Differentiating GMOs and Non-GMOs in a Marketing Channel

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Abstract

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The introduction of Genetically Modified Organisms (GMOs) has significantly altered marketing channels for crops in the United States. This study shows the conditions under which two separate markets can emerge: one for GMOs and one for non-GMOs. A price premium can result for non-GMOs. A producer-decision model is developed to help explain why the rate of adoption for GM corn is low and declining. Most of the non-GM corn is not marketed as such, and hence it does not receive any price premiums that are sufficient to cover identity preservation (IP) costs. In cases where non-GM corn is marketed as such, the price premiums (net of IP costs) appear to be small. Yet the largest percentage of corn grown is non-GM. Our results show that when IP costs are added to deal with market segregation problems, total revenue to all corn producers declines.

Keywords: genetically modified organisms, non-genetically modified organisms, identity preservation costs, market channels.

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1. Introduction

Many thought that the advent of biotechnology for agriculture in the United States would be a panacea for the farm sector and consumers. Farmers were promised crops that naturally resisted insects, were tolerant to weather variation, and were resistant to herbicides. On the other hand, consumers were promised crops that were more nutritious, had longer shelf lives, required less pesticides, and were cheaper. Biotechnology (Bt), in general, and Genetically Modified Organisms (GMOs), in particular, appeared to be a win-win proposition for all concerned. However, since 1997, several factors have arisen to cool the excitement about GMOs. In 1997, the European Union halted imports of Bt corn from the United States. In 2000, StarLink™ corn was discovered in corn for human consumption in the United States. Since then, numerous lawsuits have been filed by corn growers against Aventis, the company responsible for engineering StarLink™.

When studying GMOs, one finds that not all farmers plant genetically modified (GM) corn or soybeans. Nor do individual farmers necessarily plant just one or the other. Why is this? Why has the rate of adoption of GM corn in the United States not followed the rate of adoption path documented by Griliches (1957) for hybrid corn? The adoption of GM corn has been relatively slow and seems to have peaked at about 30 percent (Darr and Chern, 2000). This paper provides theoretical arguments as to why the rate of adoption is low, especially for corn, and why price premiums for non-GM corn are small or non-existent. Even in the presence of identity preservation (IP) costs, price premiums do not necessarily arise. Price premiums for non-GM corn are hard to come by because of the excess supply of non-GM corn available after food-corn demand is met. This study also examines the added transaction costs associated with the adoption of GMOs in the United States (a situation that gave rise to separate market channels for GM and non-GM grains). In addition to the added IP costs within the marketing channel, the farmer's decision on whether to plant GM or non-GM crops is also affected by the additional cost of separating GM and non-GM grain at the farm level. These costs include transaction costs such as those associated with testing for the existence of GM traits, and added storage in order to segment the marketing channel.

2. Adoption of GM Varieties with Undifferentiated Demands

As a first step, we considered the impact GMOs have on farmers who adopted GMOs and on those who did not. From an end-users point of view, no distinction is made between non-GM and GM varieties. Within this scenario, we assume that some farmers obtain significant agronomic advantages from adoption while other farmers do not. The dichotomy could be explained by the development of a GMO to combat a pest that only exists in a specific region. Farmers who do not encounter the pest will not adopt the GM seed, especially if the seed sells at a premium relative to non-GM seed. Given this scenario the supply curve for GM seed adopting farmers will shift to the right.

In figure 1, the demand for all corn is D, S_0 is the supply curve for producers who do not adopt the GM variety, and S_1 is the supply curve for pre-adoptive GM corn farmers. Thus, before adopting GM corn, the aggregate supply curve is S_T , and equilibrium price is p. After adopting the GM seed, the supply curve of the latter group shifts outward to S_1 , which shifts the aggregate supply curve outward to S_T . As a result of this increase in total supply, the price falls from p to p as the overall quantity consumed increases from Q_T to Q_T .

Given the shifts due to GM seed adoption, the economic rents to non-adopters of GM seed fall as both the quantity supplied and the price received declines (Figure 1). In addition, if consumers perceive the GM output to be identical to the non-GM output, consumer surplus increases. However, the welfare impact on adopters of GM seeds is dependent on the elasticity of the residual demand curve for adopting producers (the consumer demand curve less the supply of non-adopting producers). If the residual demand curve is elastic, the economic rents from adopting GM seeds will be positive; if the residual demand curve is inelastic, the economic rents accruing to GM seed adopters will decline with the release of the GMO. The residual elasticity of demand tends to be inversely proportional to the number of adopting producers. Intuitively, if only a small number of producers adopt the GM seed variety, the price remains largely unchanged and the lion's share of the economic rents generated by the adoption of GM seeds remains at the farm level. However, a small number of adopters also implies small returns to the producers of GM seed. Thus, these technologies are unlikely candidates for development because the return to seed producers will be small.

The most significant drawback to this relatively straightforward model of GMO impacts is the assumption that the GM and non-GM outputs are perceived by consumers to be identical (assuming that consumers do not perceive a health risk or advantage to GMOs). However, recent policy actions (for example, Europe's refusal to import GM corn from the United States) suggest that consumers and consumer groups perceive GMO and non-GMO products as two distinctly different products.

3. Models of Marketing Channels

We develop a model of a market channel to determine the impact of GMOs on the price and quantity of corn, assuming that consumers perceive GM output as a different commodity from non-GMO output. We specifically incorporate transaction costs into the market channel to separate GM and non-GM output for consumption. It is important to emphasize that prior to the introduction of StarLink™, GM corn and GM soybeans did not have to be tested (except for corn exports to countries that prohibited any GM content). However, non-GM corn and soybeans that are destined for non-GMO markets must be tested in order for the producer to receive a price premium for non-GMO produce. If a farmer's produce contains GM material, it cannot be sold as a non-GM product, but it can be sold in the GM corn market. (In the United States, the largest market for corn is for use as livestock feed. Sales of corn into this market include both GM and non-GM corn.)

For producers of non-GM corn who wish to sell their produce as non-GM, there are several costs that are not applicable to producers of GM corn. These costs include the cost of clean (GM-free) seed, the cost of planting barriers (either unplanted areas around the crop or male plants), the cost of removing volunteer plants, etc. A farmer who did not plant GM corn may wish to have his or her crop certified as non-GM in order to obtain a price premium. In order to obtain this premium, however, the producer must have the output certified as non-GM through a testing procedure. If the output is certified non-GM, maintaining its IP nature will add costs, but the farmer will be paid a premium (Bullock, Desquilbet, and Nitsi 2000).

a. GMOs Used for Non-GMO Uses

In the following model, we show that price premiums can exist for non-GM crops, even in the presence of IP costs. In figure 2, the demand for non-GM corn used as food is D_N. The supply of non-GM corn is S_N. The excess demand curve for non-GM corn is ED_N. The supply curve in the GM market is S_G and the demand curve for GM corn is D_G. The excess supply curve for GM corn is ES_G.

If GM corn could be used for non-GMO uses, the two markets clear at Q_T, where the excess demand curve for non-GMO uses equals the excess supply curve for GM corn. Under this scenario, Q_N^S bushels of corn would be produced in the non-GM market and Q_N^D units of non-GM corn would be consumed in non-GM uses. Similarly, in the GM market, Q_G^S units of GM corn are produced and Q_G^D bushels of GM corn are used in GMO uses such as cattle feeding. The equilibrium price would be P, where corn would flow from the GM market to the non-GMO market.

Of course, the above situation cannot happen, as D_N is the demand for non-GM corn, and in that particular market, it cannot be co-mingled with GM corn. Markets need to be separated such that GM corn is excluded from use in the non-GMO market. For this separation to occur, IP costs are incorporated, which are applied to non-GM corn. These IP costs shift the supply curve for non-GM corn upward from S_N to S_N' (because of such factors as cleaning costs and buffering costs incurred by the farmer before shipping). Demand shifts to D_N' (demand shifts inward because of that part of the IP costs that occurs after farm delivery to the elevator). Domestic production and consumption of non-GM corn is Q_N^P. Now we observe three prices: the farm price for

GM corn is P_0, the demand price for non-GM corn is P_1, and the farm price for non-GM corn is P_2. IP costs are given by $P_1 – P_2$ per bushel. The price premium for non GM corn becomes $P_2 – P_0$ per bushel. This outcome is based on the strong assumption that GM corn cannot be used for non-GMO uses by regulation (similar to a prohibitive tariff in trade). As a result of this prohibition, both the non-GM and GM markets clear independently. The result is a lower price in the GM market and a price premium in the non-GM market, even in the presence of IP costs.

b. Flows from non-GMO to GMO market

Figure 3 shows an economic equilibrium in which corn initially flows from the non-GMO market to the GMO market. As such, no premiums for non-GMO production arises. In Figure 3, prior to the introduction of IP costs, Q_N^S of non-GM corn is produced, and Q_N^D is demanded by non-GM uses. The difference, Q_T, is used to satisfy demand D_C. The demand D_C includes many uses, such as livestock feed. It is an undifferentiated product demand curve, made up of both GM and non-GM corn. (The largest demand for corn in the U.S. is feed demand, which consists of both of GM and non-GM corn.) At the equilibrium price, P, Q_G^S bushels of corn are produced and sold along with non-GM corn (Q_T) to satisfy demand D_C.

Now we incorporate IP costs. These costs are applied only to demand for non-GM corn, D_N. For simplicity, we assume that all IP costs represent increased marketing costs and do not affect the producer supply curve, S_N (the model could now be easily adjusted to take into account the case where IP costs shift both the farm supply schedule and the demand schedule). The IP costs shift the derived demand for non-GM corn to

D_N'. Correspondingly, the excess supply curve of non-GM corn shifts to $E_N^S{}'$. The resulting market separation gives rise to two prices: the price P_1 is paid by processors for non-GM corn; the price P_0 is the price received by producers for both GM and non-GM corn. IP costs are represented by $P_1 - P_0$ per bushel. The addition of IP costs lowers producer prices from P to P_0. The production of non-GM corn declines to Q_E. Domestic consumption of non-GM corn declines to Q_E'. The consumption of both GM and non-GM corn used for feed and other purposes in excess of demand D_N increases to Q_0.

The most important result in this scenario is that the prices do separate across non-GMO and GMO markets, but the difference in prices represent IP costs. Price premiums are not present in this model. Thus, unlike the case in the previous model, even though non-GM and GM prices separate, no price premium will exist for non-GM corn.

4. Modeling Crop Selection

We develop the farmer's crop selection model, keeping in mind the possibility that a price premium can exist for non-GMOs. First, we examine the deterministic choice between planting non-GM and GM corn based on differences in production and costs. We then complicate the farmer's decision problem by allowing for the possibility that GMOs contaminate non-GM plantings.

a. The Crop Selection Model under Certainty

The following is a model of crop selection in which the producer decides whether to plant non-GM corn or GM corn. Mathematically, the farmer chooses the level of variable inputs used (x_1 and x_2) to produce two possible outputs (y_1 and y_2) to maximize profit subject to a multiproduct production function, $f(y,x)$,

$$\max\ p_1 y_1 + p_2 y_2 - w_1 x_1 - w_2 x_2 \quad s.t.\ f(y,x) = 0 \qquad (1)$$

where p_1 and p_2 are output prices and w_1 and w_2 are input prices. In this case, we assumed that y_1 is the production of GM corn while y_2 is the production of non-GM corn. The inputs could be specific to this choice (for example x_1 could be GM corn seed and x_2 could be non-GM corn seed), but the results do not require this detail. The Lagrange multiplier for this problem can then be stated as

$$L = p_1 y_1 + p_2 y_2 - w_1 x_1 - w_2 x_2 - l\left[f(y,x) \right] \quad (2)$$

which yields the following first-order conditions

$$\begin{gathered}
\frac{\partial L}{\partial y_1} = p_1 - l\frac{\partial f(.)}{\partial y_1} \leq 0;\quad \frac{\partial L}{\partial y_2} = p_2 - l\frac{\partial f(.)}{\partial y_2} \\
\frac{\partial L}{\partial y_1} y_1 = 0;\ \frac{\partial L}{\partial y_2} y_2 = 0 \\
\frac{\partial L}{\partial x_1} = -w_1 - l\frac{\partial f(.)}{\partial x_1} \leq 0;\ \frac{\partial f(.)}{\partial x_2} = -w_2 - l\frac{\partial f(.)}{\partial x_2} \leq 0 \\
\frac{\partial L}{\partial x_1} x_1 = 0;\ \frac{\partial L}{\partial x_2} x_2 = 0
\end{gathered} \quad . (3)$$

Taken together, these conditions imply that the value of marginal product of each input equals the input price, if positive quantities of each output are produced and positive quantities of inputs are used.[1]

The first-order conditions in equation (3) imply three solutions. Specifically, if only GM corn is produced, then

$$\begin{gathered}
\frac{\partial L}{\partial y_1} = p_1 - l\frac{\partial f(.)}{\partial y_1} = 0,\ y_1 > 0 \\
\frac{\partial L}{\partial y_2} = p_2 - l\frac{\partial f(.)}{\partial y_2} < 0,\ y_2 = 0
\end{gathered} \quad . (4)$$

Alternatively, only non-GMO corn may be produced, implying that

$$\begin{aligned} \frac{\partial L}{\partial y_1} &= p_1 - \lambda \frac{\partial f(.)}{\partial y_1} < 0,\ y_1 = 0 \\ \frac{\partial L}{\partial y_2} &= p_2 - \lambda \frac{\partial f(.)}{\partial y_2} = 0,\ y_2 > 0 \end{aligned} \quad . \ (5)$$

Or, finally, both GM and non-GM corn could be produced, implying that

$$\begin{aligned} \frac{\partial L}{\partial y_1} &= p_1 - \lambda \frac{\partial f(.)}{\partial y_1} = 0,\ y_1 > 0 \\ \frac{\partial L}{\partial y_2} &= p_2 - \lambda \frac{\partial f(.)}{\partial y_2} = 0,\ y_2 > 0 \end{aligned} \quad . \ (6)$$

The last solution would appear unlikely because of the unique trade-off between GM and non-GM crops. Specifically, assuming both GM and non-GM crops are grown, the first-order conditions in equation (13) imply that

$$\frac{p_1}{p_2} = \frac{\lambda \dfrac{\partial f(.)}{\partial y_1}}{\lambda \dfrac{\partial f(.)}{\partial y_2}} = \frac{\partial y_2}{\partial y_1} \quad (7)$$

where $\partial y_2 / \partial y_1$ is the marginal rate of substitution between y_2 and y_1 given that the optimal amount of each variable input has been applied.[2] Given that GM and non-GM corn generally use many of the same inputs (land, fertilizer, equipment), we expect the rate at which one output could be substituted for the other output would be close to one. Some discrepancy could occur in herbicide and pesticide usage. Regardless of difference in input usage, the marginal rate of substitution between GM and non-GM corn will probably be constant over a broad range of relative outputs. This scenario typically generates two corner solutions (as observed in a mathematical programming model of crop selection). The implication is that the farmer will grow all GM corn if the price premium on non-GM corn is less than the savings in agricultural chemicals; the farmer will grow all non-GM corn if the price premium on non-GM corn is greater than the cost savings on agricultural chemicals.

b. Crop Selection Under Production Uncertainty

Equation 1 assumed that both the production function and the output prices are known with certainty. This section introduces a special form of risk faced in the decision to produce GM or non-GM crops. Specifically, this section examines the potential impact of contamination of non-GM corn by the factors outlined in the EU report (including contamination through purchased seed, contamination by volunteer crops, mechanical contamination, and cross-pollination). To examine the implications of contamination, we reformulate the model presented in equation 1 to focus on the question of separating GM and non-GM corn.

The separation model follows the basic formulation in equation 1 in that two types of corn are ultimately marketed. Either corn is marketed as non-GM corn or as potentially GM corn. As developed in the proceeding sections, non-GM corn may bring a price premium. Extending the model presented in equation 1, to market corn as non-GM corn, the producer must first pay the cost of separation (the IP cost both at the farm level and those additional costs incurred throughout the entire marketing chain). We introduce an additional variable, y_3, which is the grain delivered as non-GM that is found to be GM contaminated. We divide the quantity of non-GM corn planted in equation (1), y_2, into corn that can be marketed as non-GM corn and non-GM corn that has been GMO contaminated, y_3.

The decision now faced by the farmer is whether to plant non-GM corn, given that it may be contaminated. Mathematically, the optimization problem facing the producer can be expressed as

$$\begin{gathered}\max\, p_1 y_1 + p_1 y_2 + p_3 y_3 - C\left(y_2 + y_3\right) - w_1 x_1 - w_2 x_2 \\ s.t. \quad f\left(y, x\right) = 0,\end{gathered} \tag{8}$$

where $C(y_2+y_3)$ is the cost of separating the non-GM corn from the GM corn (or more appropriately, it is the corn sold into the non-GMO market). From the farmer's perspective, these costs could include the cost of purchasing clean seed, the cost of cleaning equipment, the cost of additional field operations to eliminate volunteer crops, or the cost of countermeasures to prevent cross-pollination. Whether the cost of testing is included is based on the marketing contract (the grain elevator may bear the cost of testing for GMOs). To narrow the focus of the model presented in equation (8), we next assume that the farmer did not plant non-GM corn with the intent of selling non-GM corn at the GMO market price. Given this assumption, we modify the model combining y_2 and y_3 into a single output variable y_G (separated corn). The mathematical model presented in equation (8) then becomes

$$\begin{gathered}\max\ p_1 y_1 + \left[\, p_2 q + \ p_3 \left(1 - q\right)\right] y_G - C\left(y_G\right) - w_1 x_1 - w_2 x_2 \\ s.t.\ f\left(y, x\right) = 0,\end{gathered} \tag{9}$$

where θ is the probability that corn planted as non-GM corn will actually grade non-GM and will not be contaminated by cross-pollination. As a final modification, we model the probability of contamination as a Bernoulli distribution

$$
\begin{aligned}
\max\ & p_1 y_1 + \left[p_2\, g\left(z_1 = 1 \middle| x_1, x_2\right) + p_3 g\left(z_1 = 0 \middle| x_1, x_2\right)\right] y_G \\
& - C\left(y_G\right) - w_1 x_1 - w_2 x_2 \\
& s.t.\ \ f\left(y, x\right) = 0 \\
& g\left(z_1 \middle| x_1, x_2\right) = q\left(x_1, x_2\right)^{z_1}\left[1 - q\left(x_1, x_2\right)\right]^{1-z_1},
\end{aligned}
\tag{10}
$$

where $g(z_1|x_1,x_2)$ is the Bernoulli distribution function for the probability of contamination based on variable inputs. Finally, p_1, the price for GM corn, could be substituted for p_3, the price for corn planted as non-GM corn that is found to be contaminated, implying that any corn not sold in the non-GMO market is sold into the undifferentiated corn market.

Following the same procedure as above, the maximization problem in equation (17) yields a Lagrangian formulation

$$
\begin{aligned}
L = & p_1 y_1 + \left[p_2\, g\left(z_1 = 1 \middle| x_1, x_2\right) + p_3\, g\left(z_1 = 0 \middle| x_1, x_2\right)\right] - C\left(y_G\right) \\
& - w_1 x_1 - w_2 x_2 - l\, f\left(y, x\right).
\end{aligned}
\tag{11}
$$

This Lagrangian yields a similar optimum to those presented above:

$$\frac{\partial L}{\partial y_1} = p_1 - l\,\frac{\partial f(.)}{\partial y_1} \le 0$$

$$\frac{\partial L}{\partial y_1} y_1 = 0$$

$$\frac{\partial L}{\partial y_G} = p_2 g\left(z_1 = 1 \middle| x_1, x_2\right) + p_3 g\left(z_1 = 0 \middle| x_1, x_2\right) - \frac{\partial C}{\partial y_G} - l\,\frac{\partial f(.)}{\partial y_G} \le 0$$

$$\frac{\partial L}{\partial y_G} y_G = 0$$

$$\frac{\partial L}{\partial x_1} = p_2 \frac{\partial g\left(z_1 = 1 \middle| x_1, x_2\right)}{\partial x_1} + p_3 \frac{\partial g\left(z_1 = 0 \middle| x_1, x_2\right)}{\partial x_1} - w_1 - l\,\frac{\partial f(.)}{\partial x_1} \le 0$$

$$\frac{\partial L}{\partial x_1} x_1 = 0$$

$$\frac{\partial L}{\partial x_2} = p_2 \frac{\partial g\left(z_1 = 1 \middle| x_1, x_2\right)}{\partial x_2} + p_3 \frac{\partial g\left(z_1 = 0 \middle| x_1, x_2\right)}{\partial x_2} - w_2 - l\,\frac{\partial f(.)}{\partial x_2} \le 0$$

$$\frac{\partial L}{\partial x_2} x_2 = 0. \qquad (12)$$

The first set of first-order conditions, with respect to GM corn, are identical with the deterministic case. Specifically, the farmer plants GM corn if the cost savings to GM seed exceed the additional cost of the GM seed. However, the non-GMO scenario is now complicated by two new factors. First, the farmer will only plant non-GM corn if the price premium exceeds the segregation costs. Second, the price premium is now probabilistic. The farmer must take into account the probability that the non-GM corn has been contaminated.

A second set of conditions introduced in equation 12 is the effect of input use on the expected price premium. The farmer may have several production alternatives to control the probability of contamination. For example, additional field operations or herbicide applications may control the probability of contamination through volunteer plants, or planting additional rows of sterile or male plants or increasing the buffer zone around non-GM plantings may control the probability of contamination through cross-pollination.

The first-order conditions in equation 12 can be combined to yield several GMO/non-GMO scenarios. Specifically, we see that farmers will only plant non-GM varieties if

$$p_2 g\left(z_1 = 1 \middle| x_1, x_2\right) + p_3 g\left(z_1 = 0 \middle| x_1, x_2\right) - \frac{\partial C\left(y_G\right)}{\partial y_G} - l\,\frac{\partial f\left(.\right)}{\partial y_G} \geq p_1 - l\,\frac{\partial f\left(.\right)}{\partial y_1}. \quad (13)$$

If the expected price premium for non-GMO production exceeds the cost of segregation and the added direct cost of growing non-GM corn (e.g. the added cost of pesticides or herbicides), then the farmer produces only non-GM corn. If the condition in equation 13 holds with equality, then the farmer would grow a combination of GM and non-GM corn. Alternatively, if the inequality in equation 13 is reversed, the farmer plants only GM corn. In that case the expected price premium is insufficient to cover the cost of grading and the additional cost of non-GMO production.

5. IP Costs, Price Premiums, and Adoption Rates

Differentiating corn as non-GM or GM is not costless. Tests must be conducted to determine which category of corn a given truck- or bin-load falls into. Differentiating between the various types of corn increases the cost of keeping the grain separate in the marketing channel. This is referred to as the cost of identity preservation (IP). IP costs include direct costs, such as the cost of maintaining multiple elevator pits and increased cleaning costs for barges and bins, along with opportunity costs.

Grain delivered to an elevator is dumped into a pit and then transferred via a lift to a chain that distributes the grain to various storage bins in the elevator. The IP cost of separating or preserving the identity can then be characterized as the cost of cleaning the grain path between GMO and non-GMO deliveries by farmers, or the establishing separate facilities (and thus doubling the investment) so that the grain path need not be cleaned after each delivery. In addition, the establishment of separation implies additional storage since GM and non-GM grains must be stored in separate bins. This separation introduces the additional cost of "storing air"; that is, the inefficient use of bins.

a. Empirical Estimates of the Transactions Costs

All corn for export into the European Union must be certified as GMO-free. Further, with the advent of StarLink™, corn bound for human consumption in the United States or for export to Japan or South Korea must be certified StarLink™ free. Thus, the price that elevators are willing and able to pay for corn due to increased monitoring and segregation costs have declined, while the price to end users (for example, Japanese importers) has increased.

Table 1 summarizes six studies that examine the IP costs for separating GM soybeans and high oil (HO) corn from their non-specialty counterparts. These IP costs range from 16 to 36.6 cents for corn and 30 to 48 cents for soybeans. Bender et al. (1999) conduct a survey of 200 U.S. firms marketing specialty grains. Maltsbarger and Kalaitzandonakes (2000a, 2000b) determine the cost of separating HO and standard corn. Their results are based on a process simulator that models the operation of grain elevators. Lin, Chambers, and Harwood (2000) present the cost of separating both GM soybeans from non-GM soybeans and GM corn from non-GM corn. Bullock, Desquilbet, and Nitsi (2000) present the cost of separating non-GM corn and soybeans at both the elevator and the farm levels. However, their results are more detailed for separation of non-GM soybeans. Finally, the results of the European Union, Directorate-General for Agriculture study, *Economic Impacts of Genetically Modified Crops on the Agri-Food Sector*, are based primarily on previous U.S. Department of Agriculture findings.

b. Price Premiums and Adoptions Rates

Given the IP costs identified above, a farmer growing non-GM corn or soybeans would have to receive a significant premium to cover these added costs. However, for corn at least, it is difficult to find many instances in which farmers do receive a significant price premium for non-GM corn. For example, Chern (2000) found that for Ohio farmers in 1999, price premiums were paid for only 7 percent of the non-GM corn varieties, while for soybeans the number was higher at 21.3 percent (Table 2). This would imply that even though the IP costs are significant, these costs may not actually be incurred by farmers because they sell little output into the non-GMO marketing channel.

Most corn consumed in the United States is for feed purposes; corn suits this purpose whether or not it is genetically modified (Table 3). Surprisingly, more than half the acreage seeded to corn is seeded non-GM corn (Darr and Chern, 2000; USDA). In 2000, only 25 percent of the U.S. corn planted was genetically modified (Table 4). In 2000, only 54 percent of the U.S. acreage planted was to GM soybeans. (Note that there has been a drop in the adoption rate of GM varieties between 1999 and 2000.) Non-GM corn production is much greater than its domestic demand (total domestic food corn demand is less than 1 billion bushels annually). Therefore, why would large premiums be paid for non-GM corn? It appears that such premiums do not exist in the corn market. Because of the nature of the corn market, the theoretical model developed in Figures 2 and 3, which shows the case in which price premiums do not exist, seems to hold.

Chern (2000) presents survey results for farmers in Ohio that are consistent with the mathematical results presented in equations 6 and 13. Chern (2000) found low rates of adoption of GM corn, and found little or no price premiums paid for non-GM corn. Our mathematical formulation earlier shows that even with low expected price premiums for non-GM corn, farmers will not adopt GM varieties where productivity gains are less than additional costs of adoption. As depicted in table 4, the adoption of GM varieties for soybeans has been significantly higher than that of corn. However, the largest share of this adoption has been for Roundup™ Ready soybeans. This technology allows for significant cost reductions in weed control. However, the GM innovations in corn have typically focused on pest resistance. The low adoption rate for GM corn suggests that either the cost of the new technology is relatively higher than other measures for controlling pests in corn, or that the pest pressure does not result in as significant cost.

c. IP Costs and Product Differentiation

We incorporate the above empirical evidence on corn into a theoretical framework to demonstrate when the markets for GM and non-GM corn become separate, and when price premiums exist for non-GM corn. As the earlier theory suggests, there is little or no price premium on non-GM corn because of excess non-GM corn production. (As Figure 3 showed, when there is an excess of non-GM corn, which is used as feed, price premiums do not exist.) In Figure 4 the demand for food is given by D_F, and total demand is given by D_T. The supply schedule for non-GM corn is $S_N{}^T$ and total supply is S^T which is made up of $S_N{}^T$ plus S_G (the supply of GM corn not shown in the graph). The equilibrium price is P_0, the quantity of non-GM corn produced is $q_0{}^1$, while the quantity of GM corn produced is $q_2 - q_0{}^1$.

Suppose the extreme case in which the demand for food is made up entirely by non-GM corn. In this case, q_0 of non-GM corn is consumed as food, leaving $q_0^1 - q_0$ of non-GM corn to be sold, along with GM corn, into the feed and other non-food markets. For a price premium to exist for non-GM corn, the quantity sold as food has to be restricted to a level below q_0. For example, if quantity were restricted to q_1, the price for non-GM corn would rise to P_1, and the price for both non-GM and GM corn sold into the feed market would fall to P_2. In this case, due to a restriction placed on the quantity of non-GM corn that can be sold in the food market, product differentiation occurs. Corn used as food is separate from corn used as feed, and the price for non-GM corn is higher than the price of corn for feed and other non-food purposes.

The restriction placed on the sale of non-GM corn for food can come about because of IP costs, as is the case in figure 4. The initial price of corn is \$1.85/bu. (the 2000 average price for all corn in the United States, USDA 2001). Total corn production is assumed to be 9.45 billion bushels as given in table 3 for 1999/00. Initially we assume that all corn used for food has to be GMO-free. This amount totals 2.45 billion bushels. We add an IP cost of \$0.29/bu. that includes additional costs in the marketing channel of \$0.19/bu. and \$0.10/bu. to offset producer costs (see earlier discussion on IP costs). This results in a market price of \$2.06/bu. for non-GM corn sold as food. The farm price for all corn falls to \$1.77/bu. In Table 5, once IP costs are added, there is a reduction in the non-GMO quantity of 140 million bushels (assuming a demand elasticity in the non-GMO market of -.5). This amount is now marketed, along with other non-GM and GM corn, into the feed and other non-food markets. The total quantity of corn marketed as non-food is 7.12 billion bushels. As a result of the IP costs, the gross revenue to all corn growers declines by $710 million.

Table 5 also gives results of GM and non-GM corn segregation, assuming that non-food demand is relatively elastic. For a residual demand elasticity of –1.2, the price of all corn falls by only $0.04/bu. to $1.81/bu. The corn price paid by non-GMO users increases to $2.10/bu. In this scenario, the total revenue to corn production falls by $350 million. Thus in both cases, IP costs of $0.29/bu. lower total revenue to corn producers. However, if the non-food demand were sufficiently elastic, the movement of corn from the non-GM market to the GM market would result in a higher average price and an increase in total revenue. (Different elasticities were used, and even with a residual demand elasticity as high as 10.0, total revenue declined due to the additional IP costs.)

What if only 50 percent of corn demanded for food use is required to be GMO free? Assuming a residual demand elasticity of –0.5, the non-GMO price paid by processors increases to $2.10/bu. Under this scenario, the farm price for all corn falls to $1.81/bu. Total revenue falls by $360 million. With a demand elasticity of –1.2, the farm price drops to $1.83/bu., and total revenue falls by $160 million.

In addition to these scenarios, Table 5 also presents the effect of doubling IP costs to $0.58/bu. For a residual demand elasticity of –0.5, the price paid for non-GM corn used as food by non-GM consumers increases to $2.28/bu. The farm level price of corn falls to $1.70/bu. (This reduction in price is due to a 280 million bushel reduction in food corn that must be marketed in the undifferentiated market.) In this case, total revenue falls by $1.4 billion. For a demand elasticity of –1.2, the demand price increases to $2.36/bu., and the farm price falls to $1.78/bu. Total revenue from corn production falls by $700 million. Total revenue falls by only $320 million when 50 percent of food demand is made up by non-GM corn.

In the above models, total revenue falls due to IP costs. However, suppose there were no IP costs, and quantities that could be sold in the non-GM corn market were restricted through marketing orders. Total revenue to corn farmers could increase. For example, for a residual demand elasticity of –1.2, total revenue to corn producers would actually increase by $530 million, assuming that 100 percent of food demand is made up of non-GM corn. (Total revenue increases by $290 million if only 50 percent of food demand is made up of non-GM corn..)

In the models presented, even though the price paid (by end users) for non-GM corn is above the price paid for GM corn, there is no price premium to be had by non-GM corn farmers, since they receive the same price for their corn regardless of whether it is GM or non-GM. For a price premium to exist, the farm price received for non-GM corn has to be above the price received for GM corn. Consider our earlier example of IP costs of $0.58/bu. (residual demand elasticity of –0.5, and 100 percent of food demand made up of non-GM corn). Suppose that the true IP costs were $0.29/bu. instead of $0.58/bu. In this case the farm price for non-GM corn is $1.99/bu. rather than $1.70/bu. The price of corn for non-food uses is $1.70/bu., thus a price premium of $0.29/bu. exists for non-GM corn. In this case, the price for non-GM corn is above the price that existed prior to the introduction of IP costs. (Note that for the price premium to arise, the quantity of non-GM corn used as food is 2.17 billion bushels rather than 2.31 billion bushels – the case when the processor price of corn only covers the IP costs of $0.29/bu.)

6. Summary and Conclusions

If the consumer does not differentiate between the GM and non-GM output, clearly no price premium exists for non-GM output. The fact that consumers differentiate between the GM and non-GM product is insufficient to generate a price premium for non-GM output. Specifically, if the supply of non-GM output exceeds the demand for non-GM output, even in the presence of IP costs, a price differential will emerge between the GM and non-GM markets. Price premiums for non-GM output, however, will not exist. If the non-GMO supply is less than the overall demand for non-GM output, markets become segmented and a price premium will emerge for non-GM output.

Unlike for hybrid corn, the adoption of GM corn has been slow. In 2000, roughly 25 percent of the corn planted was GM, and for soybeans, roughly 50 percent of acreage planted was GM. Given the relatively small demand for non-GM corn, there is an excess supply of non-GM corn. As a result, price premiums for non-GM corn are small or non-existent. We empirically show the impact of IP costs in the presence of non-GM and GM corn production. Farmers, regardless of the type of corn grown, are made worse off. Even in the presence of IP costs, we show that price premiums for non-GM corn cannot exist. We do not explore the welfare effects if additional GM corn were to be planted, replacing non-GM corn.

We show that if the consumers perceive GMOs and non-GMOs as the same commodity, then producers who fail to adopt GMOs will loose and the adopters may gain depending on the elasticity of the residual demand curve. This result is consistent with the firm-level model. Specifically, the farmer may choose not to adopt the GMO if the marginal cost of adoption is greater than the marginal benefit of adoption. Given the possibility of a premium for non-GMO production, farmers have a choice between GM and non-GM output. Previous literature (Moschini et al. 2000) suggests that the primary advantage to GM soybeans is the reduction in costs. Following from this suggestion, the present paper offers results indicating that the choice between GM and non-GM corn becomes one of comparing the cost savings under GMO production with the price premium to non-GM output. Given that price premiums are hard to find, for corn at least, why has there been a low rate of adoption of GM corn? We model theoretically why there can be a low rate of adoption, even in the presence of low or no price premiums.

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Endnotes

[1] Starting with the first-order condition for input 1, assuming that a positive quantity of the input is used so that the first-order condition holds with equality

$$-w_1 - \boldsymbol{l}\,\frac{\partial f(.)}{\partial x_1} = 0 \Rightarrow \boldsymbol{l} = -\frac{w_1}{\frac{\partial f(.)}{\partial x_1}}\,.$$

Next, we substitute this expression into the first-order condition for the first output, again assuming that the quantity of output produced is greater than zero,

$$p_1 - \left(-\frac{w_1}{\frac{\partial f(.)}{\partial x_1}} \right)\frac{\partial f(.)}{\partial y_1} = 0 \Rightarrow -p_1\frac{dy_1}{dx_1} = w_1$$

where the negative is due to the implicit multiproduct form of the production function. The expression on the left-hand side is the value of marginal product which is equal to the price of the input at the optimal level of use.

[2] Again the negative sign was reversed by the multiproduct specification.

Table 1. Additional Cost to Segregate Grain Crops

Study	*Additional Cost (cents/bushel)*	*Crop/ Characteristic*
Bender et al. (1999)	17	Specialty Corn
	48	Specialty Soybean
Maltsbarger and Kalaitzandonkes (2000a)	16-27	High Oil Corn
	16.4	High Oil Corn
	16-15	High Oil Corn
Maltsbarger and Kalaitzandonkes (2000b)	16.4-36.6	High Oil Corn
Lin, Chambers, and Harwood (2000)	22	non-GM Corn
	45	non-GM Soybeans
Bullock, Desquilbet, and Nitsi (2000)	30	non-GM Soybeans
European Union Directorate-General	18.4	non-GM Corn

Source: Authors' compilation.

Table 2. Adoption Rates of GM Crops in the United States, 1996-2000

Crops	**1996**	**1997**	**1998**	**1999**	**2000**
		Percent of Planted Acres			
GM Soybeans	7.4	17.0	44.2	57	54.0
Bt Corn	1.4	7.6	19.1	30	18
Herbicide-tolerant Corn	3.0	4.3	18.4	8	6
Total GM Corn	4.4	11.9	37.5	38	25.0
Bt Cotton	14.6	15.0	16.8	27	15.0
Herbicide-tolerant Cotton	NA	10.5	26.2	38	26.0
All GM Cotton	NA	25.5	43.0	65	61

Sources: Chern (2000); USDA.

Table 3. U.S. Corn Supply and Use (1980/81-1999/00)[a]

Year	Production	Exports	Domestic Use	Feed	FSI[b]	HFCS	Fuel
	Millions Bushels						
1980/81	6,639	2,391	4,891	4,232	**659**	165	35
1981/82	8,119	1,997	4,978	4,245	**733**	183	86
1982/83	8,235	1,821	5,427	4,573	**854**	214	140
1983/84	4,174	1,886	4,806	3,876	**930**	265	160
1984/85	7,672	1,850	5,182	4,115	**1,067**	310	232
1985/86	8,875	1,227	5,266	4,114	**1,152**	327	271
1986/87	8,226	1,492	5,893	4,660	**1,233**	338	290
1987/88	7,131	1,716	6,041	4,789	**1,252**	358	279
1988/89	4,929	2,028	5,232	3,934	**1,298**	361	287
1989/90	7,532	2,367	5,753	4,383	**1,370**	368	321
1990/91	7,934	1,727	6,034	4,609	**1,425**	379	349
1991/92	7,475	1,584	6,332	4,798	**1,534**	392	398
1992/93	9,477	1,663	6,808	5,252	**1,556**	415	426
1993/94	6,338	1,328	6,289	4,680	**1,609**	444	458
1994/95	10,051	2,177	7,165	5,460	**1,705**	465	533
1995/96	7,400	2,228	6,305	4,693	**1,612**	482	396
1996/97	9,233	1,797	6,969	5,277	**1,692**	504	429
1997/98	9,207	1,504	7,264	5,482	**1,782**	532	481
1998/99	9,759	1,981	7,332	5,472	**1,860**	565	540
1999/00	9,431	1,937	7,577	5,664	**1,913**	539	566
1997-99[c]	**9,465**	**1,807**	**7,391**	**5,539**	**1,852**	**545**	**529**

[a]Marketing Year Beginning September 1.
[b]Food, Seed, and Industrial Use.
[c]Three Year Average of 1997/98 through 1999/00 crop years (unweighted).
Source: Feed and Situation Outlook Yearbook, ERS-USDA, Various Issues.

Table 4. Survey Responses by Ohio Farmers Related to Segregation and Market Premiums (GM versus non-GM adoption)

	Corn		Soybeans	
Questions	**Yes**	**No**	**Yes**	**No**
	Percent of Respondents			
Did you encounter any elevators that would not accept GM varieties in 1999?	4.3	95.7	0	100
Did you receive premiums for non-GM varieties in 1999?	7.0	93.0	21.3	78.7
Do you plan to segregate GM from non-GM varieties in 2000?	18.6	81.2	35.5	64.5
Do you expect premiums for non-GM varieties in 2000?	7.0	93.0	22.3	77.7

Source: Chern (2000).

Table 5. Impact of IP Costs on GM and Non-GM U.S. Corn Prices

	Residual Demand Elasticity –0.5*		Residual Demand Elasticity –1.2	
	Percent of Food Demand GMO-Free		Percent of Food Demand GMO-Free	
	100	50	100	50
IP Costs $0.29/bu.				
Corn Price before IP Costs ($/bushel)	1.85	1.85	1.85	1.85
Price of Non-GM Corn: IP Costs ($0.29/bushel)	2.06	2.10	2.10	2.12
Non-GMO Price Received by Farmers ($/bushel)	1.77	1.81	1.81	1.83
Non-GM Corn before IP Costs (billion bushel)	2.45	1.23	2.45	1.23
Reduction in GMO Uses due to IP Costs (billion bushel)	-0.14	-0.08	-0.17	-0.09
Non-GM Corn after IP Costs (billion bushel)	2.31	1.14	2.28	1.14
Change in Undifferentiated Corn Price due to IP Costs ($/bushel)	-0.08	-0.04	-0.04	-0.02
Price of Undifferentiated Corn after Additional IP Costs ($/bushel)	1.77	1.81	1.81	1.83
Total Revenue before IP Costs (billion $)	17.45	17.45	17.45	17.45
Total Revenue after IP Costs (billion $)	16.74	17.09	17.10	17.29
Change in Total Revenue (billion $)	-0.71	-0.36	-0.35	-0.16
Total IP Costs (billion $)	0.67	0.33	0.66	0.33
IP Costs $0.58/bu.				
Corn Price before IP Costs ($/bushel)	1.85	1.85	1.85	1.85
Price of Non-GM Corn: IP Costs ($0.58/bushel)	2.28	2.35	2.36	2.40
Non-GMO Price Received by Farmers ($/bushel)	1.70	1.77	1.78	1.82
Non-GM Corn before IP Costs (billion bushel)	2.45	1.23	2.45	1.23
Reduction in GMO Uses due to IP Costs (billion bushel)	-0.28	-0.17	-0.34	-0.18
Non-GM Corn after IP Costs (billion bushel)	2.17	1.06	2.12	1.05
Change in Undifferentiated Corn Price due to IP Costs ($/bushel)	-0.15	-0.08	-0.07	-0.03
Price of Undifferentiated Corn after Additional IP Costs ($/bushel)	1.70	1.77	1.78	1.82
Total Revenue before IP Costs (billion $)	17.45	17.45	17.45	17.45
Total Revenue after IP Costs (billion $)	16.03	16.74	16.75	17.13
Change in Total Revenue (billion $)	-1.42	-0.71	-0.70	-0.32
Total IP Costs (billion $)	1.26	0.61	1.23	0.61

*The elasticity of food demand is held constant at –0.5.
Source: Authors' Computations.

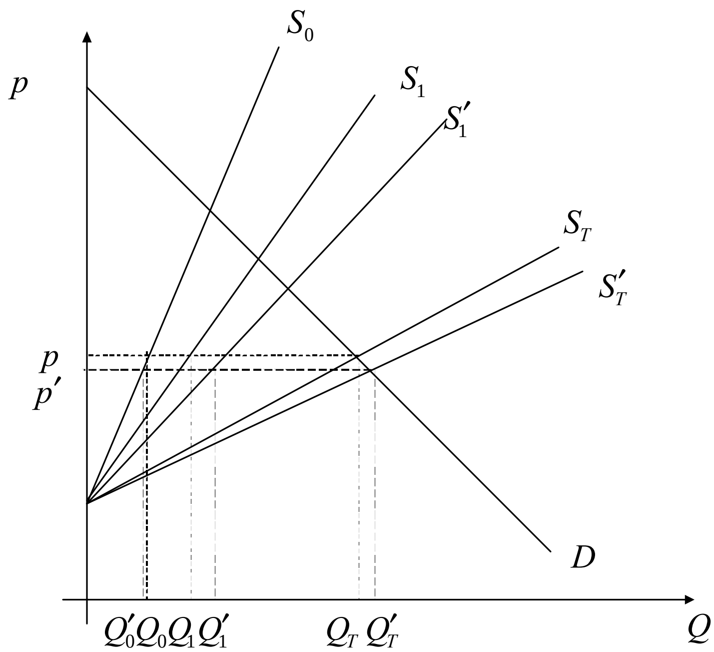

Figure 1. Adoption of GMOs without Difference in Demand

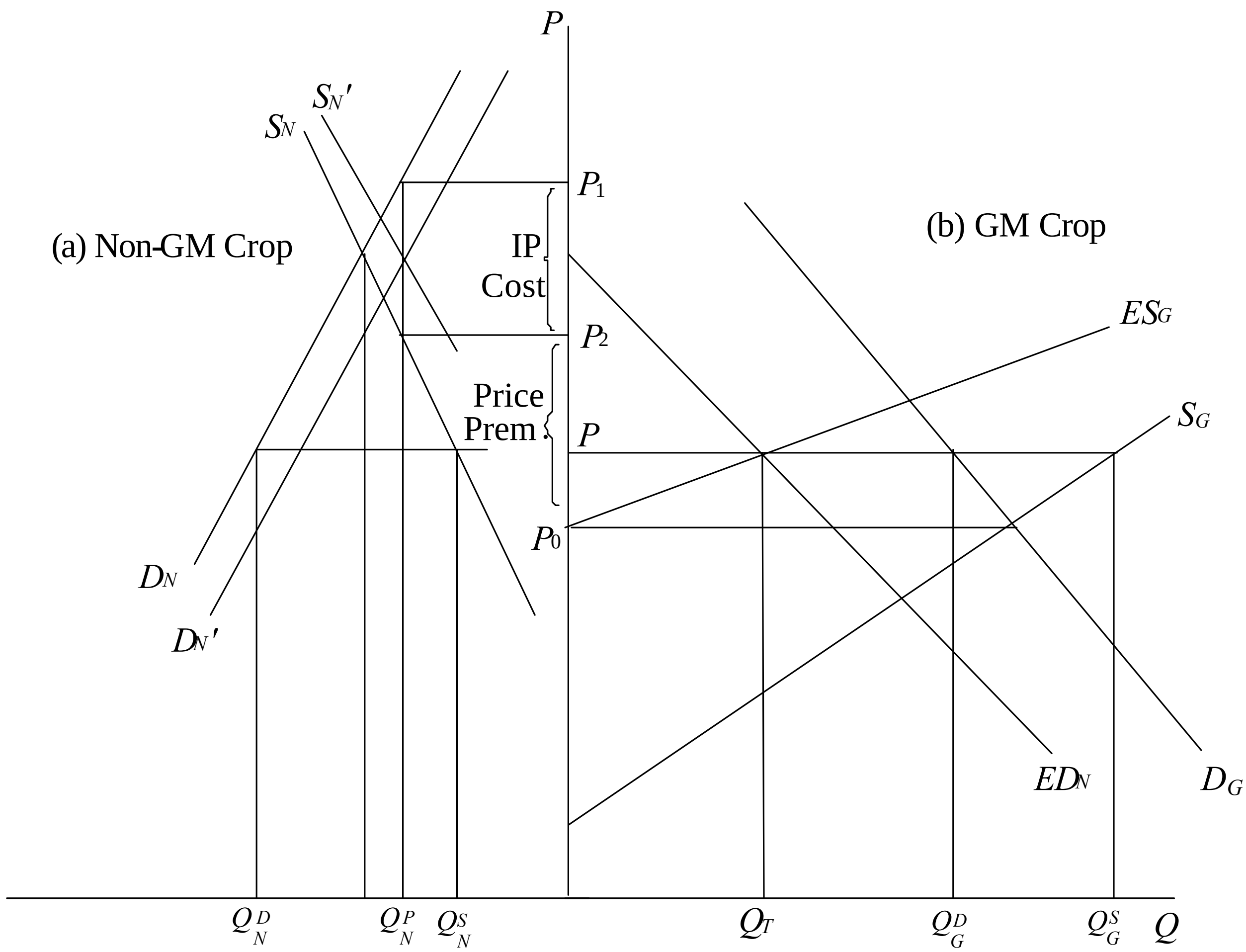

Figure 2. Price Premiums for Non-GM Crops

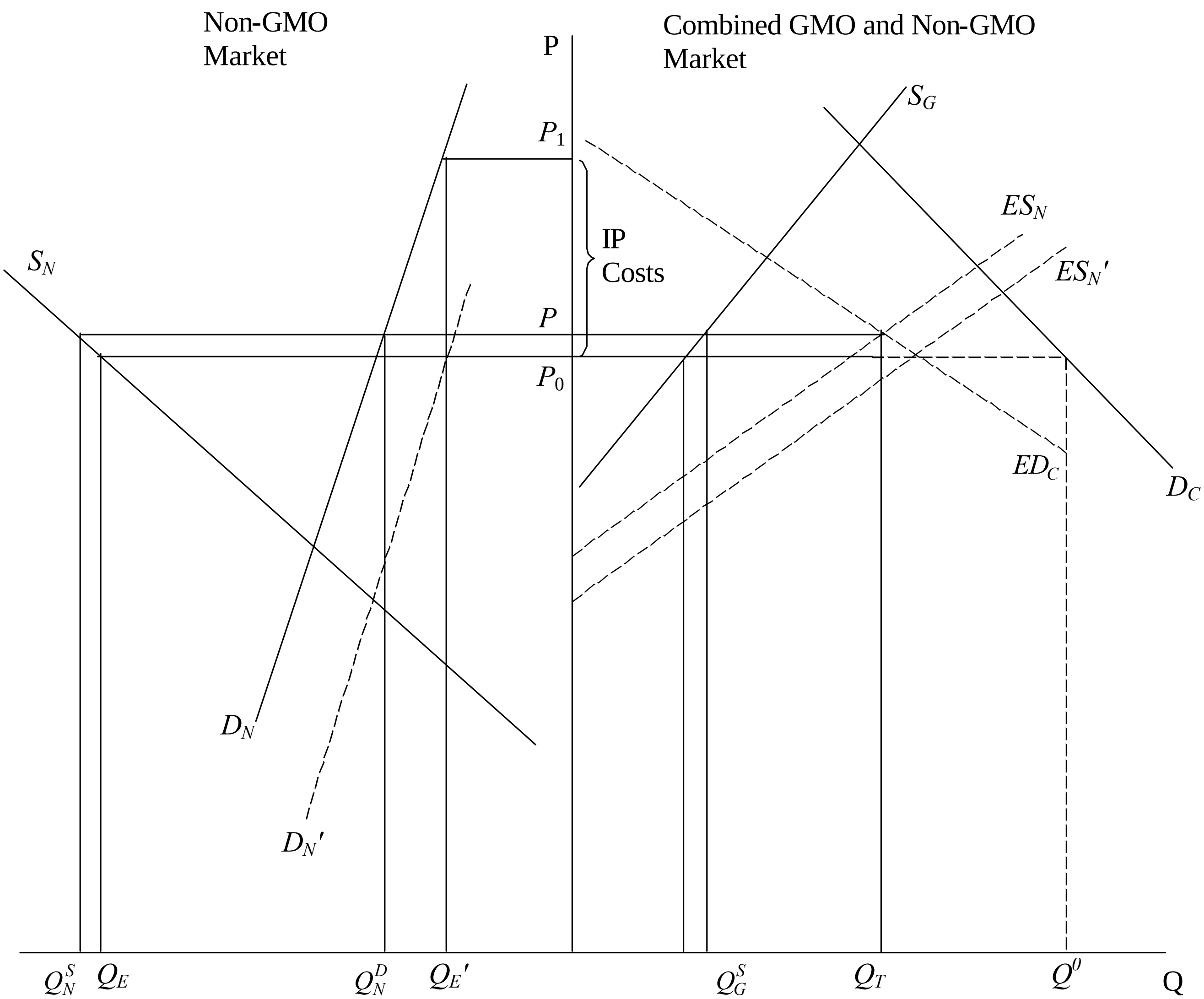

Figure 3. IP Costs for non-GM Crops

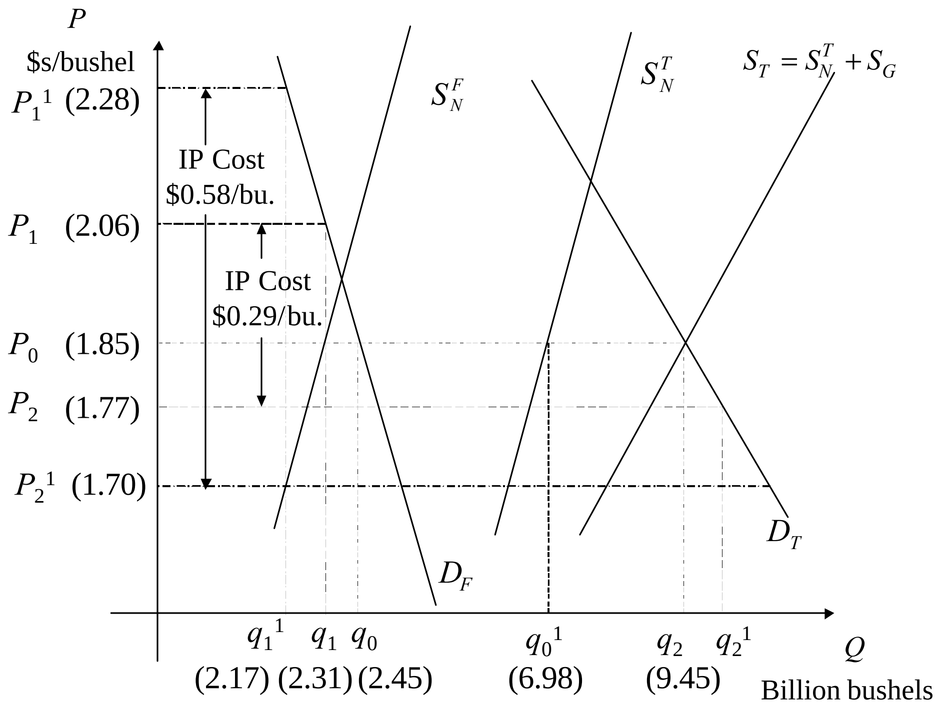

Figure 4. IP Costs and Product Differentiation
(Elasticity of Residual non-Food Demand = -0.5;
100 percent of food corn use is made up of non-GM corn)