AgBioForum, 8(2&3): 143-150. ©2005 AgBioForum.

Second-Generation GMOs: Where to from Here?

Kenrett Y. Jefferson-Moore
Department of Agribusiness, Applied Economics & Agriscience Education, North Carolina A&T State University

Greg Traxler
Agricultural Economics and Rural Sociology, Auburn University

The driving force behind the growth of the agricultural biotechnology industry is the potential to increase efficiency in the production of commodities and to provide benefits to consumers and producers as well as profits for industry. Value-enhanced genetically modified crops have the potential to provide new momentum to the industry. Using the US high-oil corn (HOC) industry as a case study, welfare measures indicate that those benefiting from HOC are HOC seed suppliers and conventional seed suppliers. Farmer gains are only attributed to larger premiums at the elevator level without technology fees and monopoly power.

Key words: equilibrium displacement modeling (EDM), high-oil corn, monopoly power, value-enhanced crops, welfare analysis.

Introduction

The introduction of a second wave of genetically modified organisms (GMOs), referred to as value-enhanced crops (VEC), includes those plant varieties that have one or more output characteristic modified adding end-user value to the commodity. VECs have the potential to provide momentum to the agricultural biotechnology industry and to enhance productivity worldwide (United States Department of Agriculture Economic Research Service [USDA ERS], 1999). Most of the VECs are new to US agricultural markets, competing with established grain crops for crop acreage and market acceptance. The intent of this study is to identify the potential for future growth of VECs in the United States by determining whether the incentives exist for farmers to adopt and for industry to invest in R&D for transgenic and nontransgenic VECs using US production of high-oil corn (HOC) as a case study.

Value-Enhanced Genetically Modified Crops in the United States

Since the introduction of second-generation product quality GMOs, the agricultural biotechnology industry has expressed optimism in its efforts to establish markets for VEC products. Most of the VECs are new to US agricultural markets, competing with established grain crops for crop acreage and market acceptance. The area devoted to VECs in the United States remains relatively small to date, with slight increases annually from 1996 to 2001. The acreage of VECs planted in 1996 was predominately value-enhanced grains, which included products such as white, waxy, hard endosperm/food grade, high oil, or high-amylose corn. The majority of VEC acreage has been planted in hard endosperm/food grade corn with as much as 1.2 million acres, followed by white, waxy, and high-oil corn. In 2001, VECs accounted for more than 4.31 million harvested acres of transgenic and nontransgenic varieties in the United States, with nontransgenic varieties accounting for more than 95% of VEC area planted in the United States (Penn, 2000; US Grains Council, 2001).

The Animal and Plant Health Inspection Service (APHIS) is a USDA agency charged with regulating the introduction of GMOs into the environment in the United States. Two main steps are involved in clearing a GMO for commercial use. The institution producing a new GMO must first either obtain a permit to conduct field trials or notify APHIS of its intent to conduct field trials of the new regulated article.[1] After conducting field trials, the institution may petition APHIS to have an article removed from regulated status. If the petition is granted, the GMO may be commercialized. Once an article is removed from regulated status, subsequent varieties of the same crop developed through commercial breeding can be developed without additional approvals. A total of 10,390 field tests[2] were conducted in the United States from 1987 through 2004.

Product quality traits have been an important focus of biotechnology research. Product quality has accounted for 18% of all trials,[3] with interest peaking in the mid-1990s. In 1994 and 1995, more trials were con-

1. *"Regulated articles are organisms and products altered or produced through genetic engineering that are plant pests or that there is reason to believe are plant pests" (USDA APHIS, 1997).*
2. *Field tests include all notifications and release permits classified as pending, acknowledged, or issued.*

ducted for product quality than for any other phenotype category. Since January 2004, attention within product quality trials has focused on corn, soybeans, rapeseed, tobacco, and tomatoes. Of the 128 permits issued for both horticultural and agronomic crops since 1988, 36 have been for rapeseed events, 34 for tomato, 13 for potato, six for corn, four for soybean, and the remaining 35 articles for a variety of horticultural products.

Even though the APHIS trial data indicate a significant level of investment by industry in developing VEC GMOs, only two of these products have been deregulated: high oleic soybeans and laurate canola in 1997 and 1994, respectively (Penn, 2000). None of these products has yet achieved significant commercial acreage, although several VEC products are in the pipeline with the potential to generate future revenue for industry and to deliver benefits to farmers. The economic traits provide value to end users—livestock producer-feeders, feed manufacturers, wet millers, dry millers, and alkaline processors (Boland, Domine, Dhuyvetter, & Herrman, 1999).

Several value-enhanced corn products developed through conventional breeding methods have been marketed in the United States by firms such as DuPont and Monsanto. Value-enhanced corn products currently marketed are white, blue, high oil, waxy, food-grade yellow, nutritionally dense, nutritionally enhanced, organic, non-GMO, and high-amylase corn. Those value-enhanced corn products in the pipeline are low phytate, low stress cracks, low-temperature dried, high starch, postharvest pesticide free, and high-lysine corn (Boland et al., 1999; US Grains Council, 2001). Several value-enhanced soybeans have also been commercialized in the United States by companies such as DuPont Specialty Grains (DSG), formerly known as Optimum Quality Grains. DSG is the only firm presently commercializing value-enhanced soybean products. In 1997, Optimum Quality Grains commercialized oilseed varieties including high-protein soybeans, high-sucrose soybeans, high-oleic soybeans, low-linolenic soybeans, and low-saturate soybeans (Penn, 2000).

Methodology

Equilibrium displacement modeling (EDM) is used to analyze incentives for producer adoption and industry R&D investment using HOC as an illustrative example. A two-product Muth (1964) type model—similar to the models used by Wohlgenant (1993) and Kinnucan and Paudel (2001) to analyze research and promotion effects in the US beef and pork industries and to evaluate the upstream effects of generic advertising in the US catfish industry, respectively—is created by introducing demand and supply function specifications excluding all exogenous factors. Using assumptions similar to those established in the James and Alston (2001) model, we assume that the production of corn includes varieties with a higher level of oil content (e.g., HOC) and a lower level of oil content (e.g., conventional corn). It is also assumed that both varieties of corn will be consumed by grain elevators. These grain elevators and growers are then allowed to substitute between the two varieties of corn product and corn seed, respectively. The structural equations are as follows:

$$D_H^d = D_H^d(P_H, P_C)\,, \tag{1}$$

$$D_H^e = D_H^e(P_H, P_C)\,, \tag{2}$$

$$D_C^d = D_C^d(P_H, P_C)\,, \tag{3}$$

$$D_C^e = D_C^e(P_H, P_C)\,, \tag{4}$$

$$S_H = f(H, C), \tag{5}$$

$$S_C = f(H, C), \tag{6}$$

$$R_H = f_H P_H, \tag{7}$$

$$R_C = f_C P_C, \tag{8}$$

$$R_H = S(H), \tag{9}$$

$$R_C = S(C), \tag{10}$$

$$D_H^d + D_H^e = S_H = Q_H\text{, and} \tag{11}$$

$$D_C^d + D_C^e = S_C = Q_C\,. \tag{12}$$

The output level of the EDM is introduced in Equations 1–6. Equations 1 and 2 represent the grain elevator's demand function, where D_H^d and D_H^e symbolize domestic and export quantities demanded (consumed)

3. *All traits include those classified as pending, acknowledged, issued, denied, withdrawn, or void. However, product quality traits exclude those classified as denied, withdrawn, or void.*

for HOC, respectively, as functions of own-price (P_H) and the price of a substitute (P_C); C represents conventional corn. Equations 3 and 4 denote the grain elevator's domestic and export demand for conventional or #2 yellow corn. The quantities demanded (consumed) for conventional corn, D_C^d and D_C^e, are functions of the prices of HOC (P_H) and conventional corn (P_C), respectively. The farm-level supply functions of HOC and conventional corn are denoted in Equations 5 and 6, where S_H represents quantity supplied (produced) for HOC and S_C represents quantity supplied (produced) for conventional corn with both as functions of HOC seed (H) and conventional seed (C).

Input use is introduced in Equations 7-10. The grower's demand for HOC seed is introduced to the model with Equation 7, where the price of HOC seed (R_H) is a function of the marginal product of HOC seed and product price (P_H). An alternative crop is included in the model to account for growers' substituting between HOC and conventional corn production. Equation 8 represents the demand for conventional corn seed, which is presented as the input price of #2 yellow corn seed as a function of the marginal product of conventional corn and output price (P_C).

The licensed seed company's supply curve for producing HOC seed is presented in Equation 9, where the input price of (R_H) is a function of the output price (P_H). The licensed seed company and other seed companies producing conventional corn are included in Equation 10, where the price of conventional corn seed (R_C) is a function of the output price (P_C).

The effect of market power in the seed markets is introduced to the structural model in Equation 7 with the introduction of Lerner indices. Such indices have been utilized in numerous studies (e.g., Alleman, Madden, & Savage, 2003, Applebaum, 1982; Bhuyan & Lopez, 1997; Kinnucan, 2003; Lopez & You, 1993) evaluating the degree of market power, that is, monopoly power or oligopoly found in the classic study by Lerner (1934). Zhang and Sexton (2002) and Kinnucan (2003) use Lerner indices, where the traditional firm purchases factors in factor markets and sells the products in product markets, where monopsony and monopoly power can exist, respectively. In the case of HOC, indices are interpreted where the firm is a supply chain with an embedded nonfirm transformation phase as for a traditional firm. Therefore, a Lerner index $\{\psi = \theta/\lambda\}$ is imposed in the structural model, which denotes monopoly power, where θ is the supply elasticity for HOC seed, and $\theta \in [0,1]$ is the input conjectural elasticity ($\theta = 0$ for perfect competition and $\theta = 1$ for pure monopoly). The input conjectural elasticity represents the magnitude of competition among HOC seed companies selling HOC seed; that is, the larger the value of the input conjectural elasticity, the greater the deviation from competition. Therefore, the Lerner index $\{\psi = \theta/\lambda\}$ represents a joint effect of imperfect competition between the market power index (θ) and the elasticity of the derived demand in the HOC market (λ). For instance, as the impact of a given level, θ, of monopoly power increases, the market demand for HOC will become more inelastic. HOC seed and nonseed marginal products are denoted as f_i ($i = H, C$). HOC seed companies are required to pay a technology fee per unit of seed, which has been labeled as a seed variety with an output trait. Generally, the licensed seed company reserves the right to transfer the technology fee on to the grower purchasing the VE seed variety. Therefore, a technology fee is introduced to the model in Equation 9.

Scenarios and Data

Scenarios are developed based on EDM model formulations of high oil as an enhancement trait of conventional corn, which is also referred to as high-oil corn (HOC). High oil is therefore utilized as a product quality trait in evaluating VEC on the future growth of other output traits in the United States. The EDM formulation includes a multilevel model including domestic and export market demand, supply of grain, and markets for seed inputs for HOC and conventional corn, assuming constant elasticity functions for all relationships. Ideally, we want the EDM formulation to address the following scenarios: (a) high oil as an enhancement trait base solution model in perfect competition, where a \$20 per bag technology fee is assessed, and (b) high oil as an enhancement trait with a technology fee and monopolistic sales of the high-oil gene to, and seed by, licensed seed companies.

Table 1 shows the baseline data and model parameters for both HOC and conventional corn industries. The own-price elasticity of domestic demand for conventional corn utilized by the USDA ERS is –0.3, a relatively inelastic demand curve. The own-price elasticity of demand for HOC is assumed to be relatively more elastic than that of conventional corn; however, both elasticities are set equal in the present analysis. The own-price elasticity for the export demand of #2 yellow corn also utilized by the USDA ERS is –0.9 and the export demand elasticity for HOC is presumed to be the same. The cross-price elasticity of demand for HOC and conventional corn is set at 2.0, assuming a relatively

Table 1. Baseline data and model parameters, high-oil corn and conventional corn industries, 1999.

Item	Definition	Value
Q_H	Grain elevator high-oil corn quantity (thousand acres of corn)[a]	1,000.00
Q_C	Grain elevator conventional quantity (thousand acres of corn)[b]	70,500.00
H	High-oil seed quantity (thousand units of seed)[c]	387.50
C	Conventional corn seed quantity (thousand units of seed)[d]	25,644.38
P_C	Conventional corn market price ($/bushel)[b]	1.82
P_H	High-oil corn market price ($/bushel)[e]	2.02
R_H	High-oil corn seed price ($/acre)[b]	60.00
R_C	Conventional corn seed price ($/acre)[b]	60.00
η_{HH}	Own-price elasticity of demand for high-oil corn[h]	-0.30
η_{HC}	Cross price elasticity of high-oil and conventional corn	2.00
η_{CC}	Own-price elasticity of demand for conventional corn[f,h]	-0.30
σ_H	Factor substitution elasticity (high-oil corn)	1.00
ε_H	Supply elasticity for high-oil corn seed	0.75
ε_C	Supply elasticity for conventional corn seed	0.50
κ_H	High-oil corn seed cost share (R_HH/P_HQ_H)	0.09
κ_C	Conventional corn seed cost share (R_CC/P_CQ_C)	0.09
τ_H	High-oil seed technology fee rate ($=T/R_H$)[g]	0.12
ρ_H	Share of high-oil corn (domestic)	0.65
ρ_C	Share of conventional corn (domestic)	0.95

[a] US Grains Council (2002).
[b] USDA World Agricultural Outlook Board (2000).
*[c] Based on a seeding rate of 0.3875 * Q_H.*
*[d] Based on a seeding rate of 0.36375 * Q_C.*
[e] Market price for #2 yellow corn plus a $0.20 per bushel premium.
[f] USDA Economic Research Service (2005).
[g] T = $7.27 ($20 per unit producing 2.75 acres); a unit is equivalent to an 80,000-kernel bag.
[h] Models assume that export demand for conventional and high-oil corn are equal to -0.900.

high level of substitutability between the two varieties. In this formulation, the farm-level supply functions for HOC and #2 yellow corn are assumed to exhibit constant returns to scale, implying that the percentage changes in output and input are the same and are distributed in fixed proportions. Therefore, κ_H and κ_C represent the proportional change in farm-level supply for HOC resulting from a unit proportional change in HOC seed and conventional seed, respectively, where $\kappa_H + \kappa_C = 1$. The share of HOC seed costs (κ_H) of producing HOC is 9% of the total cost of producing within the HOC industry; in addition, κ_C is established as 9% of the total costs of producing within the conventional corn industry. The factor substitution elasticity in the production of HOC is set at 1.0. Supply elasticities for HOC seed and conventional corn seed are set as 0.75 and 0.5, respectively. The coefficient of the technology fee exogenous variable (i.e., HOC seed technology fee rate, τ_H) is the ratio of the technology fee of $7.27 per acre to the wholesale price of HOC seed of $60 per acre, which is set equal to the price of conventional corn seed.

Table 2. Changes in prices and quantities of high oil and conventional corn.

Endogenous variable	Initial prices & quantites	New prices & quantites	Change in prices & quantites
Scenario I			
Q_H*	129.79	129.48	-0.311
Q_C*	9,432.90	9,476.70	43.799
H*	0.39	0.37	-0.022
C*	25.64	25.73	0.085
P_H*	$2.02	$2.02	$—
P_C*	$1.82	$1.82	$—
R_H*	$60.00	$60.00	$—
R_C*	$60.00	$60.00	$—
Scenario II			
Q_H*	129.79	129.24	-0.553
Q_C*	9,432.90	9,510.84	77.941
H*	0.39	0.33	-0.053
C*	25.64	25.81	0.169
P_H*	$2.02	$2.03	$0.01
P_C*	$1.82	$1.87	$0.05
R_H*	$60.00	$69.50	$9.50
R_C*	$60.00	$60.79	$0.79

Note. Prices are in dollars per bushel for corn output, and in dollars per acre (or per unit) for seeds. Quantities are in million bushels for corn output and million units for seeds.

Results

Equilibrium and monopolistic solutions of the EDM formulation are evaluated by reduced-form elasticities and welfare analysis to give some insight on the effects of technology fees and monopoly power within the US high-oil corn industry.

Table 2 shows the actual price and physical quantity changes under scenarios I and II based on the reduced-form elasticities. It is assumed that licensed seed companies reserve the right to extract a $20 per bag technology fee from HOC farmers to procure use of the innovation.

Therefore, baseline data (Table 1) are compared with changes in prices and quantities after implementing a technology fee under scenario I. HOC grain quantities are reduced by approximately 311,000 bushels with prices increasing by an infinitesimal amount due to the assessed technology fee placed on HOC seed at the HOC elevator level. With higher prices, elevators substitute HOC for conventional corn, causing a higher volume of grain (43.8 million bushels) to be sold. As at the output level, substitution also occurs at the input level. At the HOC seed level, farmers move from purchasing about 390,000 million bushels to about 370,000 million bushels with minute changes in the price of HOC seed. With higher prices of HOC seed, farmers substitute 85,000 bushels of conventional seed for the displaced HOC seed.

Under scenario II—monopoly pricing—the price of HOC seed increases by \$9.50 per bag of seed, with quantity purchased decreasing by 53,000 units. Farmers substitute conventional seed for the displaced HOC seed, increasing their purchases of conventional seed by 169,000 units. Quantities of HOC grain are reduced by 553,000 bushels due to assessed technology fees and monopoly power at the HOC seed level. The HOC grain price at the elevator level increases by \$0.01, thus increasing producer premiums from \$0.20 to \$0.21 per bushel. Substitution effects from the increase in price at the elevator level cause elevators to choose 77.94 million bushels more conventional grain with a \$0.05 change in the price of conventional grain.

Welfare Effects

There are two concerns in evaluating welfare effects of technology fee and monopolistic power at the HOC level. The first involves the problem of double-counting welfare effects, and the second involves the vertical shift in the HOC seed curve due to an increase in both the assessed technology fee and monopolistic power. The second concern is measuring the shift in the supply curve at the HOC seed level considering the effects of the technology fee and monopoly power. With acknowledging these concerns, welfare impact is evaluated at the seed level with the following equations:

$$\Delta CS_H = -R_H H_H R_H^*(1 + 0.5H^*)\,, \qquad (13)$$

$$\Delta PS_H = R_H H(R_H^* - \gamma_H)(1 + 0.5H_H^*)\,, \text{ and} \qquad (14)$$

$$\Delta TS_H = \Delta CS_H + \Delta CPS_H\,, \qquad (15)$$

where γ_H represents the vertical shift of the HOC seed supply curve due to the imposition of a technology fee. Equations 13 and 14 represent the impacts on consumer and producer surplus due to the technology fee. Producer surplus in this case is the impact of a technology fee on HOC seed companies. The consumer surplus includes the impact of the technology fee on producers using conventional seed and consumers of HOC grain. That is, the effects of imposing a \$20 technology fee are to be evaluated. The imposition of a technology fee influences a shift in the HOC seed supply curve and affects consumers of HOC grain downstream and consumers of competing commodities such as conventional corn. Thus, the total effect of the technology fee includes the effect on the HOC consumer (elevator) sector, on the conventional seed sector, and on the HOC seed sector.

Table 3 shows the distributional impacts for the two scenarios. Scenario I (technology fee in a competitive market) is compared to the baseline data given in Table 1, whereas in scenario II, the effects of monopoly power are compared to scenario I. In scenario II, welfare effects on farmers purchasing high-oil seed are measured by utilizing Equations 13 and 15 under monopoly power.[4]

Under scenario I, the HOC seed industry surplus increases by \$1.7 million due to the technology fee of \$20 per bag. HOC consumers suffer a loss of \$11.3 million. Substitution at the seed level causes the conventional corn seed sector to capture an additional \$10.2 million. The total welfare loss from the technology fee is \$10.3 million—less than 0.1% of the value of corn production. Likewise, the effects from the additional imposition of monopoly power are relatively small. Under scenario II, HOC consumers experience a loss of \$12.6 million, HOC seed firms and HOC farmers lose, and conventional corn seed producers gain. The total net effect of scenario II is estimated to be a loss of \$16.2 million.

Table 4 shows the sensitivity of welfare measures to conventional corn supply and factor substitution. As we move from initial supply and factor substitution elasticities, welfare measures can be evaluated at various elasticities. Therefore, four simulations are conducted that deviate from the initial elasticities to evaluate effects of technology fees and monopoly power. The first simulation presents welfare measures based on the initial elas-

4. *Monopoly power is imposed on the model by setting the input conjectural elasticity (θ) equal to 1.0.*

Table 3. Distributional impacts of a technology fee and of monopoly power, US high-oil corn industry, 1999 (in million $).

Item	Scenario I: effect of technology fee (compared to baseline)	Scenario II: effect of monopoly power (compared to scenario I)
HOC consumers (ΔCS_Q)	-11.25	-12.62
HOC seed firms (ΔPS_H)	1.69	-0.21
Conv. corn seed firms (ΔPS_C)	10.20	10.13
HOC farmers (ΔCS_H)	-1.05	-3.55
Conv. corn farmers (ΔCS_C)	-9.90	-9.90
Total effect (ΔTS)	-10.31	-16.15

Table 4. Sensitivity of welfare measures to factor substitution elasticity and conventional corn supply elasticity, US high-oil corn industry, 1999 (in million $).

Item	Scenario I: effect of technology fee (compared to baseline)	Scenario II: effect of monopoly power (compared to scenario I)
Simulation 1: σ = 1.0, ε_C = 0.5		
HOC consumers (ΔCS_Q)	-11.25	-12.62
HOC seed firms (ΔPS_H)	1.69	-0.21
Conv. corn seed firms (ΔPS_C)	10.20	10.13
HOC farmers (ΔCS_H)	-1.05	-3.55
Conv. corn farmers (ΔCS_C)	-9.90	-9.90
Total effect (ΔTS)	-10.31	-16.15
Simulation 2: σ = 0.1, ε_C = 0.5		
HOC consumers (ΔCS_Q)	-13.82	-32.52
HOC seed firms (ΔPS_H)	0.42	-1.03
Conv. corn seed firms (ΔPS_C)	11.44	30.81
HOC farmers (ΔCS_H)	-2.38	-4.08
Conv. corn farmers (ΔCS_C)	-11.34	-29.77
Total effect (ΔTS)	-15.69	-36.58
Simulation 3: σ = 1.0, ε_C = 0.1		
HOC consumers (ΔCS_Q)	-13.80	-15.37
HOC seed firms (ΔPS_H)	1.66	-0.25
Conv. corn seed firms (ΔPS_C)	12.73	12.91
HOC farmers (ΔCS_H)	-1.07	-3.53
Conv. corn farmers (ΔCS_C)	-12.37	-12.64
Total effect (ΔTS)	-12.86	-18.88
Simulation 4: σ = 0.1, ε_C = 0.1		
HOC consumers (ΔCS_Q)	-19.32	-38.13
HOC seed firms (ΔPS_H)	0.40	-1.23
Conv. corn seed firms (ΔPS_C)	16.92	36.61
HOC farmers (ΔCS_H)	-2.40	-3.92
Conv. corn farmers (ΔCS_C)	-16.80	-35.61
Total effect (ΔTS)	-21.19	-42.28

ticities as presented in Table 3. The second simulation assumes that the factor of substitution elasticity is 0.1, implying a relatively low level of substitution between HOC seed and conventional seed; however, the conventional corn supply elasticity is held at 0.5, a relatively inelastic supply curve. Assessing technology fees at the HOC seed level increases welfare to HOC seed firms and conventional seed firms by $420,000 and $11.44 million, respectively. By implementing monopoly power in comparison to only a technology fee, the rents distributed to HOC seed firms decline by $1.03 million. The total net effects of scenarios I and II is estimated to be a loss of $15.69 million and an additional $36.58 million, respectively. The results from simulations 3 and 4 illustrate that the more factor substitution and the less elastic conventional corn supply become, the greater the loss in terms of total net effects under both scenarios.

Table 5 shows the sensitivity of welfare measures to conventional corn supply elasticity and elevator demand elasticity. The first simulation presents welfare measures based on the initial elasticities as presented in Table 3. The second simulation shows a more elastic conventional corn seed supply curve, where elevator demand elasticity remains the same. The impacts of welfare measures at the HOC consumer level show a loss of $9.2 million and an additional $10.51 million under scenarios I and II, respectively. HOC seed firms and conventional corn seed firms gain $1.71 million and $8.17 million, respectively. Rents are substantially lost by HOC consumers, as demand becomes less elastic in simulation 3. Simulation 3 illustrates that with inelastic conventional corn supply and HOC demand, total net effects of scenarios I and II result in losses of $56.38 million and an additional $25.32 million, respectively. Overall, HOC seed and conventional corn seed firms gain rents, whereas HOC farmers experience losses in all simulations.

Conclusions

The intent of this study was to examine the experience and economic incentives for future growth of VECs in the United States. The objective was to determine

Table 5. Sensitivity of welfare measures to conventional corn supply elasticity and demand elasticity, US high-oil corn industry, 1999 (in million $).

Item	Scenario I: effect of technology fee (compared to baseline)	Scenario II: effect of monopoly power (compared to scenario I)
Simulation 1: $\varepsilon_C = 0.5$, $\eta_{HC} = 0.5$		
HOC consumers (ΔCS_Q)	-11.25	-12.62
HOC seed firms (ΔPS_H)	1.69	-0.21
Conv. corn seed firms (ΔPS_C)	10.20	10.13
HOC farmers (ΔCS_H)	-1.05	-3.55
Conv. corn farmers (ΔCS_C)	-9.90	-9.90
Total effect (ΔTS)	-10.31	-16.15
Simulation 2: $\varepsilon_C = 1.0$, $\eta_{HC} = 0.5$		
HOC consumers (ΔCS_Q)	-9.20	-10.51
HOC seed firms (ΔPS_H)	1.71	-0.17
Conv. corn seed firms (ΔPS_C)	8.17	7.98
HOC farmers (ΔCS_H)	-1.03	-3.56
Conv. corn farmers (ΔCS_C)	-7.92	-7.79
Total effect (ΔTS)	-8.27	-14.05
Simulation 3: $\varepsilon_C = 0.5$, $\eta_{HC} = 0.1$		
HOC consumers (ΔCS_Q)	-57.81	-21.53
HOC seed firms (ΔPS_H)	1.26	-0.69
Conv. corn seed firms (ΔPS_C)	56.31	19.53
HOC farmers (ΔCS_H)	-1.50	-3.50
Conv. corn farmers (ΔCS_C)	-54.65	-19.12
Total effect (ΔTS)	-56.38	-25.32
Simulation 4: $\varepsilon_C = 1.0$, $\eta_{HC} = 0.1$		
HOC consumers (ΔCS_Q)	-12.66	-9.98
HOC seed firms (ΔPS_H)	1.68	-0.20
Conv. corn seed firms (ΔPS_C)	11.59	7.48
HOC farmers (ΔCS_H)	-1.06	-3.56
Conv. corn farmers (ΔCS_C)	-11.23	-7.33
Total effect (ΔTS)	-11.68	-13.58

whether incentives exist for farmers to adopt and for industry to invest in R&D for transgenic and nontransgenic VECs. A Muth-type model was used to simulate benefit distribution under several plausible elasticity and technological parameter assumptions. A VEC developed through conventional plant breeding—high-oil corn—was used as a case study because of the absence of transgenic VECs with significant diffusion at present. Based on the welfare measures (presented in Table 3), HOC seed suppliers gain $1.7 million and conventional seed suppliers gain an additional $10.2 million. The distributional impacts of a technology fee on farmers show a loss of $1 million and of an additional $3.5 million welfare reduction due to monopoly power. Sensitivity analysis of the welfare measures to conventional supply elasticity, factor of substitution elasticity, and elevator demand elasticity reveal that the larger the factor substitution and the less elastic conventional corn supply become, the greater the total welfare loss.

Based on our analysis, we do not expect to see a significant level of adoption of VECs in the near future. Although seed companies may be willing to accept a relatively low seed premium in order to gain market share, it still appears that it will be difficult for large enough grain premiums to appear for VECs to provide farmers the necessary incentive to adopt. If farmers do not receive VEC price premiums at the elevator, they will continue to produce conventionally bred commodity varieties.

At least three major challenges face the industry as it tries to replicate the rapid market growth that has characterized first generation GMOs. First, genetically modified VECs must offer large per-acre profits compared to alternative crops. The VEC product will have to generate significant price premiums for farmers due to yield drag. Second, the adoption of VEC GMOs may also be slower than for input trait GMOs, because they introduce uncertainty into the production process, as it will take time for farmers to form yield expectations, thus increasing subjective production risk. Finally, it will take time, coordination, effort, and investment for the appropriate marketing arrangements to evolve. These transaction costs will require that some of the surplus created by VEC innovations be shared downstream in the marketing chain, making it more difficult to pay farmers a significant adoption premium.

References

Alleman, J., Madden, G., & Savage, S. (2003). Dominant carrier market power in U.S. international telephone markets. *Applied Economics*, *35*(6), 665-673.

Applelbaum, E. (1982). The estimation of the degree of oligopoly power. *Journal of Econometrics*, *19*, 287-299.

Bhuyan, S. & Lopez, R.A. (1997). Oligopoly power in the food and tobacco industries. *American Journal of Agricultural Economics*, *79*(3), 1035-1044.

Boland, M., Domine, M., Dhuyvetter, K., & Herrman, T. (1999). *Economic issues with value-enhanced corn.* Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

James, J.S., & Alston, J.M. (2002). Taxes and quality: A market-level analysis. *Australian Journal of Agricultural & Resource Economics*, *46*(3), 417-445.

Kinnucan, H.W. (2003). Optimal generic advertising in an imperfectly competitive food industry with variable proportions. *Agricultural Economics*, *29*(2), 143-158.

Kinnucan, H.W., & Paudel, L. (2001). Upstream effects of generic advertising: The case of catfish. *Marine Resource Economics*, *16*(2), 83-107.

Lerner, A.P. (1934). The concept of monopoly and the measurement of monopoly power. *Review of Economic Studies*, *29*, 291-299.

Lopez, R.A., & You, Z. (1993). Determinants of oligopsony power: The Haitian coffee case. *Journal of Development Economics*, *41*(2), 275-284.

Muth, R.F. (1964). The derived demand curve for a productive factor and the industry supply curve. *Oxford Economic Papers*, *16*(2), 221-34.

Penn, J.B. (2000). Biotechnology in the pipeline: Sparks companies' update. *Proceedings of the 2000 Beltwide Cotton Conference*. Memphis, TN: National Cotton Council.

United States Department of Agriculture Animal and Plant Health Inspection Service. (1997). *Biotechnology permits: 7 code of federal regulations part 340*. Washington, DC: USDA. Available on the World Wide Web: http://www.aphis.usda.gov/brs/7cfr340.html.

United States Department of Agriculture Economic Research Service. (1999). Value-enhanced crops: Biotechnology's next stage. *Agricultural Outlook*, March 1999.

United States Department of Agriculture Economic Research Service. (2005). *Data: Commodity costs & returns* [database]. Washington, DC: USDA. Available on the World Wide Web: http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm.

United States Department of Agriculture World Agricultural Outlook Board. (2000). *World agricultural supply and demand estimates (WASDE-BB)* [database]. Washington, DC: USDA. Available on the World Wide Web: http://jan.mannlib.cornell.edu/usda/reports/waobr/wasde-bb.

United States Grains Council. (2001). *The 2000–2001 value-enhanced grains quality report*. Washington, DC: Author. Available on the World Wide Web: http://www.vegrains.org.

United States Grains Council. (2002). *The 2001–2002 value-enhanced grains quality report*. Washington, DC: Author. Available on the World Wide Web: http://www.vegrains.org.

Wohlgenant, M.K. (1993). Distribution of gains from research and promotion in multi-stage production systems: The case of the U.S. beef and pork industries. *American Journal of Agricultural Economics*, *75*(3), 642-651.

Zhang, M., & Sexton, R. (2002). Optimal commodity promotion when downstream markets are imperfectly competitive. *American Journal of Agricultural Economics*, *84*(2), 352-65.