Production Decisions with Uncertain Markets: The Case of Bt Corn

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Abstract

The effect of marketing uncertainty due to consumer opposition over genetically modified (GM) grain is modeled in the context of a producer's decision to plant GM. The model shows that a tendency to plant less GM acreage and obtain premium prices for Non-GM grain is tempered by increased price risk.

Consumer opposition to genetically modified (GM) crops appears to be spilling over from the European Union (EU) to other parts of the world. The crops of concern are those engineered by inserting one or more genes from another species. Opposition to these crops stems from unknown health and environmental risks and other ethical concerns. Due to this opposition, labeling requirements for products containing GM grain currently exist in the EU and will soon exist in Australia, Japan, New Zealand, and South Korea. Other countries, including the U.S., are debating whether labeling is appropriate. Even though labeling is not required in the U.S., Archer Daniels Midland Company and others encouraged producers to segregate GM and Non-GM grain in the fall of 1999. Companies such as Gerber, Heinz, and Frito Lay have also announced intentions to use Non-GM grain for at least some of their processed foods.

The effect of increased consumer opposition to GM grain is an intensification of current trends toward segregation, identity preservation, and market premiums. A survey of Midwestern grain elevators conducted by the Sparks Company in the fall of 1999 found 11 and 8 percent segregating corn and soybean, with 1 and 3 percent offering premiums for Non-GM corn and soybean. Various media and marketing reports suggest premiums ranging from $0.05 to $0.10 and $0.05 to $0.35 a bushel for Non-GM corn and soybean in some markets.

Commodity grain is no longer commodity grain. Instead, a tiered market appears to be developing. These tiers differentiate Non-GM and GM grain. The structure of this market is characterized by a one way substitution for producers. Non-GM can always be sold in GM markets, but GM can not be sold in Non-GM markets. As a result, the price for Non-GM should never be less than the price of GM. The complex structure of this developing market further complicates production decisions and seed choice.

Only a few studies have assessed the effect of GM crops on market structure (Klien, Kerr, and Hobbs, 1998) and planting decisions (Pimental and Ali, 1998; and Hyde et al., 1999). Furthermore, these studies do not formally consider the potential for tiered markets due to consumer opposition. The purpose of this paper is to more formally characterize a tiered market with one way substitution and develop a model for producer planting decisions given this market structure. The market characterization shows how aggregate production, the distribution of production between GM and Non-GM, and demand conditions will affect market prices and Non-GM premiums. It also serves to highlight the sources and implications of uncertainty faced by producers. The producer model shows how risk aversion and market expectations will influence acreage allocations between GM and Non-GM crops.

The results show that the expectation of a market premium for Non-GM will discourage producers from planting GM. A more interesting result however is that risk aversion does not necessarily further discourage producers from planting GM crops. In fact, a risk averse producers may plant more GM seed than an otherwise identical risk neutral producers. The reason for this result is that both the costs and benefits of planting Non-GM are uncertain. If the benefits are more uncertain than the costs, producers with greater risk aversion will be less inclined to plant Non-GM. Alternative, if the costs are more uncertain than the benefits, producers with greater risk aversion will be more inclined to plant Non-GM.

Market Characterization

Consumer opposition to GM grain is resulting in a tiered market of differentiated products. Suppose the demand for GM, Q_{GM}, is a decreasing function of the price of GM and an increasing function of the price of Non-GM: $Q_{GM} = G(P, P + d)$ where $P > 0$ is the GM market price and $d \geq 0.0$ is the Non-GM market premium received by producers after adjusting for differences in costs due to Non-GM market certification, transportation, and segregation. The demand for Non-GM grain, Q_{Non}, that is adjusted for differences in costs, is an increasing function of the GM price and a decreasing function of the Non-GM price: $Q_{Non} = H(P, P + d)$. Let Y be the aggregate supply and $1.0 \geq F \geq 0.0$ be the proportion of aggregate supply that qualifies for the Non-GM market. Let $1.0 \geq W \geq 0.0$ be the proportion of qualified Non-GM actually sold in the Non-GM market. Equating supply and demand determines the equilibrium GM price and Non-GM premium:

(1) $YWF = \mathrm{H}(P, P + d)$ and

(2) $Y(1 - F) + Y(1 - W)F = G(P, P + d)$.

P^* and d^* are equilibrium solutions to equations (1) and (2). Two possible scenarios can emerge.

With an excess supply of Non-GM at the equilibrium GM price, there is no GM premium: $Y = G(P, P) + H(P, P)$. In this instance, it is almost as if no market differentiation exists. The only difference is any additional cost of certifying, transporting, and segregating Non-GM grain. Increases in supply will serve to decrease the equilibrium price. To support this intuition, it is sufficient to assume the magnitude of the own price elasticities of demand exceed the magnitude of cross price elasticities.

With an excess demand for Non-GM at the equilibrium GM price, premiums will emerge: $YF = \mathrm{H}(P, P + d)$ and $Y(1 - F) = G(P, P + d)$. The comparative static results reported in Table 1 show how the GM price and Non-GM premium will depend on aggregate supply, the proportion of Non-GM supply, and own and cross price elasticities of demand. Assuming the magnitude of the own price elasticities exceed the magnitude of cross price elasticities, the GM price decreases with an increase in aggregate supply and the Non-GM premium decreases as the proportion of Non-GM supply increases. These are intuitive price responses to increasing supplies.

It is less clear how GM premiums will respond to an increase in aggregate supply because the result depends on the relative magnitudes of own and cross price elasticities. To illustrate these confounding effects consider a special case where cross price elasticities are 0.0. That is, GM is not a substitute for Non-GM at any price. An increase in the aggregate supply drives the price lower. If the elasticity of demand in the GM market is greater than that in the Non–GM market, the GM price will fall faster than the Non-GM price and a larger premium can result. Alternatively, if the elasticity of demand in the Non-GM market is greater than that in the GM market, the Non-GM price will fall faster than the GM price and a smaller premium will result.

It is also unclear how increasing the proportion of Non-GM supply will affect the GM price. Increasing the proportion of Non-GM supply will reduce the supply in the GM market if market premiums are being offered. This initial supply side effect will put upward pressure on the GM price and downward pressure on the Non-GM premium. However, with relatively cheaper Non-GM grain some GM buyers may choose to substitute buying more Non-GM and less GM, which will put downward pressure on the price of GM. The net result is therefore ambiguous.

An important lesson to learn from this market characterization is that the GM price and Non-GM market premiums are uncertain to the producer when planting decisions are made. This uncertainty is attributable to unknown production levels, limited information on how much Non-GM acreage will be planted, and volatile demand conditions for Non-GM grain. Furthermore, the GM price and market premiums for Non-GM could be either positively or negatively correlated depending on the strength of the own and cross price elasticities and the proportion of Non-GM supply.

Producer Decisions with Uncertain Markets

The characterization of a tiered market highlights important factors influencing the GM price and Non-GM premium. These factors include aggregate supply, the proportion of Non-GM supply and the own and cross price elasticities of demand. Producers are accustomed to price uncertainty due to variations in aggregate supply and the elasticity of demand. The commercialization of GM grain and the emerging tiered market due to consumer opposition to GM products add new factors for consideration that substantially complicate the production decision. To understand how this new market uncertainty will affect production, a stylized decision model for a producer's acreage allocation between GM and Non-GM production is developed.

Let $y \geq 0.0$ and $(1 - d)y \geq 0.0$ be GM and Non-GM per acre yields. For d >(<) 0.0, the GM crop is relatively more (less) productive. Let $c + f \geq 0.0$ and $c \geq 0.0$ be the GM and Non-GM per acre cost of production. For f >(<) 0.0, the GM crop has a higher (lower) production cost. Yields and production costs are assumed known by the producer in order to focus on market uncertainties. Let $\phi_c \geq \phi \geq 0.0$ be the proportion of acreage devoted to GM production where ϕ_c is the maximum allowable proportion of GM acreage permitted.[1] A is the total acreage available for production. As before, P is the GM price and δ is the Non-GM premium. Both are assumed to be unknown when acreage allocations are made due to market uncertainty. The joint density function is $\gamma(P, \delta)$ with distribution $\Gamma(P, \delta)$ where $P_U \geq P \geq P_L$ and $\delta_U \geq \delta \geq 0.0$. The Non-GM market premium will never be less than 0.0 because the producer can always sell Non-GM grain in the GM market.

Producer profit is $\pi = A[Py - c - f + (1 - \phi)(f + \delta y\,(1 - d) - Pyd)]$. $Py - c - f$ is the average profit per acre of GM. For each acre of Non-GM planted, costs and revenues change by the additional cost of planting GM, f, the difference in the market price received on the Non-GM yield, $-\delta y(1 - d)$, and the difference in revenues due to differences in the GM and Non-GM yields, Pyd. The expected utility of profit is

[1] Some GM crops have planting restrictions. For example, growers are required to plant refuge corn with Bt corn for insect resistance management. These restrictions are handled by restricting ϕ to be sufficiently less than ϕ_c, which is reasonable if the refuge crop qualifies for sale in the Non-GM market. If the refuge crop would typically fail certification for sale as Non-GM due to cross-pollination or some other reason, the lower costs and yields of refuge can be subsumed into y and f.

(3) $$EU = \int_{P_L}^{P_U}\int_{0}^{\delta_U} U(\pi)\, d\tilde{A}(P,\delta) = E[U(\pi)]$$

where $U(\cdot)$ is twice continuously differentiable and increasing in income, and $E[\cdot]$ is the expectation operator defined over the joint distribution of P and δ. The first order necessary conditions for the optimum proportion of GM acreage are

(4) $$E[A(Pyd - f - \delta y(1 - d))U'(\pi)] - \lambda \leq 0.0,$$

$$\left(\frac{\partial EU}{\partial \phi} - \lambda\right)\phi = 0.0,\ \phi \leq \phi_c,\ \text{and } (\phi_c - \phi)\lambda = 0.0$$

where λ is a lagrangian multiplier that restricts the portion of GM production to be less than ϕ_c. If $ydE[PU'(\pi)] >(<) fE[U'(\pi)] + y(1 - d)E[\delta U'(\pi)]$, the expected marginal utility of planting GM is greater (less) than that of planting Non-GM and the optimum allocation is $\phi^* = \phi_c$ ($\phi^* = 0.0$). If an interior solution exists and second-order conditions are satisfied, equation (4) can be rewritten as

(5) $$ydE[PU'(\pi)] = fE[U'(\pi)] + y(1 - d)E[\delta U'(\pi)].$$

It is useful to interpret the left-hand-side of equation (5) as the cost of an option for greater market access. This cost reflects the expected marginal value of the potential loss in revenues in order for the producer to enjoy greater market access. The right-hand-side can be interpreted as the value of the option for greater market access. This value includes the marginal value of a decrease in per acre production costs and the marginal value of increased revenues due to greater market access and potential market premiums.

It is important to note that the option for greater market access differs from a more conventional marketing option that is designed to mitigate risk. The cost of the Non-GM market option can entail greater rather than less uncertainty due to price variations. Alternatively, the value of the option can entail more rather than less uncertainty due to variations in the market premium. Therefore, a producer may very well view the purchase of this option for greater market access as increasing rather than decreasing profit variability or risk.

The first question of interest is whether producers will plant more or less GM seed given a tiered market and the potential for Non-GM premiums. To answer this question, it is useful to compare equation (5) to $ydE[PU'(p)] = fE[U'(p)]$, which results when no market premiums is available. When $ydE[PU'(p)] = fE[U'(p)] + y(1 - d)E[dU'(p)]$, $ydE[PU'(p)] \geq fE[U'(p)]$ because $y(1 - d)E[dU'(p)] \geq 0.0$. This means that for the same $E[PU'(p)]$ and $E[U'(p)]$ the availability of a market premium will result in $f^* \leq f_c$, while without a market premium $f^* = f_c$. Therefore, the availability of a market premium will tend to reduce the amount of acreage producers devote to GM assuming the price of GM with and without premium is the same. This result is quite intuitive and consistent with the March 2000 planting intentions released by the United States Department of Agriculture (USDA). These planting intentions indicate a 25 percent decline in proportion of Bt corn acreage from about 33 percent 1999 to an intended 19 percent in 2000. Bt corn is genetically modified to manufacture its own insecticide for the control of the European corn borer.

Another interesting question is whether a risk averse producer is likely to reduce GM acreage more than an otherwise identical risk neutral producer. To answer this question it is useful to rewrite equation (5) as

$$(6) \qquad ydE[P] = f + y(1 - d)E[\delta]$$

$$+ \, y(1 - d) \, [\mathrm{Cov}(\delta, E[U'(\pi)|\delta])] \, / \, E[U'(\pi)]$$

$$- \, yd \, [\mathrm{Cov}(P, E[U'(\pi)|P])]\}/ \, E[U'(\pi)]$$

where $\mathrm{Cov}(\cdot,\cdot)$ is the covariance operator defined over the distribution of P or δ. Since $E[U'(\pi)|\delta]$ and $E[U'(\pi)|P]$ are decreasing in δ and P for a risk averse producer and constant for a risk neutral producer, $\mathrm{Cov}(\delta, E[U'(\pi)|\delta])$ and $\mathrm{Cov}(P, E[U'(\pi)|P])$ will be negative for a risk averse producer and 0.0 for a risk neutral producer. Therefore, when $ydE[P] = f + y(1 - d)E[\delta]$ for a risk neutral producer such that $\phi_c \geq \phi^* \geq 1.0$, $ydE[P]$ >(<) $f + y(1 - d)E[\delta] + y(1 - d) \, [\mathrm{Cov}(\delta, E[U'(\pi)|\delta])] \, / \, E[U'(\pi)] - yd \, [\mathrm{Cov}(P, E[U'(\pi)|P])]\}/ \, E[U'(\pi)]$ as $y(1 - d) \, [\mathrm{Cov}(\delta, E[U'(\pi)|\delta])] \, / \, E[U'(\pi)] - yd \, [\mathrm{Cov}(P, E[U'(\pi)|P])]\}/ \, E[U'(\pi)]$ <(>) 0.0. Hence, the risk averse producer will choose $\phi^* = \phi_c$ when $y(1 - d) \, [\mathrm{Cov}(\delta, E[U'(\pi)|\delta])] \, / \, E[U'(\pi)] - yd \, [\mathrm{Cov}(P, E[U'(\pi)|P])]\}/ \, E[U'(\pi)] < 0.0$ and $\phi^* = 0.0$ when $y(1 - d) \, [\mathrm{Cov}(\delta, E[U'(\pi)|\delta])] \, / \, E[U'(\pi)] - yd \, [\mathrm{Cov}(P, E[U'(\pi)|P])]\}/ \, E[U'(\pi)] > 0.0$. The implications of these results are that it is not clear whether a risk averse producer will reduce GM acreage more than an otherwise identical risk neutral producer. It all depends on the covariance of the price and marginal utility of income and the covariance of the market premium and marginal utility of income.

However, suppose that a producer can lock in a market price for GM grain prior to planting, then $yd \, [\mathrm{Cov}(P, E[U'(\pi)|P])]\}/ \, E[U'(\pi)] = 0$ and $\phi^* = \phi_c$. That is, a risk averse producer will plant more GM than the risk neutral producer. This result at first seems counter intuitive because planting Non-GM for greater market access does seem prudent. However, by locking in a price for GM grain, the cost of the option for greater market access becomes certain, while the value of the option remains uncertain. If this is the case, planting more Non-GM is similar to paying a premium for greater risk. Admittedly, there is value to the producer in incurring greater risk because a higher price is expected. However, due to this added risk, a risk averse producer is less likely to plant Non-GM than a risk neutral producer.

Alternatively, suppose a producer can lock in a market premium prior to planting. Then $y\delta\,[\mathrm{Cov}(\delta, E[U'(\pi)|\delta])]\}/\,E[U'(\pi)] = 0$, which implies $\phi^* = 0.0$. Now a risk averse grower will plant proportionally less GM than a risk neutral grower. By locking in a market premium, the producer assures the value of the option for greater market access, while the costs of the option remains uncertain. In this situation, producers reduce risk and obtain a higher price on average by purchasing the option. Therefore, a risk averse producer will be more inclined to buy this option than a risk neutral producer.

These diametric examples serve to demonstrate the importance of the degree of uncertainty a producer faces with respect to the cost and value of greater market access. If the producer is more uncertain about the cost, he/she is likely to plant more Non-GM. If the producer is more uncertain about the value, he/she is likely to plant more GM.

Conclusions

Consumer opposition to GM crops, crops that have been genetically engineered with a gene from another species, is complicating planting decisions by creating a tiered market. While producers can always sell their Non-GM grain in the GM market, they can not sell their GM grain in the Non-GM market. The purpose of this paper was twofold. First, we characterized the emerging tiered market for GM and Non-GM grain and then discuss the implications of this market structure on the price of GM grain and market premiums for Non-GM grain. Second, we explored how this tiered market will affect planting decisions and the role risk attitudes and producer expectations will play in influencing GM production.

We show how the emergence of market premiums will depend crucially on the aggregate supply, the proportion of Non-GM supply and demand, and own and cross price elasticities of demand. While it is clear that the GM price will likely be correlated with the Non-GM market premium, it is unclear whether this correlation will be positive or negative because it depends on the own and cross price elasticities of demand and the proportion of Non-GM supply. We find that the expectation of market premiums will likely reduce the amount of GM acreage planted. However, a more interesting result is that a risk averse producer may be less inclined to reduce GM acreage than an otherwise identical risk neutral producer. By planting Non-GM, a producer secures the option for a market premium should one arise. The value of this option is uncertain because no one knows if premiums will emerge. The cost of this option is also uncertain, since it depends on the GM price, which will also be influenced by the emergence of Non-GM premiums. If the value of this option is more uncertain than the cost, risk averse producers will be less likely to plant Non-GM. Alternatively, if the cost of this option is more uncertain than the value, a risk averse producer will be more inclined to plant Non-GM.

The market characterization and producer decision model developed in this paper provides a useful framework for evaluating the likelihood and magnitude of a market premium for Non-GM grain, information that would be prized by producers. To accomplish this objective, future research needs to focus on decomposing the demand for commodity grain into GM and Non-GM components. Additional work also remains to understand how government programs will affect planting decisions within this new market structure. While the discussion has focused on GM versus Non-GM production, the models and results are equally applicable to any identity preserved market, such as that for high oil corn or Synchrony Treated Soybeans.

References

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Table 1: Comparative static effects when market premiums for Non-GM exist.

	GM Price (P)	Non-GM Premium (δ)
Aggregate Production (Y)	$\frac{P}{Y}(\boldsymbol{e}_N - \boldsymbol{e}_{GN})\Delta^{-1} < 0$	$\left\{\frac{P}{Y}(\boldsymbol{e}_{GN} - \boldsymbol{e}_N) + \frac{P+\boldsymbol{d}}{Y}(\boldsymbol{e}_G - \boldsymbol{e}_{NG})\right\}\Delta^{-1}$
Proportion of Non-GM Production (Φ)	$-P\left(\frac{\boldsymbol{e}_N}{1-\text{Ö}} + \frac{\boldsymbol{e}_{GN}}{\text{Ö}}\right)\Delta^{-1}$	$\left\{P\left(\frac{\boldsymbol{e}_N}{1-\text{Ö}} + \frac{\boldsymbol{e}_{GN}}{\text{Ö}}\right) + (P+\boldsymbol{d})\left(\frac{\boldsymbol{e}_{NG}}{1-\text{Ö}} + \frac{\boldsymbol{e}_G}{\text{Ö}}\right)\right\}\Delta^{-1} < 0$

Note: $\boldsymbol{e}_G = \frac{\partial G}{\partial P}\frac{P}{Q_{GM}}$ and $\boldsymbol{e}_N = \frac{\partial H}{\partial(P+\boldsymbol{d})}\frac{(P+\boldsymbol{d})}{Q_{Non}}$ are the own price elasticities of demand for the GM and Non-GM markets; $\boldsymbol{e}_{GN} = \frac{\partial G}{\partial(P+\boldsymbol{d})}\frac{(P+\boldsymbol{d})}{Q_{GM}}$ and $\boldsymbol{e}_{NG} = \frac{\partial H}{\partial P}\frac{P}{Q_{Non}}$ are the cross price elasticities of demand for the GM and Non-GM markets; and $\Delta = \boldsymbol{e}_G \boldsymbol{e}_N - \boldsymbol{e}_{GN} \boldsymbol{e}_{NG} > 0$ by assumption.