Introducing Genetically Modified Plants: Now or Later – An Option Value Approach[1]

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Paper prepared for presentation at the 11th Congress of the EAAE
(European Association of Agricultural Economists),
Copenhagen, Denmark: August 24-27, 2005

Abstract

Using market data, we have estimated the quasi option value of delaying to grow genetically modified corn and soybeans in Europe. We find that the current quasi option value of growing genetically modified soybeans and corn in Europe is high. This makes it likely that for the time being the information value of waiting exceeds the market gains of growing genetically modified plants in Europe.

Key words: quasi option value, value of information, genetically modified plants.

JEL classification: Q29, G13, Q18

Introduction and motivation

There is substantial scientific disagreements on the potential risks of introducing genetically modified plants (GMPs) in the market (see for example Ando and Khanna, 2000; Phipps and Park, 2002). It may take some time before these issues are resolved and the scientific community has arrived at some sort of consensus in these matters. Several scientists, including Myhr and Traavik (2003), have therefore argued for delaying commercial use of genetically modified products.

There are two major concerns regarding the commercial of GMPs: (i) consumption of GMPs may have adverse health effects, and (ii) genomes of GMPs may spread to local plants, thereby affecting the ecosystem functions these plants perform. The costs of restoring local gene pools may be large, making the release of modified genes virtually irreversible. This latter argument has many similar features with the concern of species invasion (Thomas and Randall, 2000).

This paper takes a different perspective. Instead of looking at the potential costs of commercial introduction of GMPs, we have estimated the benefits of such an introduction now compared to a delayed introduction using market data. The rationale behind our approach is that the size of the measurable benefits provides an indication of the magnitude of the potential benefits to make current introduction beneficial.

For several years there has been separate markets for GM and non-GM corn and soybeans. By analyzing the time series data for GM and non-GM corn and soybeans, we obtained an estimate of the expected benefits of starting to grow GMP corn and soybeans in Europe, or delaying such an introduction.

GMPs are already commercially introduced in the US and some other countries. At first sight this may make our approach void. Regarding the spread of genetic material to resident plants it is reasonable to treat geographically distant regions as separate receptors. Hence, the commercial use of GMPs in the US can be perceived as a 1:1 scale experiment regarding the risk of spreading genetic materials. The existence of such an experiment at another location actually increases rate of learning, making the waiting time shorter. As such, it could reduce the costs of waiting, implying that the benefits of current introduction need to be even higher, for it to be socially welfare enhancing to commercially introduce GMPs where they have yet not been introduced.

Investment under uncertainty

Benefit-cost (BC) analyses utilizing the net present value or the benefit-cost ratio are frequently used to assess if projects are to be implemented or not. Often, there is uncertainty about key parameters in the BC analysis. Several techniques within the conventional BC framework exist to capture the impact of such uncertainty, including sensitivity analysis, and break even analysis. These techniques do not answer the questions regarding the timing of the investment, i.e., should one invest now, or wait one more period before repeating the decision analysis.

The timing question is particularly relevant if there is potential irreversibility regarding the project, or waiting provides the possibility of learning more about the uncertain future benefits (or costs) of the project. Such problems are particularly suited for using the real option framework, that focuses on the net benefits of acting today versus delaying the decision and gaining information. Within finance this perspective is much used, and is the background for how options are to be priced (Black and Scholes, 1973; Merton, 1988). The Black and Scholes / Merton framework requires that the price process of the financial object is known. This implies that one knows the underlying stochastic process of the price movement, which makes it possible to use the Dixit and Pindyck (1994) mathematical framework.

Unfortunately, the underlying available data do not adhere to a basic condition of Brownian motion associated with the Black and Scholes / Merton approach for our data, even with use of differencing and other time series techniques to make the error terms identically independently distributed (i.i.d.).

We have therefore taken another approach, namely to estimate the *quasi-option value* (Arrow and Fisher, 1974; Henry, 1974) of introducing GMPs in Europe for corn and soy beans. This methodological choice is also motivated by the possible irreversible effects of having GMP materials spreading to local plant materials. Here, the option value arise from waiting to invest in a project (start growing GMPs) with potential irreversible effects (Zilberman, 1999).

The quasi-option value vs. benefit-cost analysis

A simple example following Dixit and Pindyck (1994), illustrates the difference between *quasi-option value* and BC-analysis. Assume that one can invest in a project with an initial investment I in period $t = 0$. The project has an expected net revenue of $E(B_t)$ with probability q that net revenues will increase by ΔB_t and a probability (1 - q) for a reduction in revenues by the same amount, i.e., ΔB_t. After period 1, one assumes that revenues will remain constant for all future time periods, i.e., revenues are either $B_t - \Delta B_t$ or $B_t - \Delta B_t$.

The expected net present value for implementing the project today is

$$NPV_0 = -I + \Sigma_{t=0}^{\infty} \frac{E(B_t)}{(1+r)^t} \qquad [1]$$

It is easily seen that this expression may become positive, implying that the project should be implemented in period $t = 0$ using the net present value criterion. However, we have already assumed that the gross benefits can be either $B_t - \Delta B_t$ or $B_t - \Delta B_t$. Provided that the value goes down, and we waited with the investment the decision criterion using BC analysis becomes

$$NPV_{1^-} = -I + \Sigma_{t=1}^{\infty} \frac{B_t - \Delta B_t}{(1+r)^t} \qquad [2a]$$

which obviously is more likely to become negative than [1]. Consequently, by not waiting, one runs the risk of implementing a project that should not have been implemented. However, it is also possible that the net revenues increase by ΔB_t with probability (1 - q), implying that the net present value from period $t = 1$ an onwards becomes:

$$NPV_{1^+} = -I + \Sigma_{t=1}^{\infty} \frac{B_t + \Delta B_t}{(1+r)^t} \qquad [2b]$$

If NPV_0 is positive, obviously NPV_{1^+} must also be positive. In that case investing in period $t = 0$ would have yielded higher net benefits than delaying the investment. The issue is therefore if the informational value of waiting exceeds the benefits of implementing today.

The option value captures this uncertainty, and is – for this simple example – given by

$$OV_{0-1} = NPV_0 - [q\ NPV_{1^-} + (1-q)\ NPV_{1^+}] \quad [3]$$

The generic formulation is:

$$OV_{0-1} = NPV_0 - NPV_1 \quad [4]$$

The option value gives the worth of having flexibility in investments opportunities, as this allows for eliminating (or at least for reducing) the downside risks. The underlying idea behind the option value is to enable postponing the project until it is "deep in the money", so that the probability of getting a negative net present value of investing at time t becomes sufficiently low. This corresponds to a threshold value, the hurdle rate, η, where the project is sufficiently "deep in the money".

The development of many natural resources are particularly complicated because of the irreversibility of such projects. Using conventional BC-analysis, one implements when the BC-ratio exceeds one. The option value framework implies that there is a value in future information, and one should postpone the investment until the BC-ratio exceeds $(1 + \eta)$.

Unfortunately, it is rare that all uncertainty is resolved in the next time period. Usually, some uncertainty on net benefits remains over time. When the uncertainty is not resolved for multiple periods, one needs to capture the uncertainty by other means.

Let T denote some hypothetical future time period where the distribution of the uncertainty is known. For simplicity, assume that the net benefits, NB_t, are normally distributed with variance σ^2, i.e.,

$$B(x_t) \backsim N[B(x_0), \sigma^2] \quad [5]$$

Since the distribution of NB_T is known at time T, it is possible to calculate the value of the outcome at this time. Clearly, the project would not be implemented if

$$NB_t \leq B(x_t) \quad \forall t \in [0, t^*\rangle \quad [6]$$

i.e., until time t^* it is not optimal to implement the project. Assume that at time t^* the benefits have risen sufficiently to avoid an unacceptable downside risk. At this time, the option value becomes zero, and the BC-ratio, $B(x_t)$, equals one plus the hurdle rate, η. Figure 1 provides an illustration of the relationship between the net benefits, the implementation time, t^*, and the time when all uncertainty is resolved, T.

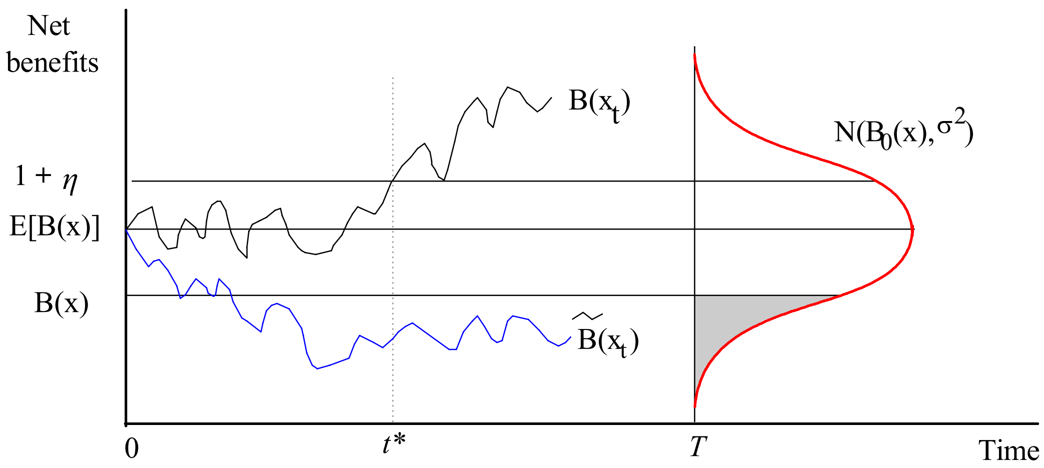

Figure 1. Implementation of uncertain projects (after Zilberman, 1999)

At time t^* the risk of obtaining a lower BC-ratio than $(1 + \eta)$ is acceptable for the project $B(x_t)$. Note that for the other possible realizations, illustrated by the line $\widetilde{B}(x_t)$, it is never optimal to implement, even if the BC-ratio is above one at some instances.

Starting to grow GMPs in Europe

As indicated earlier, there is substantial controversy surrounding the cost side of starting to grow GMPs in Europe. The largest uncertainty relate to the costs of having GMP material released and affecting other non-GMPs or wild plants. We have therefore chosen to look at the costs of not growing GMP corn and soybeans in Europe. These costs arise from higher production costs and willingness-to-pay for non-GMPs compared to GMPs.

Choice of discount rate

Benefit-cost calculations are sensitive to the choice of discount rate. We have chosen to use 4.25 % in our base calculations. This corresponds to the 10 years bond rate of the European Central Bank. Some, like Perrings (1997), argue for using lower discount rates for projects with potential long term impacts to avoid "discounting these away". This results in the marginal yields of short term projects being higher than for longer term projects, implying a dynamic inconsistency with an ensuing loss of value added in the economy. We choose to follow the advice of Krutilla and Fisher (1985) of not lowering the discount rate, but letting any long term effects be reflected in higher salvage values or terminal costs.

Degree of implementation

The degree of implementation of GMPs among US corn and soybean growers vary. It is generally a bit higher for soybeans than for corn. We expect European growers to be more skeptical than their US counterparts as public concern on GMPs appears higher in Europe. In the analyses we have used adoption rates ranging from 20 to 60 percent, in increments of 10 percent.

Prices and quantities

At the Tokyo Grain Exchange (TGE) there are separate derivatives for GMO and non-GMO products. We assume that the observed price differential at the TGE carry over the European markets. Moreover, we assume that the price differentials are transferable from soybeans to corn.

We are aware that these assumptions may appear speculative with regard to statistical validity as well as differences in preferences and commodity composition between Japanese and European consumers. However, these are the only available comparable price data on GMPs and non GMPs. If we are to use market data to estimate the cost of delaying the introduction of GMPs, these data are currently our only viable alternative.

Non-GMO futures were introduced just a few years ago. The price series is therefore on the short side to enable using the real options framework. Table 1 shows the prices and price differences for GMO and non-GMO soybeans.

Table 1. Prices on GMO (US) and non-GMO soybeans at the Tokyo Grain Exchange (2003).

Year	Mean price US $		Difference (non-GMO - US)	% price change from previous year	
	US	non-GMO	per 10 metric ton	US	non-GMO
2,000	588.79	2,027.83	1,439.04	-	-
2,001	738.04	2,258.79	1,520.75	25.35	11.39
2,002	803.51	2,603.45	1,799.94	8.87	15.26
2,003	886.36	2,868.29	1,981.93	10.31	10.17

Table 1 shows that prices for both US and non-GMO soybeans have increased since the market was introduced. This is contrary to the development at the world market, where US soybean prices declined in the same time period. In our base analyses we have therefore assumed that US soybeans prices remain constant in nominal terms, while non-GMO soybean prices remain constant or increase by three percent more than US soybeans per year.

Regarding non-GMO corn there is not yet a separate market with the associated price series data. We therefore assume a similar price path for non-GMO corn as we have for non-GMO soybeans. Our justification for a scenario with higher price growth for non-GMPs is that in the short to medium run, European consumers are likely to remain skeptical towards foods containing GMOs.

Results

Table 2 shows the quasi option value (equation [4]) of implementing GMO corn and soybeans for the given adoption rates in 2004 compared to full implementation. The option values are calculated as the price difference times the amount of non-GMPs remaining in the market, and adjusted for the cost of waiting.

Table 2. Option value (1000 US $) of implementing GMO corn/soybeans in 2004.

	Adoption rate GMO corn and soybeans				
	20 %	30 %	40 %	50 %	60 %
non-GMP produced (tons)	31,004,800	27,129,200	23,253,600	19,378,000	15,502,400
OV - 0 % price difference	2,569,696	2,248,405	1,927,204	1,606,404	1,284,803
OV - 3 % price difference	3,426,141	2,997,874	2,569,606	2,141,338	1,713,070

Remark: Discount rate 4.25 %

Table 2 shows a wide spread in option values. For the lowest adoption rate (20 percent) and a three percent difference in the price growth between non-GMPs and GMPs, the 2004 option value is about 3.4 billion dollars. With the highest adoption rate (60 percent) and no price growth difference, the option value drops to about 1.3 billion dollars. If the information value of waiting is below the option value, it is not optimal to introduce GMPs.

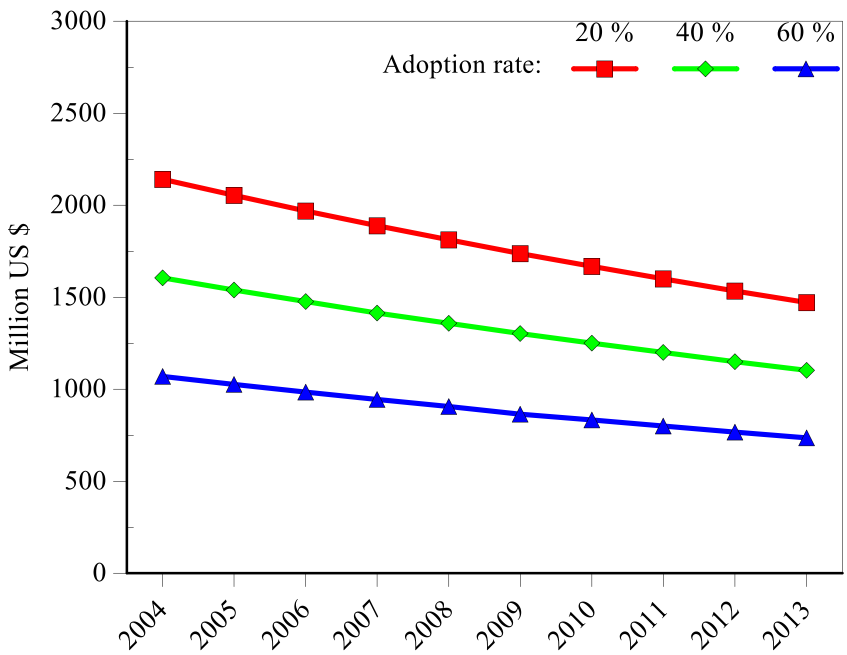

Figure 2. Option value of GMP introduction (Billion US $), no difference in price growth.

With no difference in the price growth between GMPs and non-GMPs, the option value decreases over time. This implies that it becomes less costly to introduce GMPs as time passes. Consequently, one is better of waiting..

The picture changes if one assumes that the prices of nonGMPs grow more than the prices of GMPs. This is illustrated in Figure 3.

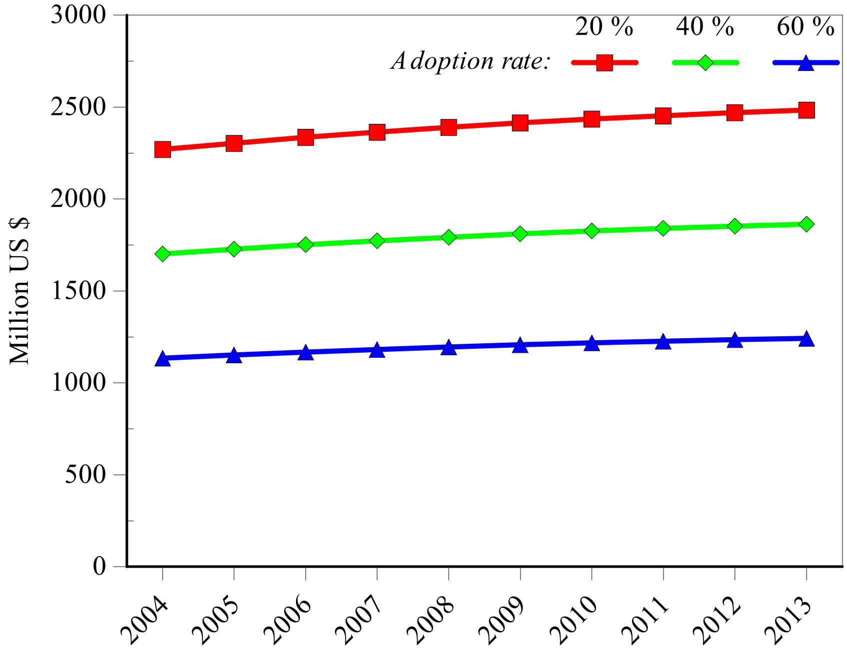

Figure 3. Option value of GMP introduction (Billion US $), 3 % difference in price growth.

With a three percent higher yearly price growth on non-GMPs compared to GMPs, the quasi option value increases over time. Usually, the information value decreases over time. The higher the price growth difference is, the more likely it becomes that the option will be exercised, i.e., it becomes optimal to introduce GMPs, before the ten year period has expired.

Implications and discussion

We find that the quasi option value of introduction now, i.e., exercising the option, is quite high. This implies that the potential costs of waiting to commercially introducting of GMPs must be high to warrant introduction today. From such a perspective, the "European position" of a moratorium on starting to grow GMPs appears sound.

One difficulty of using market data the way we have in our analyses is that the market price partly expresses consumers' willingness to pay for products. Hence, if non-GMPs are able to capture higher prices in the market, it is not correct to interpret all of the option value as a cost in terms of not growing GMPs at time *t* in Europe. This implies that the option value that is to be compared to the information value of waiting is even lower, making it even less optimal to start growing GMPs today.

What do we know about the informational value regarding GMPs over time? One major concern regarding GMPs is that many of them contain antibiotics resistant genes. Antibiotics resistant genes are added to GMPs to quickly be able to identify if gene transfers have been successful. More specifically, by treating the plant with antibiotics, the successfully modified plants will not die, while others will. Once a successful transfer of genetic materials has been established, there is really no need for the marking genes, and they can be removed from the GMP. This lowers some of the perceived negative sides of starting to grow GMPs in Europe, but raise some intriguing informational issues.

By removing the marking genes, it becomes much more difficult to find out if GMO plant materials have spread to wild local plants or to nearby crops, where the farmer does not want to grow GMPs. Moreover, if some consumers in the future demand non-GMPs, and there is a price premium to be captured in the market for non-GMPs, one needs inexpensive and reliable ways of testing if the produce is genetically modified or not. New marking gene techniques are under development. In a few years time it is reasonable to expect that it is possible to trace GMOs without having antibiotic resistance as part of the package.

Finally, GMPs are currently commercially grown in the US. "Wait and see" therefore becomes a more viable alternative as the US experiences imply faster learning, i.e., the information value of waiting is likely to remain high for still some years to come.

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