given the evidence cited in the literature that the decision to adopt GM technology would be based on the provision of an economic incentive and the reality that GM crops tend to trade at a market discount to conventional crops, it was assumed for this analysis that the difference in price between conventional and GM crops would be a proportionate price reduction for GM crops, equivalent to a percentage of the cost savings associated with its usage. Other changes in market prices or demand due to an increased level of GM crops in agriculture have not been considered. The results of this analysis cannot be used to forecast either future market prices or the demand for GM or non-GM crops.

Furthermore, as GM cultivation has yet to commence in Ireland, it was difficult to predict the price at which the GM crops would sell on the market. To account for this uncertainty the approach used by Bennett and Kitching (2001) was followed. We have assumed that a proportion of the cost savings associated with growing the GM crop would translate into a price discount, with GM crops trading at a discount to conventional non GM crops. Bennett and Kitching (2001) assumed a range of price discounts for GM crops equivalent to (i) 50%, (ii) 70%, and (iii) 90%, of the estimated cost savings associated with the cultivation of GM crops for use in the animal feed sector[iii]. These price discounts were included in the analysis as a stochastic variable, for the crops grown in Ireland that are predominantly used in animal feed sector (i.e. spring barley and winter wheat). Furthermore, it is assumed that GM crops destined for the animal feed sector, that trade at a discount to conventional crops, would be available to livestock producers at these reduced costs. Hence, the representative livestock farms presented below benefit from reduced cost livestock feed ingredients. Given that the demand for GM potatoes would, *ceteris paribus*, be more likely to trade at a discount to a conventional crop, compared to the demand in the animal feed sector, the range of price discounts for GM potatoes was assumed to be (i) 70% and (ii) 90%, of the estimated savings.

In addition to the uncertainty surrounding price differentials between conventional and GM crops, the adoption rates of the new technology were also difficult to predict with certainty. To account for this uncertainty, following the approach outlined by Bock *et al.*, (2002) two alternative adoption rates were examined. The first scenario, defined as Adoption MAX Scenario, represents the situation whereby adoption rates of the new technology reach 100% and all producers of the crop adopt the new GM crop technologies. However, a 100% adoption rate of the new technology is not considered a realistic scenario in the short to medium term. Hence, a second adoption scenario was defined whereby 30% of wheat and barley producers in the country adopt the new technologies. Following adoption practices witnessed in other countries where GM technologies have already been implemented it has been assumed that the early adopters of the new technology will be the larger, more progressive farmers. Consequently, despite the fact that only 30% of producers are assumed to adopt the technology in the medium term, these producers are assumed to represent 64% and 45% of the total area of wheat and barley respectively. This assumption is based on data from the latest census of agriculture (CSO, 2001), which is outlined in further detail in Appendix III.

The cropping regimes, including the spray programme assumed for this analysis, were based on Farm Management Protocol (FMP) data (Teagasc, 2002, 2003). Compiled from annual 'Crop Costs and Returns' (O'Mahony, 2002, 2003), this data set provided variable costs (i.e. ploughing, tilling, sowing, spraying, fertiliser spreading, harvesting, interest and transport) and was chosen ahead of the National Farm Survey (NFS) data (for details on the 2003 NFS go to http://www.teagasc.ie/publications/2004/20040809.htm). To account for annual differences with respect to yield and disease pressure, both 2003 (high yield, low disease) and 2002 (low yield, high disease) were examined. The low yields obtained in 2002 were attributed to mild humid conditions, which led to elevated levels of disease pressure.

The enterprise gross margin data for the representative livestock farms were based on National Farm Survey (NFS) data for the year 2003. Three specific representative specialist dairy, beef rearing and beef finishing farms were identified: (1) 'less efficient producers' (bottom 1/3 of producers in gross margin terms); (2) 'average producers' (middle 1/3 of producers in gross margin terms), and (3) 'more efficient producers' (top 1/3 of producers in gross margin terms).

Finally, it is important to note that in each of the scenarios defined below, the estimates provided were based on a combination of computer modelling and expert opinion. Hence, as outlined by Bock *et al.*, (2002) this method of estimating the impact of the adoption of GM technologies has a strong relative value (i.e. they are useful in predicting the effect of a change in farming practices) but the absolute figures obtained have to be taken with care since the models have not yet fully been adjusted with field data.

Results

Representative Crop Farms

For GMHT sugar beet, the reduction in spray volume and number of applications combined with the additional GM costs (seed costs equivalent to an 30 €ha^{-1} and a technology cost equivalent to an extra €25 per hectare), resulted in an average cost saving of 85.63 €ha^{-1} (6.06% of total costs per hectare); representing a 9.69% increase in gross margin (Table 3A), against the status quo baseline of no GM sugar beet production. When the estimated IP costs for 'conventional' sugar beet production are taken into consideration the increase in gross margin for GM crops relative to conventional crops is 15.16% (Table 3B). When the range of predicted yield increases (Moll, 1997; Brants and Harms, 1998; Tenning, 1998; Wevers, 1998a; Wevers, 1998b; May, 2000; Richard-Molard, 2001) was incorporated into the analysis, it was estimated with 90% confidence that crop profitability could increase by between 20.09% and 40.88% relative to the baseline conventional crop (Table 3A) and by between 26.07% and 47.91% relative to the conventional crop with additional IP costs (Table 3B).

In 2003 and 2002, growers of winter wheat incurred a cost of 150 €ha^{-1} and 179 €ha^{-1} respectively for conventional fungicide applications (Table 4A). If commercialised, GMSR varieties could decrease this expenditure to an average of 100 €ha^{-1} (40% cost savings per hectare), while GMFR varieties could decrease the fungicide requirement to an average of 113 €ha^{-1} (31% cost savings per hectare). When these costs (Table 4A) were incorporated into the cropping regime along with the accepted GM costs (which included a seed cost equal to 9 €ha^{-1} extra and a technology cost equal to 25 €ha^{-1} extra), the comparative difference between the conventional and GM regimes equated to an average cost savings of 30.5 €ha^{-1} (3.3% cost savings per hectare) for GMSR winter wheat and 17.5 €ha^{-1} (1.8% cost savings per hectare) for GMFR winter wheat (Table 4A): a potential 9.6% and 5.9% respective increase in profit. In addition, accounting for the additional IP costs which conventional crop producers would incur in the Intermediate Adoption scenario (Table 4B), the increase in gross margin associated with Septoria and Fusarium resistant wheat could be as high as 20.88% and 11.63% respectively, compared to conventional crop production.

However, given the reality that GM crops may trade at a discount relative to conventional crops, the potential increase in profit for both GM winter wheat crops examined has been estimated with a 90% confidence interval to be between 1% and 4.8% for GMSR and 0.58% and 2.95% for GMFR per hectare, against the baseline position of no GM crop production in Ireland. The percentage increase in profits associated with the adoption of GM winter wheat crops in the intermediate adoption scenario was estimated with 90% confidence to be between 11.36% and 15.67% for GMSR and 5.88% and 8.38% for GMFR per hectare (see Table 4B); hence representing an increase in gross margin for GM winter wheat relative to conventional winter wheat crops.

Furthermore, assuming that Ireland is not a GM free state, and adoption rates of the new technology reach 100%, the aggregate impact[iv] of the new technology for winter wheat producers has been estimated with 90% confidence to be between €336,737 and €1,701,963 for both crops (Table 4A).

Similar cost evaluations showed that the adoption of GMRR spring barley could reduce the cost of fungicide applications from 83 €ha^{-1} to 41.5 €ha^{-1} (Table 5A). When combined with additional GM costs (seed cost (9.6 €ha^{-1} extra) and technology cost), an average cost saving of 6.9 €ha^{-1} (0.8%) could be returned to the producer (see Table 5A): corresponding to a 10.5% profit increase, against the baseline position of no GM spring barley production in Ireland. Furthermore, accounting for the additional IP costs which conventional crop producers would incur in the Intermediate Adoption scenario (Table 5B), the increase in gross margin associated with Rhynchosporium resistant barley could be as high as 17.95%, compared to conventional crop production.

However, assuming that GMRR spring barley would trade at a discount to conventional crops, the overall impact on profitability would be reduced. It was estimated with a 90% confidence interval that GMRR spring barley (with a price discount accounted for) would be between 0.29% and 1.48% more profitable than a conventional crop in the baseline scenario of no GM crop production and between 14.89% and 16.25% more profitable than a conventional crop with IP costs respectively. Furthermore, the aggregate impact of the new technology [ii] for spring barley producers was estimated with 90% confidence to be between €107,474 and €545,273 per annum (Table 5A).

In the case of main crop potatoes reducing blight control applications from 13 to 2 in main-crop potato production could decrease associated expenditure from 343 €ha^{-1} to 57 €ha^{-1} respectively. When combined with expected GM costs (15% seed cost (122 €ha^{-1} extra) and technology cost), this would provide a cost saving of 199 €ha^{-1} (4.3%) against the baseline conventional crop (Table 6A) and a cost saving of 241 €ha^{-1} (5.2%) against conventional crops in the intermediate adoption scenario when IP costs must be borne by conventional crop producers (Table 6B). However, given that potatoes are the only crop examined that is sold directly for human consumption the impact of price discounts for GM crops is significantly important for this analysis. Assuming a price discount equivalent to between 70% and 90% of the estimated cost savings associated with the growing crop, we estimate that, with a 90% confidence interval, the profit margins from GM potatoes could be 1.39% and 4.18% higher than conventional crops in the baseline scenario and between 4.43% and 7.30% against conventional crops in the intermediate scenario, when IP costs must be borne. Furthermore, in aggregate terms this increase in profits for potato growers could represent between €727,420 and €1,316,016 per annum extra in income terms, in the event of 100% adoption rates.[ii]

In summary, all five GM crops were more cost efficient than their conventional equivalent, with the highest saving recorded by GMHT sugar beet. Similarly, an increase in gross margin was reported for each GM crop, with GMHT sugar beet recording the highest percentage cost saving.

Table 3A: The total cost and profit margins for sugar beet – Adoption MAX Scenario

	€/Ha	2003	GM 2003	GM vs. Convent 2003	2002	GM 2002	GM vs. Convent 2002	Convent average	GM average	GM vs. Convent average	Difference (%)	Saving (%)
Sugar beet (no yield increase)	Yield t/Ha	45.00	45.00	0.0	45.00	45.00	0.0	45.00	45.00	0.0		
	Output	2295.00	2295.00	0.0	2295.00	2295.00	0.0	2295.00	2295.00	0.0		
	Seed	106.00	136.00	30.00	97.00	127.00	30.00	101.50	131.5	30.00		
	Technology cost	0.0	25.00	25.00	0.0	25.00	25.00	0.0	25.00	25.00		
	Herbicides	155.00	27.90	-127.10	188.00	33.84	-154.16	171.50	30.87	-140.63		
	Spray application	56.00	56.00	0.0	57.00	57.00	0.0	56.50	56.50	0.0		
	Other costs	1045.00	1045.00	0.0	1120.00	1120.00	0.0	1082.50	1082.50	0.0		
	Total Costs	1362.00	1289.90	-72.10	1462.00	1362.84	-99.16	1412.00	1326.37	-85.63	93.93	-6.06
	Gross Margin	933.00	1005.10	72.10	833.00	932.16	99.16	883.00	968.63	85.63	109.69	9.69
Sugar beet (yield increase included)	Yield t/Ha (Average)	45.00	47.70	-2.70	45.00	47.70	-2.70	45.00	47.70	-2.70		
	Output (Average)	2295.00	2432.70	-137.70	2295.00	2432.70	-137.70	2295.00	2432.70	-137.70		
	Seed	106.00	136.00	30.00	97.00	127.00	30.00	101.50	131.50	30.00		
	Technology cost	0.0	25.00	25.00	0.0	25.00	25.00	0.0	25.00	25.00		
	Herbicides	155.00	27.90	-127.10	188.00	33.84	-154.16	171.50	30.87	-140.63		
	Spray application	56.00	56.00	0.0	57.00	57.00	0.0	56.50	56.50	0.0		
	Other costs	1045.00	1045.00	0.0	1120.00	1120.00	0.0	1082.50	1082.50	0.0		
	Total Costs	1362.00	1289.90	-72.10	1462.00	1362.84	-99.16	1412.00	1326.37	-85.63	93.93	-6.06
	Gross Margin (Average)	933.00	1142.80	209.80	833.00	1069.86	236.86	883.00	1106.33	223.33	125.29	25.29
	Gross Margin (90% Confidence Interval)								1060.43 ---- 1244.03	177.43 ---- 361.03	120.09 ------ 140.88	20.09 ---- 40.88

Table 3B: The total cost and profit margins for sugar beet – Intermediate (30%) Adoption Scenario

€/Ha		Conventional Baseline	Conventional Intermediate	GM
Sugar beet (no yield increase)	Yield t/Ha	45.00	45.00	45.00
	Output	2295.00	2295.00	2295.00
	Seed	101.50	101.50	131.5
	Technology cost	0.0	41.90	25.00
	Herbicides	171.50	171.50	30.87
	Spray application	56.50	56.50	56.50
	Other costs	1082.50	1082.50	1082.50
	Total Costs	1412.00	1453.90	1326.37
	Gross Margin	883.00	841.10	968.63
Sugar beet (yield increase included)	Yield t/Ha (Average)	45.00	45.00	47.70
	Output (Average)	2295.00	2295.00	2432.70
	Seed	101.50	101.50	131.50
	Technology cost	0.0	41.90	25.00
	Herbicides	171.50	171.50	30.87
	Spray application	56.50	56.50	56.50
	Other costs	1082.50	1082.50	1082.50
	Total Costs	1412.00	1453.90	1326.37
	Gross Margin (Average)	883.00	841.10	1106.33
	Gross Margin (90% Confidence Interval)			1060.43 - ---1244.03

Table 4A: The total cost and profit margins for winter wheat[v] - Adoption MAX Scenario

	€/Ha	2003	GM 2003	GM vs. Convent 2003	2002	GM 2002	GM vs. Convent 2002	Convent average	GM average	GM vs. Convent average	Difference (%)	Saving (%)	Aggregate Industry (90% Conf Interval)
Winter wheat (GMSR)	Yield t/Ha	9.10	9.10	0.00	9.10	9.10	0.00	9.10	9.10	0.00			
	Output €/t	866.90	866.90	0.00	866.90	866.90	0.00	866.90	866.90	0.00			
	EU area aid	383.00	383.00	0.00	383.00	383.00	0.00	383.00	383.00	0.00			
	Output /Ha	1249.90	1249.90	0.00	1249.90	1249.90	0.00	1249.90	1249.90	0.00			
	Seed	63.00	72.50	9.40	57.00	65.60	8.60	60.00	69.00	-9.00			
	Technology cost	0.00	25.00	25.00	0.00	25.00	25.00	0.00	25.00	25.00			
	Fungicides	150.00	91.00	-59.00	179.00	108.00	-71.00	164.50	100.00	64.50			
	Spray application	70.00	70.00	0.00	72.00	72.00	0.00	71.00	71.00	0.00			
	Other costs	616.00	616.00	0.00	658.00	658.00	0.00	637.00	637.00	0.00			
	Total costs	899.00	874.50	-24.60	966.00	928.60	-37.50	932.50	902.00	-30.50	96.70	-3.30	
	Gross Margin (Average with no price discount)	350.90	375.40	24.60	283.90	321.30	37.50	317.40	347.90	30.50	109.60	9.60	
	Gross Margin (90% Confidence Int. accounting for price discount)								320.47 ----- 332.88	3.07 ------ 15.48	101.0 ------ 104.8	1.0 ------ 4.8	**€ 215,821 ---- €1,088,244**
Winter wheat (GMFR)	Yield t/Ha	9.10	9.10	0.00	9.10	9.10	0.00	9.10	9.10	0.00			
	Output €/t	866.90	866.90	0.00	866.90	866.90	0.00	866.90	866.90	0.00			
	EU area aid	383.00	383.00	0.00	383.00	383.00	0.00	383.00	383.00	0.00			
	Output /Ha	1249.90	1249.90	0.00	1249.90	1249.90	0.00	1249.90	1249.90	0.00			
	Seed	63.00	72.50	9.40	57.00	65.60	8.60	60.00	69.00	-9.00			
	Technology cost	0.00	25.00	25.00	0.00	25.00	25.00	0.00	25.00	25.00			
	Fungicides	150.00	103.00	-47.00	179.00	123.00	-56.00	164.50	113.00	51.50			
	Spray application	70.00	70.00	0.00	72.00	72.00	0.00	71.00	71.00	0.00			
	Other costs	616.00	616.00	0.00	658.00	658.00	0.00	637.00	637.00	0.00			
	Total costs	899.00	886.50	-12.60	1009.00	986.60	-22.50	954.00	936.50	-17.50	98.20	-1.80	
	Gross Margin (Average with no price discount)	350.90	363.40	12.60	240.90	263.30	22.50	295.90	313.40	17.50	105.90	5.90	
	Gross Margin (90% Confidence Int. accounting for price discount								297.62 ----- 304.63	1.72 ---- 8.73	100.58 ------ 102.95	0.58 --- 2.95	**€120,916 --- €613,719**

Table 4B: The total cost and profit margins for winter wheat[vi] - Intermediate (30%) Adoption Scenario

	Winter wheat €/Ha	Conventional – Baseline	GMSR/ GMFR winter wheat	Intermediate Conventional
GMSR	Yield t/Ha	9.13	9.13	9.13
	Value of output @ 95€/tonne	866.88	866.88	866.88
	EU area aid	383.00	383.00	383.00
	Total output /Ha incl. area aid	1249.88	1249.88	1249.88
	Seed 140kg @ 450/tonne	60.00	69.00	60.00
	Fertilisers	198.00	198.00	198.00
	Technology cost	0.00	25.00	29.60
	Spray costs	268.00	203.50	268.00
	Hire Machinery	344.50	344.50	344.50
	Interest (7%)	25.50	25.50	25.50
	Transport€4/tonne	36.50	36.50	36.50
	Total costs	932.50	902.00	962.10
	Gross margin (average)	317.38	347.88	287.78
	Gross margin (90% confidence, with proportional price reduction)		320.47---332.88 (Average: 332.88)	
GMFR	Yield t/Ha	9.13	9.13	9.13
	Output @ €95/tonne	866.88	866.88	866.88
	EU area aid	383.00	383.00	383.00
	Total output /Ha incl. area aid	1249.88	1249.88	1249.88
	Seed 140kg @ €450/tonne	60.00	69.00	60.00
	Fertilisers	198.00	198.00	198.00
	Technology costs	0.00	25.00	29.60
	Spray Costs	268.00	203.50	268.00
	Hire Machinery	383.50	383.50	383.50
	Interest (7%)	25.50	25.50	25.50
	Transport €4/tonne	19.00	19.00	19.00
	Total costs	954.00	936.50	983.60
	Gross Margin (average)	295.88	313.38	281.08
	Gross margin (90% confidence, with proportional price reduction))		297.62 ---304.63 (Average: 301.12)	

Table 5A: The total cost and profit margins for spring barley[iii] – Adoption MAX Scenario

	€/Ha	2003	GM 2003	GM vs. Convent 2003	2002	GM 2002	GM vs. Convent 2002	Convent average	GM average	GM vs. Convent average	Difference (%)	Saving (%)	Aggregate Industry (90% Confidence)
Spring barley (GMRR)	Yield t/Ha	5.60	5.60	0.00	5.60	5.60	0.00	5.60	5.60	0.00			
	Output	504.00	504.00	0.00	520.80	520.80	0.00	512.40	512.40	0.00			
	EU area aid	383.00	383.00	0.00	383.00	383.00	0.00	383.00	383.00	0.00			
	Total output /Ha	887.00	887.00	0.00	903.80	903.80	0.00	895.40	895.40	0.00			
	Seed	68.00	78.20	10.20	60.00	69.00	9.00	64.00	73.60	9.60			
	Technology cost	0.00	25.00	25.00	0.00	25.00	25.00	0.00	25.00	25.00			
	Fungicides	75.00	37.50	-37.50	91.00	45.50	-45.50	83.00	41.50	-41.50			
	Spray application	42.00	42.00	0.00	44.00	44.00	0.00	64.00	64.00	0.00			
	Other costs	456.00	456.00	0.00	489.00	489.00	0.00	472.50	472.50	0.00			
	Total costs	641.00	638.70	-2.30	684.00	672.50	-11.50	662.50	655.60	-6.90	99.20	-0.80	
	Gross Margin (Average with no price discount)	246.00	248.30	2.30	219.80	231.30	11.50	232.90	239.80	6.90	110.50	10.50	
	Gross Margin (90% Confidence Interval accounting for price discount)								233.58 ---- 236.35	0.68 ----- 3.45	100.29 ----- 101.48	0.29 ----- 1.48	**€107,474 --- €545,273**

Table 5B: The total cost and profit margins for spring barley[iii] – Intermediate (30%) Adoption Scenario

	Spring barley €/Ha	Conventional Baseline	GMRR barley	Intermediate Conventional
GMRR	Yield t/Ha	5.60	5.60	5.60
	Output @ 90€/tonne in 2003 and 93€/tonne in 2002	512.40	512.40	512.40
	EU area aid	383.00	383.00	383.00
	Total output /Ha	895.40	895.40	895.40
	Seed (150kg @€450 per tonne)	64.00	73.60	64.00
	Technology fee	0.00	25.00	29.60
	Fertilisers	117.50	117.50	117.50
	Herbicides	38.50	38.50	38.50
	Fungicides	83.00	41.50	83.00
	Insecticides	21.50	21.50	21.50
	Growth Reg.	0.00	0.00	0.00
	Hire Machinery	301.50	301.50	301.50
	Interest (7%)	9.00	9.00	9.00
	Transport€4/tonne	27.50	27.50	27.50
	Total Costs	662.50	655.60	692.10
	Gross Margin (Average)	232.90	239.80	203.30
	Gross margin (90% Confidence Interval accounting for price discount)		233.58---236.35 (Average: 234.97)	

Table 6A: The total cost and profit margins for potatoes[iii] – MAX Adoption Scenario

	€/Ha	2003	GM 2003	GM vs. Convent 2003	2002	GM 2002	GM vs. Convent 2002	Convent average	GM average	GM vs. Convent average	Difference (%)	Saving (%)	Aggregate Industry (90% Confidence
Potato (GMBR)	Yield t/Ha	31.70	31.70	0.00	31.70	31.70	0.00	31.70	31.70	0.00			
	Output	6016.70	6016.70	0.00	6016.70	6016.70	0.00	6016.70	6016.70	0.00			
	Seed	813.00	935.00	-122.00	813.00	935.00	-122.00	813.00	935.00	-122.00			
	Technology cost	0.00	25.00	25.00	0.00	25.00	25.00	0.00	25.00	25.00			
	Fungicides	343.00	57.20	285.80	343.00	57.20	285.80	343.00	57.20	285.80			
	Spray application	84.00	24.00	60.00	86.50	26.60	59.90	85.30	25.30	59.90			
	Other costs	3364.00	3364.00	0.00	3334.00	3334.00	0.00	3349.00	3349.00	0.00			
	Total costs	4604.00	4405.10	198.90	4635.00	4436.20	198.80	4590.25	4391.42	198.83	95.70	4.30	
	Gross Margin (Average with no price discount)	1412.70	1611.60	198.90	1381.70	1580.40	198.80	1426.42	1625.24	198.83	113.90	13.90	
	Gross Margin (90% Confidence Interval accounting for price discount)								1446.30 --- 1486.07	19.88 ---- 59.65	101.39 ---- 104.18	1.39 ---- 4.18	

Table 6B: The total cost and profit margins for potatoes[iii] – Intermediate (30%) Adoption Scenario

Potato €/Ha	Conventional Baseline	GMLBR potato	Intermediate Conventional
Price / Tonne	€190.00	€190.00	€190.00
Yield t/Ha	€32.00	€31.67	€32.00
Value of Output	€6,017.00	€6,016.67	€6,017.00
Seed 3.2 tonnes @ €254/tonne	€813.00	€934.95	€813.00
Co-existence levy	€0.00	€15.00	€42.00
Research levy	€0.00	€10.00	€0.00
Fertiliser 1.2 tonne 10.10.20 @ €235/tonne	€282.00	€282.00	€282.00
Herbicide Mixtures	€64.00	€64.00	€64.00
Blight Sprays x 12 (€30 per spray)	€343.00	€57.17	€343.00
Desiccant	€64.00	€64.00	€64.00
Bags / Ties 20 kg bags - €11.5/tonne	€287.00	€287.00	€287.00
Misting - €213 per acre	€213.00	€213.00	€213.00
Total material cost	€2,066.00	€1,927.12	€2,108.00
Margin over material costs	€3,950.67	€4,089.55	€3,909.00
Ploughing	€38.00	€38.00	€38.00
Cultivations/Destoning	€317.00	€317.00	€317.00
Fertiliser Application	€25.00	€25.00	€25.00
Planting	€64.00	€64.00	€64.00
Spraying (x 14) @ €6 each	€85.25	€25.31	€85.00
Harvesting €12 / tonne	€285.00	€285.00	€285.00
Transport €5 / tonne (up to 6 miles)	€125.00	€125.00	€125.00
Grading in and out of store €25.4/tonne	€635.00	€635.00	€635.00
Storage + boxes + Misc. €38/tonne)	€950.00	€950.00	€950.00
Total costs	€4,590.25	€4,391.42	€4,632.00
Gross Margin - average	€1,426.00	€1,625.24	€1,385.00
Gross Margin (90% Confidence Interval accounting for price discount)		€1446.30 ---€1486.07	

Representative Livestock Farms

The results in Table 7 show the estimated impact for livestock producers resulting from the Adoption MAX Scenario specified above, whereby all crops of barley and wheat grown in the country are GM crops. This scenario is based on expert opinion regarding inclusion rates in feed rations i.e. 15% for cereals, of which it is assumed 57% is represented by barley and 43% represented by wheat, based on 2002 and 2003 production levels.

The results show that the average impact on gross margin, as a result of the introduction of GM wheat and barley production in Ireland, for specialist dairy farmers, specialising in manufacturing milk production, is estimated at – 0.3 % per cow i.e. gross margins per cow would increase by on average 0.3 % if Ireland was not declared a GM Free State. Furthermore, to capture the uncertainty surrounding the impact of a ban on the use of non-GM free feed ingredients, a 90% confidence interval was computed for the change in gross margin for the average producer. This 90% confidence interval ranged from 0.02% to 0.04 %. Similar analyses were also conducted for the 'more efficient' and 'less efficient' specialist dairy producers. These showed that on a percentage of total gross margin basis and in absolute terms the 'less efficient' producers would gain slightly more from the introduction of GM crops in Ireland. This is due to the fact that feed costs as a percentage of output were higher on these farms.

In addition, the aggregate impact for specialist dairy producers is estimated with 90% confidence to be between €120,000 and €220,000 with an average estimated aggregate impact of €160,000.

A similar analysis was conducted for specialist 'beef rearing' and 'finishing farms', the results of which are also outlined in Table 7 below. These results show that the 'less efficient' producers stand to gain more on a percentage and actual gross margin basis from the introduction of GM wheat and barley crops. The aggregate impact for specialist 'beef rearing' and 'finishing farms' combined is estimated with 90% confidence to be between €128,000 and €225,000 per annum.

Table 7 Descriptive statistics of the stochastic economic estimate for livestock producers of the introduction of GM crops in Ireland – Adoption MAX Scenario

	Minimum Actual Difference (% Difference)	**Mean** Actual Difference (% Difference)	**Maximum** Actual Difference (% Difference)
'Dairy Farm – average efficiency' (per cow)	.22 (.02%)	.31 (.03%)	.39 (.04)
'Dairy Farm – less efficient' (per cow)	.28 (.04%)	.40 (.05%)	.52 (.07%)
'Dairy Farm – more efficient' (per cow)	.28 (.02%)	.39 (.03%)	.49 (.04%)
Aggregate Impact for Specialist Dairy Producers	**1.2E+05**	**1.6E + 05**	**2.2E+05**
'Specialist beef rearing – average efficiency' (per LU)	.08 (1%)	.11 (.99%)	.13 (1%)
'Specialist beef rearing– less efficient' (per LU)	.07 (1%)	.10 (.99%)	.13 (1%)
'Specialist beef rearing– more efficient' (per LU)	.06 (1%)	.08 (.99%)	.10 (1%)
Aggregate Impact for 'Specialist Beef Rearing'	**5.3E + 04**	**7.4E+ 04**	**9.5E+ 04**
'Specialist beef finishing – average efficiency' (per LU)	.07 (.24%)	.09 (.32%)	.11 (.41%)
'Specialist beef finishing– less efficient' (per LU)	.12 (.99%)	.16 (.99%)	.21 (.99%)
'Specialist beef finishing– more efficient' (per LU)	.04 (.02%)	.06 (.03%)	.07 (.04%)
Aggregate Impact for 'Specialist Beef Finishing'	**7.5E+04**	**1.0E+05**	**1.3E+05**
Aggregate Impact for Specialist Dairy & Beef Farms	**2.5E + 05**	**3.3E + 05**	**4.5E + 05**

The large variation in the estimated aggregate impact for dairy and cattle farms can be directly associated with the estimated range in price differentials between GM and non-GM free feed ingredients.

However, 100% adoption rates of the new technologies are not considered a realistic GM scenario in the short to medium term. Hence, a further adoption scenario was defined whereby 30% of wheat and barley producers in the country adopt the new technologies. Following adoption practices witnessed in other countries where GM technologies have already been implemented it has been assumed that the early adopters of the new technology will be the larger, more progressive farmers. Consequently, despite the fact that only 30% of producers are assumed to adopt the technology in the medium term, these producers are assumed to represent 64% and 45% of the total area of wheat and barley respectively. This assumption is based on data from the latest census of agriculture (CSO, 2001), which is outlined in further detail in Appendix III. The economic impact of this adoption scenario for livestock farms is outlined in Table 8. Unlike the 100% adoption scenario outlined in Table 7 above, the intermediate adoption scenario necessitates the specification of an additional budget for crops which are based on conventional production methods but which now incur additional Identity Preservation costs, this contrasts with the baseline position where all crops grown are conventional crops and IP costs are irrelevant.

Table 8 Descriptive statistics of the stochastic economic estimate for livestock producers of the introduction of GM crops in Ireland – Intermediate Scenario (30% Adoption Rates)

	Minimum Actual Difference (% Difference)	Mean Actual Difference (% Difference)	Maximum Actual Difference (% Difference)
'Dairy Farm – average efficiency' (per cow)	.14 (.01%)	.19 (.02%)	.23 (.02%)
'Dairy Farm – less efficient' (per cow)	.18 (.02%)	.23 (.03%)	.30 (.04%)
'Dairy Farm – more efficient' (per cow)	.18 (.01%)	.23 (.02%)	.30 (.02%)
Aggregate Impact for Specialist Dairy Producers	**7.3E + 04**	**1.0E + 05**	**1.3E + 05**
'Specialist beef rearing – average efficiency' (per LU)	.06 (1.0%)	.07 (1.0%)	.09 (1.0%)
'Specialist beef rearing– less efficient' (per LU)	.04 (1.0%)	.06 (.99%)	.08 (1.0%)
'Specialist beef rearing– more efficient' (per LU)	.04 (1.0%)	.05 (1.0%)	.06 (1.0%)
Aggregate Impact for 'Specialist Beef Rearing'	**3.2E + 04**	**4.4E + 04**	**5.6E + 04**
'Specialist beef finishing – average efficiency' (per LU)	.04 (.14%)	.05 (.20%)	.07 (.25%)
'Specialist beef finishing– less efficient' (per LU)	.07 (1.0%)	.10 (1.0%)	.12 (1.0%)
'Specialist beef finishing– more efficient' (per LU)	.02 (.01%)	.03 (.02%)	.04 (.02%)
Aggregate Impact for 'Specialist Beef Finishing'	**4.4E + 04**	**6.2E + 04**	**7.8E + 04**
Aggregate Impact for Specialist Dairy & Beef Farms	**1.5E +05**	**2.1E +05**	**2.6E +05**

The results show that, with 30% adoption rates for GM wheat and barley, the average impact on gross margins per cow of Irish farmers specializing in manufacturing milk production is estimated at – 0.2 %. Furthermore, to capture the uncertainty surrounding the impact of a ban on the use of non-GM free feed ingredients, a 90% confidence interval was computed for the change in gross margin for the average producer. This 90% confidence interval ranged from 0.02% to 0.04 %. Similar analyses were also conducted for the 'more efficient' and 'less efficient' specialist dairy producers. These showed that on a percentage of total gross margin basis as well as in absolute terms the 'less efficient' producers gain slightly more from the introduction of GM crops in Ireland. This is due to the fact that feed costs as a percentage of output were higher on these farms.

In addition, the aggregate impact for specialist dairy producers is estimated with 90% confidence to be between €73,000 and €130,000 with an average estimated aggregate impact of €100,000.

Similar analyses were conducted for specialist 'beef rearing' and 'finishing farms', the results of which are also outlined in Table 8. The aggregate impact for specialist 'beef rearing' and 'finishing farms' combined is estimated with 90% confidence to be between €76,000 and €130,000 per annum.

Discussion and Conclusions

This analysis has provided an assessment of the likely impact on profitability of a ban on the use and production of GM crops in Ireland. However, it should be noted a ban on the cultivation of GM crops or on the importation of GM feed is not open to any Member State; the GM free scenarios considered above can only be achieved on the basis of voluntary decisions made by the industry. Hence, while the economic impact of a ban on the import of GM feed material was examined separately from the economic impact of the cultivation of GM crops in Ireland, for interpretative purposes these two scenarios should not necessarily be considered in isolation. If a voluntary decision on the part of industry not to plant GM crops were to be reached it is probable that there would be pressure for a parallel voluntary decision to "ban" the importation of non cGMF materials.

In conclusion, it is clear that the likely costs associated with not producing, importing and use of GM crops are significant, in particular for the livestock and dairy industries. In aggregate, the economic impact for crop producers (winter wheat and spring barley in particular) and livestock producers of a ban on the use an importation of GM crops was estimated with 90% confidence to be between €9,9 million and €47,5 million.

Clearly, in the current environment where Irish agriculture is already under financial pressure as a result of the recent CAP reform process, continuing developments in environmental policy, and a possibly trade liberalising outcome to the ongoing WTO talks, further policy decisions that increase farm costs and reduce profitability could force additional producers to cease production. What has not considered by this analysis are the changes in market prices and demand due to the likely increased level of GM crops in agriculture. Hence, the results of the study cannot be used to forecast either future market prices or the demand for GM and non-GM crops. Consequently, further work is recommended that would seek to develop a more comprehensive framework for the analysis of the economic impacts on the diverse market demands for crop and meat products in a world where GM products become more pervasive.

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Appendix 1: Volume of Imports of Feed Ingredients

	2004	2003
	Imports Tonnes (Jan- December)	
Cereals:		
Wheat	**363,401**	**519,160**
Barley	**81,823**	**88,649**
Oats	**613**	**8,649**
Maize	**180,611**	**184,296**
Total	**626,448**	**801,002**
Proteins:		
Soybeans	**56,590**	**29,450**
Soybeanmeal (full fat)	**14,250**	**9,589**
Soybeanmeal	**307,876**	**346,073**
Cotton	**22,644**	**23,382**
Linseed	**1,533**	**4,278**
Sunflower	**93,267**	**117,434**
Rapeseed	**110,520**	**112,662**
Copra	**5,290**	**8,607**
Palm Kernel	**103,393**	**88,922**
Poultry Offal Meal etc	**1,917**	**2,680**
Fishmeal	**4,246**	**6,642**
Maize Gluten Feed	**625,903**	**441,989**
Peas	**9,686**	**14,053**
Total	**1,357,115**	**1,205,761**
Other Materials:		
Corn Distillers	**175,614**	**214,047**
Maize Screenings	**36,650**	**30,732**
Rice Bran	**27,701**	**23,189**
Wheat Bran/Wheatfeed	**94,979**	**113,929**
Screenings	**3,877**	**5,593**
Molasses(Cane&Beet)	**223,240**	**217,690**
Citrus Pulp	**232,121**	**211,332**
Beet Pulp/by -products	**54,321**	**41,943**
Beet Pulp Molassed	**2,054**	**2,162**
Alfalfa	**2,964**	**4,144**
Compound Feed	**85,719**	**79,034**
Other		
Total	**939,240**	**943,795**

Appendix II – Rationale for the Selection of Hypothetical GM Crop Traits

Sugar beet

In 2003, 31,500 hectares (ha) [representing 1.5 million tonnes of saleable product] of sugar beet was cultivated in Ireland. Weed control is a critical component of Irish sugar beet cropping, as less than 80% weed control will decrease yield through increased competition or greater losses at harvest. Though sugar beet is bred to be biennial, approximately 1% will bolt and flower in the first year (bolters). The resulting bolter seed will emerge in the rotation as 'weed beet' which at one bolter plant per square metre can reduce crop yield by up to 12% (Mitchell, 2002). Non-selective/selective herbicides (glyphosate/diquat and sulfonylureas respectively) will eradicate weed beet in cereal crops but to reduce the weed beet population in the longer term 98% bolter control is required (O' Mahony, 2004).

A recent multi-dimensional examination of cost-benefit analysis for GMHT sugar beet estimated that the private benefits forgone for the European Union were approximately €169 million per year due to the non-cultivation of GMHT sugar beet (Demont *et al.*, 2004). It is clear therefore that herbicide tolerant (GMHT) sugar beet could present the Irish farmer with an opportunity to reduce herbicide input, while decreasing the labour intensive requirements of bolter control, and subsequently improve crop yields (Moll, 1997; Brants and Harms, 1998; Tenning, 1998; Wevers, 1998a; Wevers, 1998b; Wilson, 1999; May, 2000; Mitchell, 2000; Wauters, 2000; Richard-Molard, 2001; Wilson *et al.*, 2002; May, 2003).

<u>Winter wheat</u>

As a consequence of the mild and wet climate fungal diseases are the greatest challenge to Irish tillage farmers with *Septoria tritici*/*Septoria nodorum* ('Septoria') and *Fusarium* spp. (Fusarium head blight) the principal diseases of wheat. Over 60,500 ha of winter wheat were sown in 2003 but traditional disease control regimes have been complicated with the recent emergence of fungicide resistant strains of *S. tritici* (O'Sullivan 2004). Septoria can inflict annual yield losses of 10-20%, while head blight though not as prevalent as Septoria can, under favourable conditions, produce mycotoxins, which pose a serious risk to animal and human health. As both Septoria and Fusarium are of economic importance to Ireland, GM winter wheat varieties expressing resistance to either Septoria (GMSR) or Fusarium (GMFR) could serve to benefit the farmer through reduced chemical input.

<u>Spring barley</u>

163,270 ha of spring barley was sown in 2003 and as with wheat, disease control is crucial to achieving high yields. The primary fungal disease of spring barley is *Rhynchosporium secalis* ('leaf scald'), which is currently controlled with a fungicide mix. The development of GM *Rhynchosporium* resistant (GMRR) barley could therefore present the farmer with an opportunity to reduce current levels of fungicide input.

Potato

Phytophthora infestans ('late blight'), continues to be a major problem in Ireland, causing annual losses in yield and quality estimated at €15 million per annum[vii] (Copeland *et al.*, 1993). Present crop regimes require a regular, high-rate fungicide application at short intervals throughout the growing season. In 2003, 3.6% of Ireland's total crop production area (14,150 ha representing 488,210 tonnes) was planted with potato with producers having to spray 12-14 times to ensure adequate blight protection (Dowley *et al.*, 2001). As with the previous crops, the commercialisation of a specific GM late blight resistant (GMLBR) potato variety could potentially offer a significant cost savings to the producer (Gianessi *et al*, 2003).

Appendix III

Farms growing wheat classified by farm size (AAU) and area under wheat

Area under wheat (hectares)	**Farm Size (AAU) - hectares**							Total
	<5	**5 ≤ 10**	**10 ≤ 20**	**20 ≤ 30**	**30 ≤ 50**	**50≤100**	**≥100**	
> 0 ≤ 1	11	3	3	6	2	2	-	27
1 ≤ 2	8	8	15	19	20	20	1	91
2 ≤ 5	15	18	56	62	150	251	59	611
5 ≤ 10	-	33	81	60	161	329	115	779
10 ≤ 20	-	-	52	54	152	308	237	803
20 ≤ 50	-	-	-	10	78	272	319	679
≥50	-	-	-	-	-	44	313	357
Total	34	62	207	211	563	1226	1044	3347
Area under wheat	63	320	1476	1640	6172	18667	49628	77966
Average area (ha)	1.9	5.2	7.1	7.8	11.0	15.2	47.5	23.3

Farms growing barley classified by farm size (AAU) and area under barley

Area under barley (hectares)	**Farm Size (AAU) - hectares**							Total
	<5	**5 ≤ 10**	**10 ≤ 20**	**20 ≤ 30**	**30 ≤ 50**	**50≤100**	**≥100**	
> 0 ≤ 1	76	32	79	55	38	20	2	302
1 ≤ 2	38	46	127	151	181	84	10	637
2 ≤ 5	113	145	341	456	906	832	76	2869
5 ≤ 10	-	187	402	407	881	995	230	3102
10 ≤ 20	-	-	418	426	943	1377	369	3533
20 ≤ 50	-	-	-	90	458	947	588	2083
≥50	-	-	-	-	-	83	371	454
Total	227	410	1367	1585	3407	4338	1646	12980
Area under barley	450	1908	9718	12743	35546	62621	59321	182307
Average area (ha)	2.0	4.7	7.1	8.0	10.4	14.4	36.0	14.0

Endnotes

[i] Further detail on the economic importance of the aforementioned crops in Irish crop production is outlined in Appendix II.
[ii] IP costs for conventional crops were assumed to represent monitoring costs. Insurance costs and costs associated with changes in farm practises were not estimated due to difficulties in estimating these costs in *ex ante* analyses.
[iii] Alternative differentials in the market value of GM crops and non GM crops such as the current difference between market value of conventional and organic produce. which were suggested during a stake holder consultation process, were not considered appropriate. The authors believe that the method outlined above has a more scientific foundation in the literature. The aforementioned approach, which would involve the use of a niche market premium would not be appropriate in the assessment of the costs and benefits of a ban on the use of GM technologies by farmers producing commodity products.
[iv] Based on the average area of crop planted in 2002 and 2003.
[v] Yield: The presented yields were generated by taking an average of the output levels listed in the Farm Management Protocol Data (Teagasc, 2002; 2003).
Technology cost: This comprises a proposed €15 co-existence levy and a €10 research levy.
Other costs: This category consists of all costs not affected by changing to a GM regime: fertilisers, herbicides, insecticides, growth regulators, ploughing, tilling, sowing, fertiliser spreading, harvesting, interest (7%), transport, miscellaneous and for potato (desiccant, bags and ties, misting, cultivations/de-stoning, planting, grading in and out of store, storage boxes).

[vi] Yield: The presented yields were generated by taking an average of the output levels listed in the Farm Management Protocol Data (Teagasc, 2002; 2003).

[vii] This figure was updated using price indices from the CSO to represent yield and quality losses in terms of 2003 data.