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Segregation of Grain Markets: Consequences for Price Behavior

Kevin McNew and Vincent H. Smith

The introduction of genetically modified grain and oilseed products at the farm level and resistance for these products by consumer groups have led to segmentation in grain markets. This study explores the implications for market price behavior for a segregated soybean market for genetically modified (GM) and non-GM varieties. A stochastic dynamic simulation model of production and storage is solved, and Monte Carlo simulation procedures are used to examine price behavior between GM and non-GM soybeans. The results suggest important differences in price behavior between GM and non-GM soybeans. The results obtained in the model simulations are compared with evidence from the Tokyo Grain Exchange, where non-GM and GM soybean futures contracts have traded simultaneously since May 2000. The evidence from the Tokyo Grain Exchange contracts is largely consistent with the results of the simulation model. Price correlations between the Tokyo Grain Exchange non-GM and GM soybean contracts tended to be similar in magnitude to those found in the simulations.

Key words: genetically modified organisms, soybeans, storage

Introduction

Genetic engineering of crops represents a substantial breakthrough in agricultural technology. In the United States, the most widely used applications of this technology are BT Corn and Roundup Ready® Soybeans, first introduced in 1995. These first-generation transgenic crops are designed to lower farm production costs by reducing input costs and, as a result, have been rapidly adopted by U.S. farmers. In 1996, for example, less than 10% of the total areas planted to corn and soybeans in the United States consisted of genetically modified (GM) varieties. By 2002, over 35% of U.S. corn acreage and 75% of U.S. soybean acreage were planted to GM crops.

While many U.S. farmers have embraced this technology, many consumers have been more skeptical because of perceived health and environmental risks. Consumer and environmental groups in the European Union and Japan, both of which are major buyers of U.S. grain commodities, have been especially vocal about these concerns. As a result, some foreign food manufacturers have decided not to accept GM crops altogether, others have developed plans to institute labeling programs, and some foreign governments have introduced regulations requiring labeling and, in some cases, product segregation for GM products.[1]

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[1] To the extent that consumers with preferences for non-GM products also purchase organic products, evidence from empirical studies of the demand for organic products such as organic milk may be relevant. Recent research suggests some U.S. consumers are willing to pay premiums for these products, but own-price elasticities of demand are larger than for competing non-organic products (Glaser and Thompson).

The short-run reaction by participants in the U.S. grain market has been to segregate commodities by GM and non-GM varieties. A 1999 survey found that 11% of all Midwest grain elevators were segregating corn and 8% were segregating soybeans, with more elevators expected to segregate in the future [U.S. Department of Agriculture, Economic Research Service (USDA/ERS) 2000a]. As a result of segregation, price differences have begun to emerge with non-GM crops at a premium to GM crops. However, only limited anecdotal evidence is available on the size of these premiums, and there is even less information about how these premiums will behave in the future. In addition, the U.S. markets for GM and non-GM commodities are relatively unsophisticated, consisting of spot cash exchanges and contracts for delivery, but no futures or options contracts. For soybeans, however, GM and non-GM soybean futures contracts have been available on the Tokyo Grain Exchange since 2000.

Most previous research on GM issues has been related to welfare effects and the distribution of benefits (Moschini, Lapan, and Sobolvesky; Kalaitzandonakes) as well as consumer issues such as food safety and labeling (Caswell 1998, 2000; Caswell and Mojduszka; Hobbs and Plunkett; McCluskey; Feldman, Morris, and Harrington). This study explores issues concerning how segregated U.S. grain markets for GM and non-GM soybeans are likely to behave. Segregation does not just separate production and demand along GM and non-GM lines. It also requires that inventories, a key element in determining price behavior in grain markets, be segregated as well.

In addition, because demands for GM and non-GM products may differ with respect to price elasticities and demand variability, such differences may have important effects on the storage function in each market, and therefore on relative price behavior for GM and non-GM commodities. One important issue is whether segregated markets result in greater price instability. A second concern is what will be the long-run average level and the volatility of the price spread between GM and non-GM crops. If the price spread is unstable, separate forward pricing markets for GM and non-GM products may become both viable and, from an economic welfare perspective, desirable.

In this study, these issues are investigated in the context of a dynamic model of the markets for two commodities (GM and non-GM varieties of the same crop, soybeans) that are linked through constraints on production and storage and face stochastic demands. Simulations of market price behavior under alternative assumptions about the segregation of the market for soybeans reveal that price differences between GM and non-GM varieties reflect differences in production costs but are sufficiently volatile to suggest that separate futures markets may emerge. Comparisons of the simulation results with the actual performance of futures contracts for GM and non-GM soybeans on the Tokyo Grain Exchange indicate that correlations between GM and non-GM soybean prices obtained from the simulation model are consistent with actual market behavior.

A Market Model of Variety Segregation

Price behavior in grain markets is a function of several important attributes, including a significant time lag between planting and harvesting, uncertainty about yields and prices at harvest time, and the ability of market participants to store the commodity from one year to the next. These characteristics also exist when the market is segregated by sub-commodity groups such as GM and non-GM soybeans, although subtle differences arise.

First, in a segregated market, farmers must now decide whether to produce GM or non-GM crops, and in what amounts, with an eye to differences in the expected harvest prices for each variety and differences in per unit production costs. Second, in a non-segregated market, demand is aggregated across both varieties, but in a segregated market, the demands are disaggregated by GM and non-GM varieties. Moreover, in the segregated market, the demand functions for the GM and non-GM varieties are likely to have different price elasticities and stochastic properties. As a consequence, not only must separate stockpiles of GM and non-GM crops be maintained, but also storage behavior may be inherently different and result in distinct behavior for the price of GM and non-GM crops.

The model presented in this section is similar in approach to the work of Williams and Wright on competitive storage which has been used in other applications by Miranda and Glauber (1993, 1995); Makki, Tweeten, and Miranda; and McNew and Gardner. An important difference here is that the model accounts for two distinct but related commodities (GM and non-GM crops) for which the separate demands may have different elasticities and stochastic properties.

More formally, suppose the farm-level demand for GM and non-GM crops in year t can be represented as:

$$(1) \qquad P_t^i = d^i(D_t^i) + e_t^i, \quad \text{for } i = g, n,$$

where D is quantity demanded, P is price, and e represents a zero-mean random shock. The random shocks e^g and e^n are independent with potentially different variances. The indices g and n refer to GM and non-GM, respectively. Equation (1) defines the farm-level demand functions, but price behavior is determined through the interplay of production decisions, random shocks, and inventories as described below.

On the supply side of the model, production of each crop variety is assumed to occur once a year. We assume the total area planted to soybeans is fixed at $\bar{A}$ with farmers deciding each year the relative acreage of each variety to plant, such that:

$$(2) \qquad \bar{A} = A_t^g + A_t^n,$$

where A_t^g and A_t^n are, respectively, the acreages planted to GM and non-GM crops in year t.

Crops planted in year t are assumed to be harvested the following year, $t+1$, with a random yield, Y_{t+1}, which for purposes of convenience is assumed to be identical for GM and non-GM crops. Farmers' production costs are assumed to be identical across producers for each variety and vary only with respect to the variety planted; that is, GM and non-GM varieties have different per acre production costs. Specifically, we assume the per acre total cost of producing a non-GM variety is a constant, c, and the per acre total cost of producing a GM variety is $c-m$, where m is a positive constant; i.e., because yields are assumed to be identical, the GM variety is cheaper to produce. These assumptions imply that per acre total production costs for the entire crop (both GM and non-GM varieties) are equal to:

$$(3) \qquad TC = \frac{A_t^g}{\bar{A}}(c - m) + \frac{A_t^n}{\bar{A}}c = c - \frac{A_t^g}{\bar{A}}m.$$

If no GM crops are produced, then per acre total production costs would be c. However, the introduction of a lower-cost GM variety reduces production costs by the per acre cost savings (m) multiplied by the share of total acreage planted to the GM crop.

As a group, farmers are assumed to be risk-neutral and rational, so that acreage decisions are made on the basis of the expected price relative to the cost. The equilibrium condition for a representative farmer's soybean planting decision is written as:

$$E\left[P^g_{t+1}Y_{t+1}\right] - E\left[P^n_{t+1}Y_{t+1}\right] + m = 0, \quad A^g_t + A^n_t = \bar{A}. \tag{4}$$

This condition ensures that in a market equilibrium, the difference between the expected per acre revenues from the GM and non-GM varieties equals the difference in per acre costs.[2]

In period $t+1$, the market-level quantity of each crop available for sale or storage consists of new production and inventories carried over from period t. The market-clearing condition for GM and non-GM crops is therefore:

$$H^i_{t+1} + I^i_t = D^i_{t+1} + I^i_{t+1}, \quad \text{for } i = g, n, \tag{5}$$

where $H^i_{t+1} = Y_{t+1}A^i_t$ is period $t+1$ production, D^i_{t+1} is period $t+1$ quantity consumed, and I^i_t is the inventory carried from period t to period $t+1$.

Assuming physical storage costs are identical for GM and non-GM crops at a constant rate of k, and the nonstochastic interest rate is r, it follows that intertemporal arbitrage will ensure inventories satisfy the following equilibrium conditions:

$$\frac{E[P^i_{t+1}]}{1+r} - P^i_t - k \le 0, \quad I^i_t \ge 0, \quad \left[\frac{E[P^i_{t+1}]}{1+r} - P^i_t - k\right] I^i_t = 0, \quad \text{for } i = g, n. \tag{6}$$

The first condition is the usual intertemporal arbitrage condition that expected profits from storage are exhausted. The second condition assures nonnegative inventories. The third condition states that if stocks are carried, then the intertemporal arbitrage condition must be satisfied as an equality. If the arbitrage condition is negative, implying the current price exceeds the difference between the discounted value of the expected price next period less storage costs, then inventories are depleted (i.e., they are zero).

In addition to the intertemporal arbitrage condition, we also impose a cross-product arbitrage condition:

$$P^n_t - P^g_t \ge 0. \tag{7}$$

This condition arises from the assumption that the non-GM variety can be used to satisfy the demand for the GM variety, but not vice versa. As a result, the price spread between the non-GM and the GM variety cannot be negative.

The solution to this dynamic problem yields a functional expression for the controls in terms of the states. Here, there are two state variables, the total supply of the GM and non-GM crops, S^g_t and S^n_t. The controls are the inventory variables and the acreage decisions. Specifically, the functions are:

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[2] We abstract from total soybean acreage decisions as well as shifts in acreage among competing crops, such as corn. Such decisions likely have small impacts on our analysis of price behavior between GM and non-GM soybeans.

(8a) $$A_t^g = a(S_t^g, S_t^n), \quad A_t^n = \bar{A} - a(S_t^g, S_t^n),$$

(8b) $$I_t^g = i^g(S_t^g, S_t^n), \quad I_t^n = i^n(S_t^g, S_t^n),$$

(8c) $$S_t^i = I_{t-1}^i + Y_t A_t^i, \quad \text{for } i = g, n.$$

While the distributions for the yield and demand disturbances are imbedded in these solutions, there is no closed-form solution for the unknown functionals described above. Current storage decisions are affected by future storage decisions and, when combined with the nonnegativity constraint, this creates an equilibrium storage relationship that is analytically intractable. However, numerical solution techniques are available for solving this stochastic dynamic programming problem.

While analytical results cannot be obtained, the arbitrage conditions indicate the price spread between the two commodities will increase as the cost difference between the two commodities increases. In addition, it is likely that increases in the volatility of demand for each variety will increase the volatility of their relative prices and reduce the correlation between those prices. Differences in demand elasticities between the two varieties may also affect the volatility of their relative prices and the correlation between those prices. These potential relationships are examined through an empirical version of the above model which is based on the structure of the U.S. soybean market.

Parameter Estimates

Solving the stochastic dynamic programming model presented in the previous section requires estimates of market parameters, including elasticities of demand for GM and non-GM varieties of the crop, as well as the size of random shocks for yields and market demands. This section presents estimates of these parameters for the U.S. soybean market.

Segregation between GM and non-GM soybean varieties is a fairly recent event. Thus no adequate data are available on prices and quantities traded for GM and non-GM soybeans, precluding direct econometric estimation of disaggregated market demand parameters for GM and non-GM soybeans. To address this problem, we assume the demand for GM and non-GM products can be disaggregated into a domestic component representing the demand for GM varieties and an export component representing the demand for non-GM varieties.[3]

Some previous estimates of domestic and export demand elasticities are available in the literature. Gardiner and Dixit, for example, reported a point estimate of the aggregate export demand price elasticity for U.S. soybeans of −0.96, while Moschini, Lapan, and Sobolevsky estimate the domestic demand elasticity for soybeans to be −0.40. However, the export demand estimates presented by Gardiner and Dixit were obtained using data prior to the mid-1980s. Relatively recent changes in the world market for soybeans suggest these estimates may not accurately represent the current situation. In particular,

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[3] The assumption that export demand can be used as a proxy for the market demand for non-GM products produced in the United States stems from the fact that resistance to GM varieties is widespread in several major export markets, including the EU and Japan as well as some other markets like South Korea, Thailand, Indonesia, and Hong Kong which have announced plans to institute GM labeling regulations (USDA/ERS 2000b). Although some U.S. food manufacturers have turned to non-GM products, at this stage the bulk of the segregation seems to be occurring in the export market.

soybean production in South America expanded substantially in the late 1980s and 1990s. Thus, we utilize new econometric estimates of both domestic and export demands for soybeans using annual soybean data for the marketing years 1970 to 2000. Details of the econometric models, estimation methods, and results are presented in the appendix.

The econometric results presented in appendix table A1 show, for the period 1985–2000, the estimated own-price export demand elasticity (estimated to be -1.61) is much larger in absolute terms than the own-price elasticity estimate for the period 1970–1984 (-0.84). It is also larger in absolute terms than the estimate of -0.96 reported by Gardiner and Dixit. This finding is consistent with the hypothesis that the export elasticity for U.S. soybeans increased in the 1990s. The results also provide point estimates of the price elasticity for domestic soybean demand of -0.56 for the period 1970–1984 and -0.31 for the period 1985–2000. These estimates are quite similar to the estimate of -0.40 reported by Moschini, Lapan, and Sobolevsky.

The standard errors of the estimated domestic and export demand functions were also used to compute coefficients of variation for each estimated equation, which are estimated consistently with the price elasticity estimates reported in appendix table A1. These coefficients of variation are utilized to establish distributions from which demand shocks are drawn in the simulation models. Specifically, multiplying the estimated coefficient of variation for the domestic model and the export model by the average price over the sample gives a standard deviation estimate for the distribution of the demand shocks for each market. These standard deviation estimates are used to obtain domestic and export demand shocks that are assumed to be independent and normally distributed with zero means.

In the simulation model's supply side, GM and non-GM per acre yields are assumed to be identical and to be normally distributed with a mean of 38 bushels and a standard deviation of three bushels. These estimates are based on a trend-line linear regression of U.S. average soybean yields for 1985–2000, where the residuals are used to compute the standard deviation and mean yield is based on the expected yield for the year 2000.

Utilizing estimates reported by Marra, Carlson, and Hubbel, the cost savings associated with producing GM soybean varieties are assumed to be $6 per acre. Total U.S. soybean acreage is assumed to be fixed at 73 million acres, although, as discussed above, the mix between GM and non-GM crops is determined endogenously. Given the estimated parameters for the import and export demand functions, if the mean yield of 38 bushels per acre is realized on the total soybean area of 73 million acres, stocks remain constant, and the market for U.S. soybeans is not segregated between GM and non-GM varieties, then, in the absence of any shocks to aggregate demand (domestic or GM demand plus export or non-GM demand), the market will clear at an equilibrium price of $5.75 per bushel.

Finally, to complete the parameterizaton of the model, annual storage costs are assumed to be 12¢ per bushel, and the real interest rate is assumed to be 5%. The resulting empirical model is used to simulate market behavior over time. Results of the simulations are reported in the next section.

Simulation Results

Simulation methods are used to explore the implications of market segregation between GM and non-GM crops. As a means of comparison, several different simulations are used first to assess what the broad impact of market segregation should be, and second, to determine the sensitivity of the results to key parameters, including the size of demand shocks and price elasticities of demand.

In each scenario, the simulation procedure is as follows. First, the stochastic dynamic programming problem is solved numerically. The numerical solution provides decision rules for the stockpiling of GM and non-GM crops as well as for the allocation of land between the GM and non-GM crops. These decision rules change based on the state of nature, which in this case is represented by the total supplies of GM and non-GM crops in a given year.

Based on the numerical solution, a Monte Carlo simulation is then used to generate random shocks to yield and demands, and to generate equilibrium prices, stocks, and quantities. For each scenario, 1,000 replications are produced, and each replication consists of 300 observations where each observation represents one period in the model. The average values over the 1,000 replications for each simulation are reported in tables 1 and 2.[4]

In the initial simulation, we assume there is no segregation between GM and non-GM crops. In this case, aggregate demand is the sum of the export demand and domestic demand functions. No price difference exists between GM and non-GM soybeans. All acreage is utilized in the production of soybeans, and no distinction is made between GM and non-GM varieties.[5]

The second simulation assumes the market is segmented between GM and non-GM soybeans. Market demand for the GM variety is based on the domestic demand equation, while market demand for the non-GM variety is based on the export demand equation. Producers allocate the fixed total soybean acreage between the GM and non-GM crops.

The results of these two simulations (without segregation and with segregation) are reported in table 1. In the absence of variety segregation, the average soybean price is \$5.80 per bushel. When segregation is implemented, the price of non-GM soybeans increases to \$5.88 per bushel, while the price of GM soybeans decreases to \$5.58 per bushel. A spread between non-GM and GM soybeans of \$0.30 per bushel is reasonably consistent with anecdotal evidence of the spreads observed at the farm level. For example, Miranowski et al. report that non-GM soybeans have received premiums of between \$0.05 and \$0.35 per bushel.

It may seem curious that the non-GM price premium is larger than the cost of producing non-GM soybeans. The cost of producing non-GM soybeans, assuming an average yield of 38 bushels per acre and \$6 per acre higher cost, suggests a \$0.16 per bushel higher cost for non-GM soybean production. However, the acreage decision by an individual producer is based on expected net revenues, and therefore takes account of covariability between a producer's price and yield.

Specifically, the equilibrium condition for the farmer's planting decision is given by:

$$E\left[P_{t+1}^{g}Y_{t+1}\right] - E\left[P_{t+1}^{n}Y_{t+1}\right] + m = 0, \tag{9}$$

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[4] The numerical solution methods and simulations were conducted using code written in GAUSS (available upon request from the authors).

[5] Although the no-segregation simulation does not distinguish between GM and non-GM crops, if producers did have the opportunity to grow GM soybeans with no price discount, then all production would be GM because of the cost savings.

Table 1. Simulation Results With Segregation and Without Segregation of GM and Non-GM Soybeans

Variable	Without Segregation	With Segregation (SCENARIO 1)	
		GM	Non-GM
Price ($/bushel)	5.80 (0.053)	5.58 (0.052)	5.88 (0.053)
Std. Dev. of Price ($/bushel)	0.69 (0.032)	0.66 (0.035)	0.70 (0.031)
Stocks (mil. bushels)	90.8 (11.9)	41.6 (5.1)	76.4 (8.9)
Std. Dev. of Stocks (mil. bushels)	137.1 (13.7)	67.6 (5.2)	112.2 (7.2)
Acreage (%)		64.0 (0.001)	36.0 (0.001)
Correlation of Price		0.798 (0.029)	

Note: Standard errors are reported in parentheses.

where m is the cost savings of producing GM soybeans. This can be rewritten in terms of the expected price spread and the covariance of prices with yields as:

$$\text{(10)} \qquad \mathrm{Cov}\left[P_{t+1}^{g} Y_{t+1}\right] - \mathrm{Cov}\left[P_{t+1}^{n} Y_{t+1}\right] + E\left(P_{t+1}^{g} - P_{t+1}^{n}\right) E\left(Y_{t+1}\right) + m = 0.$$

If the covariance terms offset each other such that $\mathrm{Cov}[P_{t+1}^{g} Y_{t+1}] = \mathrm{Cov}[P_{t+1}^{n} Y_{t+1}]$, then the expected price spread, $E(P_{t+1}^{n} - P_{t+1}^{g})$, equals the expected cost per bushel, $m/(Y_{t+1})$. However, from our simulation, the term $\mathrm{Cov}[P_{t+1}^{g} Y_{t+1}] - \mathrm{Cov}[P_{t+1}^{n} Y_{t+1}]$ is positive, suggesting expected non-GM price must increase relative to the expected GM price to offset the covariances and maintain the acreage equilibrium condition.[6]

Another important point to note is that the non-GM premium varies from year to year and exhibits a substantial degree of variability. Figure 1, which shows a sample time path of prices for GM and non-GM soybeans, illustrates this point. Both price series have a tendency to move in the same direction, but the spread is not constant.[7] From the simulation results presented in table 1, the annual correlation coefficient between the GM and non-GM soybean prices is 0.798. Thus, although GM and non-GM prices have a *tendency* to move together, they are by no means perfectly correlated. Based on this finding, separate forward pricing markets may be required for GM and non-GM soybeans to provide adequate risk management protection.

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[6] The fact that producers account for covariability between price and yield has been illustrated by Williams and Wright (p. 34) in their discussion of a producer incentive price, which differs from the expected price in making planned output decisions under uncertainty.

[7] In figure 1, a few instances exist where non-GM prices and GM prices diverge substantially. These divergences occur because of the inability to substitute GM soybeans for non-GM soybeans in the non-GM market. Large negative demand shocks in the GM market and/or large positive demand shocks in the non-GM market can create relative shortages in the non-GM market.

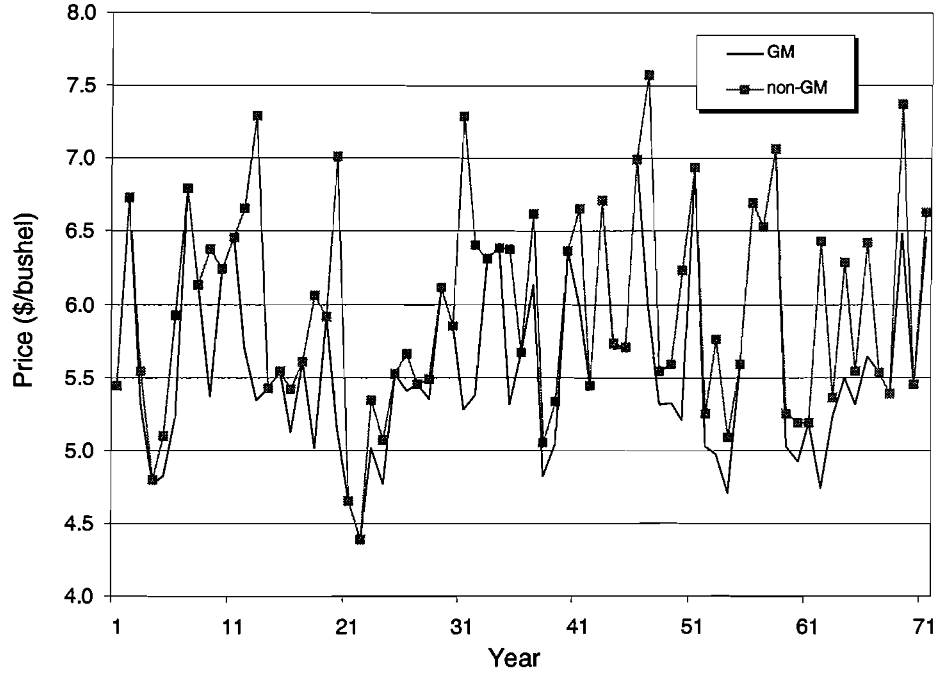

Figure 1. Simulated prices for GM and non-GM soybeans

Comparing the results for the two simulations reported in table 1 also illustrates that price variability is higher for non-GM soybeans and lower for GM soybeans when the market is segregated. On average, however, there is no substantial change in the overall variability of soybean prices in the segregation scenario (in which the standard deviations for the GM price and non-GM price are 0.66 and 0.70, respectively) as compared to the no-segregation scenario (where the standard deviation of the undifferentiated soybean price is 0.69). With segregation, in the aggregate more stocks are carried than when there is no segregation. Total stocks (GM and non-GM) average 118 million bushels in the segregation scenario and only 90.8 million bushels in the no-segregation scenario. This is a consequence of separating out the demand elasticities and demand shocks for the GM and non-GM markets. The own-price elasticity of demand is much larger in absolute value in the non-GM market than in the GM market.

However, the non-GM market also experiences much larger stochastic demand shocks. In the scenario for which results are reported in table 1, the larger demand shocks experienced in the non-GM market offset the price variability dampening effects which result from a more elastic demand function for non-GM varieties. Consequently, relatively large stocks of non-GM varieties are held.

A further issue is the nature and volatility of the price spread between non-GM and GM soybeans. The simulation results presented in figure 1 for the scenario reported in table 1 reveal that price spreads tend to be largest in years when prices are relatively low, and smallest in years when prices are relatively high. For example, when the per bushel price of GM soybeans is $5, the average price premium for non-GM soybeans is $0.30, but when the price of GM soybeans is $7, the average price premium for non-GM soybeans is only $0.05.

To assess the sensitivity of these results to changes in the parameters of the model, we conducted simulations of four additional scenarios (scenarios 2, 3, 4, and 5) in which the markets for GM and non-GM soybeans are segregated. Results for each of these scenarios are presented in table 2, and are compared with the initial market segregation scenario from table 1.

Scenario 2 assumes consumers are willing to pay a premium for non-GM soybeans if there is credible information to show the varieties are segregated. In scenario 2, this effect is represented by a permanent vertical shift in the non-GM demand function of $0.30 per bushel.

In scenario 3, demand shocks for both the GM and non-GM varieties are assumed to be identical. Specifically, we utilized the demand shock for the aggregate demand function as the demand shock for the GM and non-GM demand functions—i.e., the shocks to export demand and domestic demand are identical in each of the 1,000 replications for this scenario.

Scenario 4 utilizes demand parameter estimates from the 1970–1984 period. The GM demand from this time period is more elastic than the post-1985 period, while the non-GM demand is less elastic than in the baseline scenario. The elasticity estimates used for scenario 4 are -0.56 for GM demand and -0.84 for non-GM demand. Along with differing elasticities, the 1970–1984 period exhibits larger demand shocks than the baseline scenario. Finally, Scenario 5 considers the case of higher storage costs for non-GM soybeans as compared to GM soybeans.

In scenario 2, the permanent $0.30 per bushel vertical increase in the demand for non-GM varieties causes the average price for non-GM varieties to increase, but also induces an increase in the GM price. There is a modest acreage shift from GM to non-GM soybeans. As a result, the non-GM price premium only increases by $0.18 (from $0.30 in scenario 1 to $0.48 in scenario 2) even though the non-GM vertical demand shift is $0.30 per bushel. The degree of price correlation between GM and non-GM soybeans also increases from 0.798 to 0.858.

In scenario 3, in which export and domestic demand shocks for GM and non-GM varieties are assumed to be identical, the effect is to substantially reduce storage of non-GM soybeans and slightly increase storage of GM soybeans. The reason is that, in comparison to the baseline scenario, the average size of demand shocks in the non-GM market has decreased while the average size of demand shocks in the GM market has increased. The price spread, however, is largely unaffected by this change, although the prices of non-GM and GM varieties are slightly more correlated (the correlation coefficient is 0.822 in scenario 3 and 0.798 in scenario 1).

Scenario 4 considers the case when GM demand is more elastic and non-GM demand is less elastic. Both GM and non-GM demand have larger demand shocks. In this case, both prices increase slightly, but the price spread does not change substantially. Because of larger demand shocks in both the GM and non-GM markets, price volatility increases slightly and the correlation between the GM and non-GM prices decreases marginally as compared to the baseline of scenario 1.

The introduction of segregation along GM and non-GM variety lines is likely to lead to higher storage costs from testing, cleaning, and handling to assure the integrity of non-GM soybeans. Such costs would likely be borne by non-GM producers, although even storage costs for GM varieties may increase as the available supply of storage services is now split between GM and non-GM varieties.

Table 2. Simulation Results with Permanent Increase in Non-GM Demand, with Same Size Demand Shocks, and Changes in Elasticity of Demands

	Baseline Scenario (SCENARIO 1)		Permanent Increase in Non-GM Demand (SCENARIO 2)		Same Size Demand Shocks (SCENARIO 3)		Change in Demand Elasticities, 1970–1984 (SCENARIO 4)		Higher Non-GM Storage Costs (SCENARIO 5)	
Variable	GM	Non-GM	GM	Non-GM	GM	Non-GM	GM	Non-GM	GM	Non-GM
Average Price ($/bu.)	5.58 (0.052)	5.88 (0.053)	5.67 (0.050)	6.15 (0.054)	5.57 (0.048)	5.88 (0.040)	5.67 (0.055)	5.92 (0.065)	5.58 (0.053)	5.87 (0.055)
Avg. Std. Dev. of Price ($/bu.)	0.66 (0.035)	0.70 (0.031)	0.63 (0.037)	0.70 (0.032)	0.63 (0.029)	0.53 (0.023)	0.70 (0.036)	0.84 (0.042)	0.68 (0.037)	0.73 (0.031)
Average Stocks (mil. bu.)	41.6 (5.1)	76.4 (8.9)	40.4 (4.9)	75.4 (9.2)	48.9 (5.5)	27.7 (3.9)	35.4 (5.4)	76.5 (8.7)	41.2 (4.9)	64.4 (8.6)
Avg. Std. Dev. of Stocks (mil. bu.)	67.6 (5.2)	112.2 (7.2)	66.3 (5.1)	111.9 (7.7)	73.7 (4.6)	53.3 (5.3)	67.8 (6.2)	107.1 (7.0)	67.5 (4.9)	104.3 (7.8)
Average Acreage (%)	64.0 (0.001)	36.0 (0.001)	63.4 (0.001)	36.6 (0.001)	64.4 (0.001)	35.6 (0.001)	63.7 (0.001)	36.3 (0.001)	64.0 (0.001)	36.0 (0.001)
Correlation of Price	0.798 (0.029)		0.858 (0.025)		0.822 (0.027)		0.779 (0.034)		0.794 (0.032)	

Notes: Values reported for prices, stocks, and their standard deviations are averages based on 1,000 replications. Standard errors are reported in parentheses.

We consider the extreme case of storage costs increasing by 50% (from 1¢ per month to 1.5¢ per month) in only the non-GM market, while GM storage costs remain the same at 1¢ per month in the GM market. These results are presented as scenario 5 in table 2. As expected, higher non-GM storage costs lead to lower non-GM inventories and more price variability. The GM variety is indirectly affected as well by higher non-GM storage costs as inventories decline slightly and price variability increases slightly. This result is due to the substitution possibilities between GM and non-GM varieties in cases of extreme high prices.

These general findings suggest that the price spread between GM and non-GM soybeans is not constant, and that a plausible range for the correlation coefficient between the GM and non-GM prices is 0.80 to 0.85. Thus, although market prices for GM and non-GM varieties are still reasonably correlated, movements in those prices may be sufficiently dissimilar to warrant separate forward pricing markets for GM and non-GM soybeans. We turn now to an investigation of the Tokyo Grain Exchange where separate contracts for GM and non-GM soybeans have been traded since May 2000.

Evidence from the Tokyo Grain Exchange

The Tokyo Grain Exchange (TGE) is a commodity futures market that trades corn, soybeans, azuki beans, arabica coffee, robusta coffee, and raw sugar. The soybean futures contract is a 30,000-kilogram (1,100 bushels) contract, which can be settled by physical delivery with warehouse receipts for designated facilities in Tokyo, Kanagawa, Chiba, and Saitama. A unique feature of this contract is that the soybeans must be of U.S. origin.

In May of 2000, the TGE introduced a non-GM soybean futures contract and changed the existing soybean futures contract to be delivered with GM or mixture of GM and non-GM soybeans. Like the standard soybean contract, the non-GM contract calls for delivery of U.S.-origin soybeans to approved warehouse facilities in Tokyo, Kanagawa, Chiba, and Saitama. The one subtle difference between the two contracts is their size; the non-GM contract is for 10,000 kilograms (360 bushels) as compared to the 30,000-kilogram standard soybean contract.

Since its inception in May of 2000, trading activity in the non-GM soybean contract has been robust by most measures. By September 2001, 40% of all trading volume and 47% of all open contracts for soybeans have been for non-GM soybeans on a kilogram basis. Thus, based on trading activity, it would appear there is significant demand by commercial users for pricing non-GM soybeans.[8]

To explore the correlation between GM and non-GM futures prices, we collected daily closing price data from the TGE website from May 2000 to September 17, 2001. Prices for all contracts from the GM and non-GM futures market, which are reported in yen per 1,000 kilograms, were converted into a U.S. measure of dollars per bushel using the spot rate for the Japanese yen and the U.S. dollar. Figure 2 shows the nearby contract prices for GM and non-GM soybean futures for the period November 2000 to September 2001.

As observed from figure 2, although the contract prices for the two commodities tend to move together, the spread between them shows a tendency to narrow or widen quite

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[8] Holbrook Working, in 1954, was one of the first to point out that futures markets are vehicles for hedging and that a futures market will only be viable if tailored to the needs of commercial users.

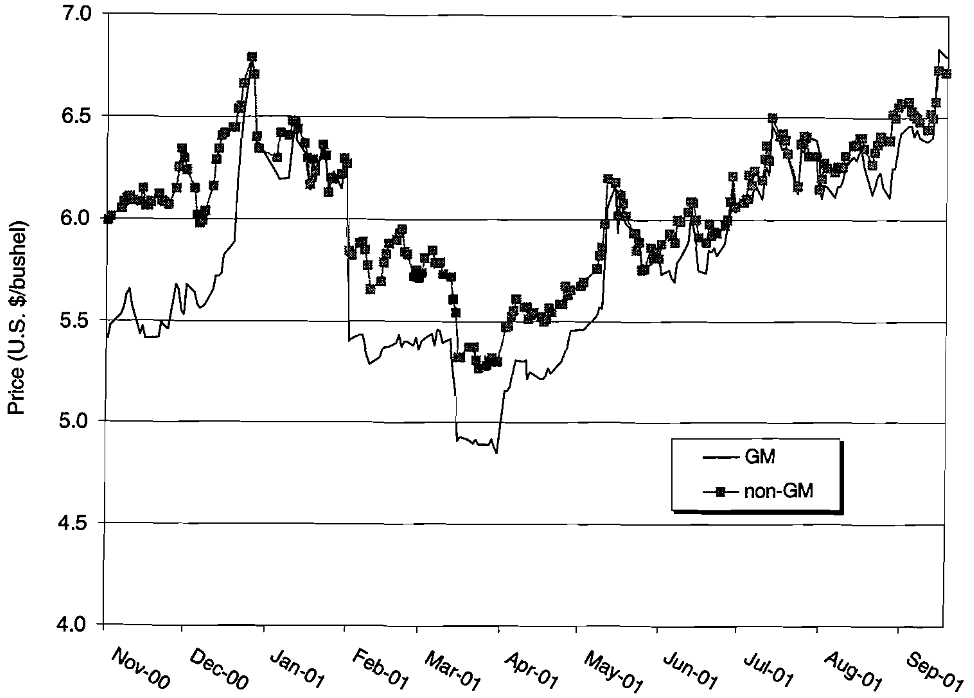

Figure 2. Tokyo Grain Exchange nearby soybean futures prices, in U.S. dollars

significantly over this time period.[9] For the entire sample, the correlation between the two prices is 0.903. Within this short time period, the premium for non-GM soybeans appears to decrease (increase) as the overall soybean price level increases (decreases). This is consistent with the findings reported in the simulations where higher prices were associated with a smaller spread between non-GM and GM soybeans.

Table 3 shows the correlation between the Tokyo Grain Exchange GM and non-GM soybean futures contract prices for different delivery months. The five contracts that have expired demonstrate a wide range of correlation estimates, from 0.65 to 0.95, with an average of 0.81 for all contracts over the sample. These correlation estimates are also reasonably consistent with the simulation results (as shown in table 2) where the range of correlations is from 0.80 to 0.85.

Conclusions

As grain markets move from homogeneous to heterogeneous products, it is important to understand how pricing behavior will change. In this study, we have explored the implications for market price behaviors of market segregation between GM and non-GM soybeans using a stochastic dynamic simulation model similar in approach to a competitive storage model developed by Williams and Wright for a single commodity. As there are no closed-form solutions for the unknown functionals, the stochastic model is solved

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[9] Parcell found similar patterns based on an earlier subset of these data from May 2000 to December 2000.

Table 3. Correlation Between Non-GM and GM Soybean Futures Prices by Contract at the Tokyo Grain Exchange

Contract	Correlation of Futures Prices	No. of Observations
December 2000	0.651	150
February 2001	0.835	190
April 2001	0.950	223
June 2001	0.780	257
August 2001	0.835	262
Average for expired contracts	0.810	

numerically for each set of model parameters. Monte Carlo simulations were utilized to examine the impacts of random shocks on both yields and market demands to characterize price behaviors in different market settings. These market settings included the baseline situation in which the markets for GM and non-GM soybeans are not segregated, and alternative scenarios where GM and non-GM soybeans are segregated.

The demand side of the model was parameterized by assuming the export market for U.S.-produced soybeans represents the demand for non-GM soybeans while the U.S. domestic market represents the demand for GM soybeans, and then estimating econometric models of these separate demands. One important finding is that while the estimated own-price elasticity of demand for the domestic market obtained in this study (-0.31) is relatively small and quite similar to previously reported estimates, the estimated own-price elasticity of export demand (-1.61) is substantially larger than a previously reported estimate by Gardiner and Dixit (-0.96). The difference in these estimates can probably be attributed to important changes in the soybean export market as a result of expanded production in South America in the 1990s, which are accounted for in the data used in this study. The econometric results also indicate that the estimated standard error for the export demand function is larger than for the domestic demand function. Jointly, these empirical findings imply that the demand for non-GM soybeans is more price-elastic and more volatile than the demand for GM soybeans—a result having important implications for price behavior when the two markets are segregated.

The simulation results provide new insights about potential price behaviors for GM and non-GM commodities.

- First, not surprisingly given that production costs for GM soybeans are assumed to be lower, over time the introduction of market segregation results in a lower average price for GM soybeans ($5.58 per bushel) and a higher price for non-GM soybeans ($5.88 per bushel) than when the market is not segregated ($5.80 per bushel).

- Second, the results also indicate GM and non-GM prices are not separated by a constant premium for non-GM soybeans equal simply to the difference in per unit production costs. Instead, the price spread tends to vary significantly from year to year depending on market forces. It is worth noting that the range of the price spreads estimated in the Monte Carlo simulations is quite similar to premiums actually observed at the farm level in the United States (Miranowski et al.). In addition, in the simulations for alternative segregated market scenarios, the estimated correlation between the prices of non-GM and GM soybeans is relatively high, between 0.798 and 0.858, but not equal to one. This finding suggests there is the potential for separate futures markets for non-GM and GM soybeans. The estimated correlations are quite similar to those actually observed between prices for commodities such as spring wheat and winter wheat, for which separate futures markets currently exist.

- Third, the average price spread between non-GM and GM soybeans was almost twice as large as the difference in unit production costs between non-GM and GM soybeans. This is because the negative covariance of prices and yields resulting from both yield and demand shocks is larger in absolute terms for non-GM soybeans than for GM soybeans. A sensitivity analysis revealed that even when demand shocks in the non-GM (export) market and the GM (domestic) market were assumed to be similar, the estimated average price spread was largely unaffected.

- Fourth, the simulation results suggest market segregation will result in substantial increases in stockholding with commensurate increases in storage costs. In the absence of segregation, the average annual amount of total combined stock holdings of both GM and non-GM soybeans is 90.8 million bushels. When market segregation is introduced, total stock holdings of both non-GM and GM stocks increase by 30% to an annual average of 118 million bushels. The increase in stock holding occurs largely because of increased holdings of non-GM stocks in response to larger demand shocks associated with the (now segregated) export market. The results obtained in the model simulations were compared with evidence from the Tokyo Grain Exchange, where non-GM and GM soybean futures contracts have traded simultaneously since May 2000. The evidence from the Tokyo Grain Exchange contracts is largely consistent with the results of the simulation model. Price correlations between the Tokyo Grain Exchange non-GM and GM soybean contracts tended to be similar in magnitude to those found in our simulations. In addition, both the correlations and spreads between prices appear to change rather dramatically over the short time period examined.

The evidence from this study indicates that the price behaviors of GM and non-GM soybeans exhibit important differences. Moreover, this is also likely to be the case for other commodities such as corn and wheat, for which GM varieties are currently or will shortly be available. Market participants, many of whom operate in competitive markets, will need information on both GM and non-GM prices as well as other market information, such as production and inventories, to make optimal production and marketing decisions. An important issue for policy makers is therefore the allocation of resources to provide publicly available data on these markets.

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References

Caswell, J. A. "Should Use of Genetically Modified Organisms Be Labeled?" *AgBioForum* 1(1998): 22–44.

———. "An Evaluation of Risk Analysis as Applied to Agricultural Biotechnology (With a Case Study of GMO Labeling)." *Agribus.: An Internat. J.* 16(2000):115–23.

Caswell, J. A., and E. M. Mojduszka. "Using Informal Labeling to Influence the Market for Quality in Food Products." *Amer. J. Agr. Econ.* 78(1996):1246–53.

Feldman, M. P., M. L. Morris, and D. Harrington. "Genetically Modified Organisms: Why All the Controversy?" *Choices* (1st Quarter 2000):8–12.

Gardiner, W. H., and P. M. Dixit. "Price Elasticity of Export Demand: Concepts and Estimates." Foreign Agr. Econ. Report No. 228, U.S. Department of Agriculture, Economic Research Service, Washington, DC, February 1987.

Glaser, L. W., and G. D. Thompson. "Demand for Organic and Conventional Beverage Milk." Paper presented at the Western Agricultural Economics Association annual meetings, Vancouver, British Columbia, June 29–July1, 2000.

Haniotis, T., J. Baffes, and G. C. Ames. "The Demand and Supply of U.S. Agricultural Exports: The Case of Wheat, Corn, and Soybeans." *S. J. Agr. Econ.* 20,2(1988):45–55.

Hobbs, J. E., and M. D. Plunkett. "Genetically Modified Foods: Consumer Issues and the Role of Information Asymmetry." *Can. J. Agr. Econ.* 47(1999):445–55.

Kalaitzandonakes, N. "A Farm-Level Perspective on Agrobiotechnology: How Much Value and for Whom?" *AgBioForum* 2(Spring 1999):61–64.

Makki, S. S., L. G. Tweeten, and M. J. Miranda. "Wheat Storage and Trade in an Efficient Global Market." *Amer. J. Agr. Econ.* 78(November 1996):879–90.

Marra, M., G. Carlson, and B. Hubbell. "Economic Impacts of the First Crop Biotechnologies." Dept. of Agr. and Resour. Econ., North Carolina State University, Raleigh, 1997.

McCluskey, J. J. "This Product May Contain GMOs." *Choices* (2nd Quarter 2000):39–42.

McNew, K., and B. L. Gardner. "Income Taxes and Price Variability in Storable Commodity Markets." *Amer. J. Agr. Econ.* 81(1999):544–52.

Miranda, M. J., and J. W. Glauber. "Intraseasonal Demand for Fall Potatoes Under Rational Expectations." *Amer. J. Agr. Econ.* 75(February 1993):104–12.

———. "Solving Stochastic Models of Competitive Storage and Trade by Chebychev Collocation Methods." *Agr. and Resour. Econ. Rev.* 24(April 1995):70–77.

Miranowski, J. A., G. Moschini, B. Babcock, M. Duffy, R. Wisner, J. Beghin, D. Hayes, S. Lence, C. P. Baumel, and N. E. Harl. "Economic Perspectives on GM Market Segregation." Work. paper, Dept. of Econ., Iowa State University, Ames, February 2000.

Moschini, G., H. Lapan, and A. Sobolevsky. "Roundup Ready Soybeans and Welfare Effects in the Soybean Complex." *Agribus.: An Internat. J.* 16(2000):33–55.

Parcell, J. L. "An Initial Look at the Tokyo Grain Exchange Non-GMO Soybean Contract." *J. Agribus.* 19,1(Spring 2001):85–92.

Smith, K. J. "Advances in Feeding Soybean Meal." *Feedstuffs* 69(January 1997):22–23.

Tokyo Grain Exchange. "GM and non-GM Daily Futures Prices" (May 2000–September 17, 2001). Online. Available at http://www.tge.or.jp.

U.S. Department of Agriculture, Economic Research Service. "Biotechnology: Implications for U.S. Corn and Soybean Trade." *Agricultural Outlook* (April 2000a):24–28.

———. "Biotechnology: U.S. Grain Handlers Look Ahead." *Agricultural Outlook* (April 2000b):29–34.

———. "Real Monthly Commodity Exchange Rates." Various months. Online. Available at www.ers.usda.gov/data/exchangerates/.

U.S. Department of Agriculture, World Agricultural Outlook Board. "World Agricultural Supply and Demand Estimates." USDA/WAOB, Washington DC. Various monthly issues, 1972–2001.

Williams, J. C., and B. D. Wright. *Storage and Commodity Markets.* New York: Cambridge University Press, 1991.

Working, H. "Whose Markets? Evidence on Some Aspects of Futures Trading." *J. Marketing* 19(1954): 1–11.

Appendix:
Description of Econometric Models, Estimation Methods, and Results

Estimates of U.S. export and domestic demand elasticities for soybeans are required for parameterization of the simulation model. Previous estimates of export demand elasticities may be too small for current market conditions because they were obtained using time-series data prior to the mid-1980s, and thus do not reflect expanded international competition in U.S. export markets from increased production in South America in the 1990s. The econometric approach used here is to estimate a simultaneous set of demand and supply equations for the export and domestic markets for U.S. soybeans.

For the export market model, we follow the approach of Haniotis, Baffes, and Ames. In the export demand equation, export quantity demanded is specified as a function of price and demand shift variables, including the exchange rate. The export supply function is expressed in price-dependent form where the export price depends upon quantity exported and domestic supply (including current production and carry in stocks). Given that the empirical focus is the estimation of export demand parameters, the specification of the export supply function can be viewed as permitting the selection of an appropriate set of instrumental variables to permit the estimation of unbiased parameters in the export demand function.

The specific export demand and supply estimation equations are as follows:

$$\ln(X_t) = \alpha_0 + \alpha_1 \ln(P_t) + \alpha_2 \ln(E_t) + \alpha_3 \ln(W_t) + U_t, \tag{A1a}$$

$$\ln(P_t) = \beta_0 + \beta_1 \ln(X_t) + \beta_2 \ln(S_t) + v_t. \tag{A1b}$$

Equation (A1a) is the export demand function and (A1b) the export supply function. The variables in equations (A1a) and (A1b) are the U.S. average soybean price (P), the quantity of U.S. soybean exports (X), world ending stocks (W), the U.S. supply of soybeans (S) computed as the beginning stocks plus production and any imports for the year, and E is the trade-weighted real exchange rate index for soybeans, as constructed by the USDA's Economic Research Service.[10] Because an increase in the value of E represents an increase in the value of the U.S. dollar relative to other currencies, we would expect E to be negatively related to exports. The world stocks variable (W) is expected to negatively affect the demand for U.S. exports, as higher world stocks imply a lower level of demand for U.S. exports. In the export supply equation, an increase in total U.S. supply is likely to increase the supply of U.S. exports and lower the export price.

In the domestic market model, soybeans are used almost exclusively for the production of soybean meal and soybean oil. Every 60-pound bushel of soybeans yields approximately 48 pounds of soybean meal and 11 pounds of soybean oil. Soybean meal is widely used in feed rations (Smith). Therefore, the domestic demand for soybeans (D_t) is assumed to depend on the U.S. annual production of all meat (beef, pork, and poultry), M_t. As meat supplies increase, the demand for soybeans is also likely to increase. The domestic market is represented as follows:

$$\ln(D_t) = \gamma_0 + \gamma_1 \ln(P_t) + \gamma_2 \ln(M_t) + w_t, \tag{A2a}$$

$$\ln(P_t) = \delta_0 + \delta_1 \ln(D_t) + \delta_2 \ln(S_t) + z_t. \tag{A2b}$$

With the exception of the exchange rate variable, data for all of the dependent and explanatory variables utilized in both the export and domestic demand and supply models were obtained from various issues of the USDA's "World Agricultural Supply and Demand Estimates" (USDA/World Agricultural Outlook Board). The exchange rate data were obtained from the USDA/ERS website (available at www.ers.usda.gov/data/exchangerates/).

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[10] The USDA/ERS's trade-weighted exchange rate, an aggregate measure of the U.S. dollar exchange rate for all export and import countries that trade with the United States, is utilized because the dependent export demand variable is aggregate U.S. soybean exports rather than exports to a specific country.

Table A1. Domestic and Export Supply and Demand Estimates for Soybeans: 1970–1984 and 1985–2000

A. Export Market

Demand

Variable[a]	Estimate (1970–84)	t-Stat.[b] (1970–84)	Estimate (1985–00)	t-Stat.[b] (1985–00)
Intercept	3.88	3.24	10.72	5.25
P_t	-0.84	-1.22	-1.61	-3.85
E_t	-0.05	-0.58	-0.13	-0.38
W_t	0.01	0.49	-0.04	-2.63
C.V.[c]	22.5%		16.0%	
F-Test[d] for structural change in export market models				3.94 (0.003)

Supply

Variable[a]	Estimate (1970–84)	t-Stat.[b] (1970–84)	Estimate (1985–00)	t-Stat.[b] (1985–00)
Intercept	3.04	3.06	8.06	2.21
X_t	0.84	2.46	0.32	3.17
S_t	-0.89	-1.46	-1.08	-2.05
C.V.[c]	15.8%		12.9%	

B. Domestic Market

Demand

Variable[a]	Estimate (1970–84)	t-Stat.[b] (1970–84)	Estimate (1985–00)	t-Stat.[b] (1985–00)
Intercept	-4.02	-4.30	-2.79	-3.23
P_t	-0.56	-3.35	-0.31	-3.87
M_t	1.48	10.91	0.94	12.51
C.V.[c]	11.7%		4.3%	
F-Test[d] for structural change in export market models				0.41 (0.745)

Supply

Variable[a]	Estimate (1970–84)	t-Stat.[b] (1970–84)	Estimate (1985–00)	t-Stat.[b] (1985–00)
Intercept	4.21	4.85	7.39	4.42
D_t	0.92	2.91	0.87	2.80
S_t	-2.82	-3.68	-1.53	-4.37
C.V.[c]	17.6%		11.9%	

[a] Variables: P_t = U.S. soybean price, E_t = exchange rate, W_t = world stocks, X_t = U.S. soybean exports, S_t = U.S. soybean supply, M_t = U.S. meat (beef, pork, and poultry) production, and D_t = domestic demand.

[b] Asymptotic t-statistics.

[c] C.V. = coefficient of variation, calculated as the root mean squared error of the regression divided by the mean of the dependent variable.

[d] The F-test is a test of whether all coefficients in the demand and supply equations have changed (p-values are presented in parentheses).

Parameter estimates for the two-equation export market model and the two-equation domestic market model were each estimated for the entire period 1970–2000 using three-stage least squares (3SLS) procedures in SAS. In each model, the endogenous variables are the soybean price and soybean quantities demanded. All other variables are exogenous and used as instruments in the estimation procedures. In both models, the estimated equations are either over-identified or exactly identified. Tests for serial correlation failed to reject the hypothesis of no serial correlation. Chow tests for structural change between the sample sub-periods of 1970–1984 (which approximately corresponds to the period utilized in Gardiner and Dixit in their estimates of export demand for U.S. soybeans) and 1985–2000 rejected the null hypothesis of no structural change for the export market model. However, Chow tests failed to reject the null hypothesis of no structural change for the domestic market model.

Parameters for the models estimated for each of the two sample sub-periods are presented in table A1. The estimated parameters for the export and domestic demand equations have the expected signs and, with one exception (the parameter for the exchange rate, E_t), are also all statistically significant at the 5% level. The estimated elasticity of export demand of -1.61 for the period 1985–2000 is substantially larger in absolute terms than the estimate of -0.84 for the period 1970–1984. The latter estimate is very similar to the estimate of -0.96 reported by Gardiner and Dixit for a similar period prior to the mid-1980s. The domestic demand elasticity estimates of -0.56 and -0.31 for the periods 1970–1984 and 1985–2000 are not dissimilar from the estimate of -0.4 reported by Moschini, Lapan, and Sobolevsky.

Coefficients of variation for the export demand and domestic demand equations computed from the standard errors of the regressions are also reported in table A1. These coefficients of variation, estimated consistently with the export and domestic demand function parameters, are utilized to obtain distributions of the domestic and export demand shocks required for the simulation models. Specifically, multiplying the estimated coefficient of variation for the domestic model and the export model by the average price over the sample of $5.75 gives a standard deviation estimate for the distribution of the demand shocks for each market. These standard deviation estimates are used to generate domestic and export demand shocks used in the simulation, which are assumed to be independent and normally distributed with zero means.