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# Quarterly Econometric Analysis of U.S. Soybean Market

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This article is the further development and refinement of quarterly models of U.S. field crops, drawing upon the theory of pricing, production, and storage under uncertainty. The decisions of storage industry and farm production are taken into account. The findings of this research are both methodological and empirical.

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The major objective of this article is the further development and refinement of quarterly econometric models of U.S. filed crops, drawing upon recent theoretical discoveries in the theory of pricing, production, and storage under uncertainty. In this proposed research, the entire model for the U.S. soybean market will be examined including the estimation of U.S. export demand for soybeans. In addition, the EC policy implications for the U.S. soybean market will also be investigated based on the quarterly model.

The research method employed involves the construction and estimation of an econometric model designed for the policy analysis estimated using 3SLS and quarterly time series data for the market year 1961-1991. The major findings of this article are both technological and empirical. As to methods, the recent research on pricing and storage has, drawing upon Muth's hypothesis of rational expectations, assigned a central role to (1) price expectations, (2) arbitrage condition that relates discounted expected prices to current prices and the cost of bin space, and (3) expected price functions that link expected prices to current values of endogenous variables. The latter have been estimated using numerical methods akin to dynamic programming. Following Choi and Helmberger (1993), this article explores an alternative research approach that substitutes econometrics for numerical methods.

We model the storage industry under conditions of uncertainty and derive the supply function for storage, a function that relates the current carryout of stocks to the expected price. The arbitrage condition used in recent research is shown to be a restrictive condition. Eliminating the expected price and combining the storage supply and the expected price function yields the demand function for stocks, a relationship that shows the carryout of stocks varies with the current price. The demand for stock, embedded as it is in a structural model of a market for a storable commodity, is then estimated using econometrics rather than numerical methods. The estimated elasticities of the demands for storage for quarters one to four are respectively, -1.168, -1.167, -3.259, -7.893. These estimates are similar to those based on numerical methods and appear to be highly reliable according to the usual statistical tests.

A second methodological advanced concerns the acreage response function. In the econometric modeling of farm commodity markets, it has become standard practice to express acreage as a function of lagged prices of the future price, where in both cases the independent variable is proposed as proxy for the unobservable expected price. We show this procedures restrictive and proposed, instead, to express acreage planted as a function of what is called "expected gross return per unit of planned output." This suggestion flows naturally from modeling farm output and input decisions under conditions of uncertainty. A procedure is proposed for measuring expected gross returns and our econometric findings lend support to the proposed approach.

As to empirical results, we find that over the sample period, the EC oilseed subsidies lowered both U.S. exports to the European Community and U.S. soybean prices. The percentage declines in the annual U.S. soybean price reached their maximum (7.8 percent) in 1987. The percentage declines average 5.9 percent over the period 1987-1991, the period during which the oilseed subsidies were in force.

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## I. Introduction

The major objective of this article is the further development and refinement of quarterly econometric models of U.S. field crops, drawing upon recent theoretical discoveries in the theory of pricing, production, and storage under uncertainty.

Helmberger and Akinyosoye (1984), using numerical techniques akin to dynamic programming to derive functions that show how expected prices are related to current values of endogenous variables. Expected price functions are included in complete models of commodity markets in which storers make optimal decisions in the case of price uncertainty. Their article has some important limitations reflecting the limitations of annual models in general. The crucial role of storage within the marketing year is ignored. Annual models also imply that crop production, the acreage planting decision, and the inter-marketing year carryover are determined at the same time, but this is not realistic. Therefore, annual models are not only incomplete in their characterization of the role storage in agricultural commodity markets, they may lead to results that are inconsistent with those of less restrictive quarterly models.

The article by Lowry et al. (1987) is particularly notable in that it was the first to incorporate within the same model both intryear and interyear storage. In their work, Lowry et al. centered on the implications of changes in the interest rate and storage cost for commodity storage and pricing within a steady-state model. The numerical methods were used to quantify expected price functions, while consumption demanded functions were estimated by econometric methods.

Choi and Helmberger (1993) estimated an econometric model for U.S. soybeans for the third quarter that is based squarely on recent developments in theory of storage. A key feature of their empirical analysis is the estimation of an expected price function using econometrics instead of the numerical methods proposed by Lowry et al. Although the Choi-Helmberger research aggregates the domestic and export demands and although the application is restrictive to the third quarter, their findings appear to be every promising.

The research will draw mainly on the Choi-Helmberger research approach. The entire model for the U.S. soybean market will be examined including the estimation of U.S. export demand for soybeans. In addition, the EC policy implications for the U.S. soybean market will also be investigated based on the quarterly model.

## II. The Analytical Framework

1. Model of Farm Production Under Uncertainty

Farm production often involves both price and production uncertainties. The model of farm production developed below allows for these conditions. Assume that crop production is affected by random weather and that farmers have a multiplicative production function, which may be written:

$$q_{t+1} = q(a_t, k_t, h_t)V_{t+1}$$

where $q_{t+1}$ equals output in period t+1; $a_t$ equals acreage planted in period t; $k_t$ equals input of producer goods (fertilizer, for example); $h_t$ equals labor input; and $V_{t+1}$ is a random variable measuring weather during period t+1, after planting. Assume $E_t(V_{t+1})$ equals one. Then, taking the expectation of both sides of the production function, we have:

$$E_t(q_{t+1}) = q(a_t, k_t, h_t)\, E_t(V_{t+1}) = q(a_t, k_t, h_t) = \theta_q$$

Inserting expected output into the production function, we have:

$$q_{t+1} = \theta_q V_{t+1}$$

The farmer's profit is defined as :

$$\pi_{t+1} = P_{t+1} \cdot q_{t+1} - r \cdot a_t - m \cdot k_t - j \cdot h_t + W$$

where $P_{t+1}$ equals output price, r is rent per unit of land; m is price of producer goods; and j is wage rate for labor; and W is the farmer's initial wealth or, alternatively, the negative fixed cost in production.

The farmer's profit function can be also expressed as :

$$\pi_{t+1} = G_{t+1}\theta_q - r \cdot a_t - m \cdot k_t - j \cdot h_t + W$$

where $G_{t+1} = P_{t+1} \cdot V_{t+1}$ is defined as the gross return per unit of planned output. Taking the expectation of both sides of the profit function we have the expected profit:

$$E_t(\pi_{t+1}) = \theta_G \cdot \theta_q - r \cdot a_t - m \cdot k_t - j \cdot h_t + W = \theta$$

where $\theta_G = E_t(G_{t+1})$.

The variance of profit used at a later point in the analysis is given by :

$$Var(\pi_{t+1}) = \theta_q^2 \cdot \sigma_G^2 = \sigma^2$$

where $\sigma_G^2$ is the variance of $G_{t+1}$.

Assume farmers are risk-averse and cannot use hedging to avoid risk. Furthermore, assumed that their main goals are to maximize utility. Let the individual farmer's utility function be a function of expected profit and the standard deviation of profit thus:

$$U_t = U(\theta, \sigma)$$

where $U_t$ is the farmer's utility level; and where $\theta$ equals expected profit and $\sigma$ equals the standard deviation of the profit. Because the farmer's profit is a random variable ($G_{t+1}$ is random ), profit maximization is not possible. Thus, we must introduce the utility function to analyze the farmer's supply decision. Based on the assumed production and profit function, the utility function can be expressed as:

$U_t = U(\theta_G \cdot \theta_q - r \cdot a_t - m \cdot k_t - j \cdot h_t + W, \ \theta_q^2 \cdot \sigma_G^2)$

Assuming the farmer intends to maximize utility, we have:

$\text{Max } U_t(\theta, \sigma^2) = \text{Max } U_t = U(\theta_G \cdot \theta_q - r \cdot a_t - m \cdot k_t - j \cdot h_t + W, \ \theta_q^2 \cdot \sigma_G^2)$

Finding the first order conditions and solving for the optimum levels, we have:

$a_t^* = a(\theta_G, \sigma_G, r, m, j)$

$k_t^* = k(\theta_G, \sigma_G, r, m, j)$

$h_t^* = h(\theta_G, \sigma_G, r, m, j)$

Importantly, acreage planted, even in the simple case of risk-neutral behavior, is a function of expected gross return rather than expected price as posited in the Lowry et a1. model.

## 2. A Quarterly Model of Pricing and Storage

The quarterly model reported in this section based upon the model of pricing and storage originally developed by Lowry et al., but with two significant modifications. First, assuming that storers hedge and that the futures price equals the expected price, we derive a supply function for storage in which quantity of stocks is positively related to the expected price. The unobservable expected price may be eliminated from the model by using both the supply for storage and the expected price function. When this is done, quarterly demands for storage appear in the model together with the demands for domestic processing and exports. Second, modeling the farmer's input choices under considerations of both price and production uncertainty, conditions that appear likely in the case of soybean production, leads to input demand functions in which input quantities are functions of both the expectation and variance of gross returns per unit of planned output. This suggests the need to modify conventional analysis of acreage response in which lagged price or the futures price is adopted as a proxy for expected price.

The first quarter model is as follows:

(1) $DD_{t1} = DD_1(P_{t1}, L_{t1}, U_{t1})$

(2) $XD_{t1} = XD_1(P_{t1}, M_{t1}, Z_{t1})$

(3) $E_{t1}(P_{t2}) = (P_{t1} + K)*(1 + r)$

(4) $E_{t1}(P_{t2}) = f_1(I_{t1}, \gamma_{t1})$

(5) $H_{t1} = A_{t-1,3} Y_{t1}$

(6) $Y_{t1} = Y_1(W_{t1}, W_{t-1,4})$

(7) $DD_{t1} + XD_{t1} + I_{t1} = I_{t-1,4} + H_{t1}$

The model for the second quarter is:

(8) $DD_{t2} = DD_2(P_{t2}, L_{t2}, U_{t2})$

(9) $XDt2= XD_2(P_{t2}, M_{t2}, Z_{t2})$

(10) $E_{t2}(P_{t3})= (P_{t2}+ K)*(1+ r)$

(11) $E_{t2}(P_{t3})= f_2(I_{t2}, \gamma_{t2})$

(12) $DD_{t2}+ XD_{t2}+ I_{t2}= I_{t1}$

The third quarter model is:

(13) $DD_{t3}= DD_3(P_{t3}, L_{t3}, U_{t3})$

(14) $XD_{t3}= XD_3(P_{t3}, M_{t3}, Z_{t3})$

(15) $E_{t3}(P_{t4})= (P_{t3}+ K)*(1+ r)$

(16) $E_{t3} (P_{t4})= f_3(I_{t3}, \gamma_{t3})$

(17) $A_{t3}= A_3[E_{t3} (P_{t+1,1}), A_{t-1,3}, N_{t3}, V_{t3}]$

(18) $SD_{t3}= \alpha A_{t3}$

(19) $E_{t3}(P_{t+1,1})= g_3(I_{t3}, A_{t3}, \gamma'_{t3})$

(20) $DD_{t3}+ XD_{t3}+ I_{t3}= I_{t2}$

The fourth quarter model is:

(21) $DD_{t4}= DD_4(P_{t4}, L_{t4}, U_{t4})$

(22) $XD_{t4}= XD_4(P_{t4}, M_{t4}, Z_{t4})$

(23) $E_{t4}(P_{t+1,1}) = (P_{t3}+ K)*(1+ r)$

(24) $E_{t4}(P_{t+1,1})= f_4[I_{t4}, W_{t4}, E_{t4}(H_{t+1,1}), \rho_{t4}]$

(25) $DD_{t4}+ XD_{t4}+ I_{t4}= I_{t3}$

**Table 1. Definition of Functions and List of Variables in the Theoretical Model.**

| Variable | Definition |
|---|---|
| **Quarterly Demands: (1), (8), (13), and (21)** | |
| $DD_{ti}$ | = Quarterly domestic crush for U.S. soybeans |
| $P_{ti}$ | = Quarterly price of soybeans |
| $L_{ti}$ | = a vector of exogenous demand shifters |
| $U_{ti}$ | = a random variable with zero mean. |
| **Export Demands: (2),(9),(14), and(22)** | |
| $XD_{ti}$ | = Quarterly exports of U.S. soybeans |
| $M_{ti}$ | = A vector of exogenous export demand shifters |
| $Z_{ti}$ | = A random variable with zero mean |
| **Arbitrage Conditions: (3),(10),(15), and(23)** | |
| $E_{ti}(P_{ti+1})$ | = farmers‘ expected price formed in quarter i for quarter i+1 |
| K | = per unit cost of storage or bin space |
| $r_{ti}$ | = quarterly rate of interest. |
| **Expected Prices : (4), (11), (16), (19) and(24)** | |

$I_{ti}$ = Quarterly end stock of soybeans.

$\gamma_{ti}$ = Vector of the expected values of demand and supply shifters.

**Soybean Production: (5)**

$A_{t-1,3}$ = Acreage planted to soybeans lagged one year

$Y_{t1}$ = Soybean yield per acreage

**Yield: (6)**

$W_{t-1,4}$ $W_{t1}$ = Weather conditions during the growing season. (independent random variables with zero means).

**Acreage Supply: (17)**

$A_{t3}$ = Acreage Planted to soybeans.

$N_{t3}$ = A vector of exogenous shifters.

$V_{t3}$ = A random variable with zero mean.

$E_{t3}(P_{t+1,1})$ = Expected price at harvest time.

**Seed Demand: (18)**

**Market Clearing Conditions: (7),(12), (20), and (25)**

## III. Model Specification and Estimation

### 1. Measuring the expected gross return

Because time series data on the expected gross return per unit of planned output ($\theta_G$) are not available, a method was developed to estimate such a series. Two assumptions are imposed in the procedure: (1) the reduced form for the output price is linear in all independent variables; and (2) the mean of the weather variable ($V_{t+1}$) equals one. The reduced form for the output price, the price of soybeans in the present application, can be written:

$$P_{t+1} = a + bV_{t+1} + c\,Z_{t+1} + d\,X_{t+1} + u_{t+1}$$

where $P_{t+1}$ equals the real price; $Z_{t+1}$ is a vector of lagged endogenous variables; $X_{t+1}$ is a vector of exogenous variables; $u_{t+1}$ equals the error term with zero mean and finite variance. Rewriting, we have:

$$\begin{aligned} P_{t+1} &= (a + c\,Z_{t+1} + d\,X_{t+1}) + bV_{t+1} + u_{t+1} \\ &= \alpha_{t+1} + bV_{t+1} + u_{t+1} \end{aligned}$$

where $\alpha_{t+1} = a + c\,Z_{t+1} + d\,X_{t+1}$

The three main steps used to estimate the real expected gross return are as follows:

Step one involves measuring the weather variable, $V_{t+1}$. Weather is a complex phenomena. The time patterns for rainfall and temperature, the extent of sunshine, and the wind velocities over space rather defy description with a few variables. For this reason, we propose to use yield ratios as a proxy for weather under the assumption of a multiplicative production function.

Let soybean yield be a function of trend, fertilizer used per acre of soybeans, and acreage planted to soybeans. Let the quantity of fertilizer demanded be a function of fertilizer price, acreage planted to soybeans, and trend. These two functions are estimated simultaneously using three-stage least squares. Then we estimate for each year of the same sample $V'_{t+1}$ defined as the ratio of actual yield, $Y_{t+1}$, to the estimated yield, $Y^{*}_{t+1}$. The estimate of the weather variable $V_{t+1}$ is obtained by dividing $V'_{t+1}$ by the sample mean of $V'_{t+1.}$

In step two, we estimate the reduced form for price:

$P_{t+1}= \alpha_{t+1} + bV_{t+1}+ u_{t+1}$

In step three, we multiply both sides of the estimated price function by Vt+1, which yields:

$V_{t+1}P_{t+1}=\alpha_{t+1}V_{t+1}+ b V_{t+1}^{2}+V_{t+1}u_{t+1}$

Taking the expectation, assuming that $V_{t+1}$ and $u_{t+1}$ are independent, we have:

$E_{t}[V_{t+1}P_{t+1}] = \alpha_{t+1} +b E_{t}[Var (V_{t+1})+ 1]$

where $E_{t}[V_{t+1}P_{t+1}]$ is defined as expected gross return per unit of planned output; $E_{t}[V_{t+1}]$ is the expected value of the weather variable, which is assumed to equal to one; and $Var[V_{t+1}]$ is the variance of the weather variable, which is constant.

## 2. Model Specification

According to the theoretical model presented in pervious section, each quarter has a particular demand-supply system. The main differences among quarters are that soybeans are harvested in the first quarter of the marketing year and planted in the third quarter. In order to estimate all four quarters' demand-supply system simultaneously, two assumptions are imposed. First assume that each demand equation slopes the same for all four quarters. Second, assume all equations appearing in the demand and supply system are linear. The demand-supply model used for the analysis of the U.S. soybean market is presented as follows:

$DD_{ti} = f_{1} (RP_{ti}, LXF_{T}, LES_{T}, LPDI_{T}, PP_{T}, ECP_{T}, ABX_{j}, FTBF_{T}, FTDC_{T}, FTPK_{T}, DS_{ti}, DN_{ti}, D2_{ti}, D3_{ti}, D4_{ti})$ Domestic Demand for Crush

$XD_{ti} = f_{2} (RP_{ti}, LXF_{T}, LES_{T}, LREPI_{T}, SPP_{T}, ECP_{T}, ABX_{j}, FEJBF_{T}, FEJDC_{T}, FEJPK_{T}, DS_{ti}, DN_{ti}, D2_{ti}, D3_{ti}, D4_{ti})$ Export Demand

$RPti = f_{3} (I_{ti}, LXF_{T}, LES_{T}, R_{ti}, LPDI_{T}, PP_{T}, TREND, FTBF_{T}, FTDC_{T}, FTPK_{T}, DS_{ti}, DN_{ti}, D2_{ti}, D3_{ti}, D4_{ti})$ Storage Demand

$EG_{t3} = f_{4} (I_{ti}, LXF_{T}, LES_{T}, A_{t3}, LPDI_{T}, L3YS, PP_{T}, FTBF_{T}, FTDC_{T}, FTPK_{T}, TREND)$ Expected Gross Return Function

$A_{t3} = f_{5} (EG_{t3}, A_{t-1,3}, TA_{T}, DL_{ti}, LEC_{T}, LPDI_{T})$ Acreage Decision Function

The definitions for the variables are presented in Table 2.

**Table 2. List of Variable and Definitions.**

Variable Definition

**Endogenous Variable :**

$DD_{ti}$ = Quarterly domestic crush for U.S. soybeans (100 million bushels).[a]

$XD_{ti}$ = Quarterly exports of U.S. soybeans (100 million bushels).

$I_{ti}$ = End of quarter stocks of soybeans, U.S. market (100 million bushels).

$RP_{ti}$ = Quarterly real soybean price in the U.S. farm-level market (nominal price ,$ per bushel, deflated by index of farm input price).[b]

$A_{t3}$ = U.S. acreage planted to soybeans (million averages).

$EG_{t3}$ = Expected gross return per unit of planned output.[c]

**Exogenous Variables:**

$LXF_T$ = Annual exports of fish meal by the rest of the world, lagged one year (million metric ton).[d]

$LES_T$ = Annual average exchange rate weighted by soybeans exported to foreign markets, lagged one year (index,1985=100).

$LDPIT_T$ = Real U.S. personal disposable income($100, 1987 dollars per person).

$LREPI_T$ = Real personal income for the EC-10 ($100 , per person, nominal deflated by CPI, $CPI_{1980}$ =100, of EC-10).

$ECP_T$ = Annual rapeseed, sunflower seed, and soybean production in EC-10 (million metric tons).

$ABX_j$ = The sum of annual Argentine and Brazilian soybean exports (100 million bushels).[e]

$R_{ti}$ = Quarterly real interest rate (annual Production Credit Association rate divided by four and then adjusted for inflation in each quarter by subtracting the nominal rate from the inflation rate).

$PP_T$ = U.S. total population (millions).

$SPP_T$ = Aggregate population for EC-10, Japan , and Taiwan (millions).

$FTBF_T$ = Aggregate number of beef cows in U.S., EC-10, and Japan (millions).

$FTDC_T$ = Aggregate number of dairy cows in U.S. , EC-10, and Japan (millions).

$FTPK_T$ = Aggregate number of hogs in U.S. , EC-10, and Japan (millions).

$FEJBF_T$ = Aggregate number of beef cows in EC-10 and Japan (millions).

$FEJDC_T$ = Aggregate number of dairy cows in EC-10 and Japan (millions).

$FEJPK_T$ = Aggregate number of hogs in EC-10 and Japan (million).

TREND = Trend, equaling one in the first quarter of the first sample crop year (1961), t=2 for the second quarter of crop year 1961, and so on.

$DS_{ti}$ = Binary variable for dock strike equaling one for the second quarter of crop year 1968 and zero otherwise.

$DN_{ti}$ = Binary variable for embargo equaling one for the third and fourth quarter of crop year 1972 and zero otherwise.

$L3YS$ = Lagged three-year moving average of U.S. soybean yield (Bushels per acre).[f]

$A_{t-1,3}$ = Acreage lagged one year (million acres).

$TA_T$ = U.S. acreage planted to principal crops (million acres).

$DL_{ti}$ = Binary variable for farm programs, equaling zero for years when program were in effect and one otherwise (equals one for one for crop years 1974-1977 and 1980-1981).

$LEC_T$ = Exchange rate weighted by corn exported to foreign markets, lagged one year (index,1985=100).

$D2_{ti}$ = Binary variable for the second quarter equaling one in the second quarter of each crop year and zero otherwise.

$D3_{ti}$ = Binary variable for the third quarter equaling one in the third quarter of each crop year and zero otherwise.

$D4_{ti}$ = Binary variable for the fourth quarter equaling one in the fourth quarter of each crop year and zero otherwise.

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a. Here and elsewhere, the subscript t indicates crop year t (run from September 1 of calendar year t to August 31 of calendar year t+1); subscript i (i=1,2,3,4).

b. Index of farm input prices used in production, 1910-14=100.

c. See text for definition.

d. Here and elsewhere, T indicates the calendar year T. An example will explain when t indicates a convention used here and elsewhere :when t indicates crop year 1980-81 (begins September 1, 1980), T indicates calendar year 1980.

e. Here j indicates the marketing year for Argentina and Brazil . Brazil‘s marketing year for soybeans is from February of calendar year T to January of the year T+1;
Argentina‘s marketing year for soybeans is from April to March of the following year.

f. For example, $DD_{ti}$ is linked with L3YS for crop years t-1, t-2 , t-3.

## 3. Estimation

All the equations in the system are assumed linear and are estimated using 3SLS over the sample period 1961-1991. Each demand equation in the system is assumed to have the same slope across quarters in order to preserve degrees of freedom. Binary variables for the second, third, and fourth quarters were constructed to capture the effect of quarterly shifts in demand. The first equation in Table 3 is the demand for processing. The t-ration for the price coefficient is negative and statistically significant at one percent level using a one-tailed test. The price elasticities of the quarterly demands, estimated at the mean value, equal -0.217, -0.205, -0.225, and -0.247 for quarter one, two, three, and four respectively. The second equation in Table 3 is the export demand for U.S. soybeans. The t-ration for price is 2.5, which is statistically significant at the five percent level using a one-tailed test.. The price elasticities for the export demands equal -0.374, -0.342, -0.408, and -0.641. The third equation is the storage demand for storage. The price elasticities for quarter one through four, respectively, are -1.17, -1.67, -3.26, and -7.89. These results suggest that the demand for storage, particularly in the last two quarters, may be a source of significant elasticity as regards of total demand. The fourth equation is the expected gross return function. The exogenous variable included in this equation are used as proxies for the expected values of future demand and supply shifters. The coefficient for the third quarter carryout has the expected sign and is statistically significant at one percent level. The elasticity of the carryout with respect to gross return equals to -2.432. The fifth equation is the acreage response function. The short-run elasticity of acreage planted with respect to gross returns equals 0.13. Lagged acreage is also included drawing upon Nerlove’s partial adjustment hypothesis. The long-run elasticity is 0.43.

**Table 3 Estimated Structural Parameters of the Quarterly Demand and Supply Model of the U.S. Soybean Market.**

| Variable | 3SLS Estimate | Asymptotic t-ratio |
|---|---|---|
| **Quarterly Domestic Demand for U.S. Soybeans ($DD_{ti}$):** | | |
| $Con_1$[a] | 0.6062 | 0.5242 |
| $RP_{ti}$ | -0.5487 | 3.5791 |
| $LXF_T$ | 0.0174 | 0.5406 |
| $LES_T$ | -0.0047 | 2.6178 |
| $LPD_T$ | 0.0095 | 1.1992 |
| $PP_T$ | -0.0065 | 0.7709 |
| $ECP_T$ | -0.0218 | 1.4685 |
| $ABX_j$ | -0.0527 | 0.9920 |
| $FTBF_T$ | 0.0398 | 1.5919 |
| $FTDC_T$ | -0.0052 | 0.4720 |
| $FTPK_T$ | 0.1321 | 5.2862 |
| $DS_{ti}$ | -0.3136 | 2.0240 |
| $DN_{ti}$ | 0.5052 | 2.2677 |
| $D2_{ti}$ | 0.1524 | 4.0026 |
| $D3_{ti}$ | 0.0448 | 1.1694 |
| $D4_{ti}$ | -0.1384 | 3.6486 |
| **Quarterly Export Demand for U.S. Soybeans ($XD_{ti}$):** | | |
| $CON_2$ | -1.5390 | 0.7388 |
| $RP_{ti}$ | -0.6412 | 2.5036 |
| $LXF_T$ | -0.0822 | 1.2270 |
| $LES_T$ | -0.0082 | 1.6588 |
| $LREPI_T$ | -0.0023 | 0.1663 |
| $SPP_T$ | 0.0059 | 0.8742 |
| $ECP_T$ | -0.0735 | 2.6088 |
| $ABX_j$ | -0.3528 | 3.4576 |
| $FEJBF_T$ | -0.0096 | 0.1078 |
| $FEJDC_T$ | 0.0086 | 0.4408 |
| $FEJPK_T$ | 0.2377 | 4.5165 |
| $DS_{ti}$ | -0.6569 | 2.2561 |
| $DN_{ti}$ | 0.8258 | 2.2692 |
| $D2_{ti}$ | 0.1723 | 2.4135 |
| $D3_{ti}$ | -0.0406 | 0.5666 |

|  |  |  |
|---|---|---|
| $D4_{ti}$ | -0.5480 | 7.7029 |
| **Quarterly Storage Demand for U.S. Soybeans ($RP_{ti}$):** |  |  |
| $CON_3$ | -1.3262 | 0.1948 |
| $I_{ti}$ | -0.0549 | 5.3628 |
| $LXF_T$ | -0.0647 | 2.3660 |
| $LES_T$ | -0.0030 | 2.4364 |
| $R_{ti}$ | -0.0957 | 2.7238 |
| $LPDI_T$ | 0.0143 | 2.0914 |
| $PP_T$ | 0.0011 | 0.0287 |
| TREND | - 0.0139 | 0.6270 |
| $FTBF_T$ | 0.0652 | 3.7359 |
| $FTDC_T$ | 0.0185 | 2.1835 |
| $FTPK_T$ | 0.0405 | 1.9133 |
| $DS_{ti}$ | - 0.0453 | 0.3847 |
| $DN_{ti}$ | 1.1655 | 13.4687 |
| $D2_{ti}$ | - 0.1890 | 3.5119 |
| $D3_{ti}$ | - 0.4109 | 4.1781 |
| $D4_{ti}$ | - 0.5539 | 4.1374 |
| **Expected Gross Return Function ($EG_{t3}$):** |  |  |
| $CON_4$ | 2.8897 | 0.4596 |
| $I_{ti}$ | - 0.0607 | 4.4752 |
| $LXF_T$ | - 0.0632 | 2.4600 |
| $LES_T$ | - 0.0011 | 1.1253 |
| $A_{t3}$ | 0.0012 | 0.3620 |
| $LPDI_T$ | 0.0528 | 7.7072 |
| L3YS | -0.0609 | 3.9927 |
| $PP_T$ | - 0.0259 | 0.7606 |
| $FTBF1_T$ | 0.0170 | 1.0633 |
| $FTDC1_T$ | - 0.0024 | 0.2847 |
| $FTPK1_T$ | 0.0519 | 2.0348 |
| TREND | - 0.0179 | 0.8649 |
| **Acreage Decision Function ($A_{t3}$):** |  |  |
| $CON_5$ | -8.2313 | 0.6558 |
| $EG_{t3}$ | 8.9166 | 2.4138 |
| $A_{t-1,3}$ | 0.7066 | 13.0364 |
| $TA_T$ | 0.1263 | 6.9742 |
| $DL_{ti}$ | - 8.0260 | 8.4538 |
| $LEC_T$ | - 0.1995 | 5.6684 |
| $LPDI_T$ | - 0.0271 | 0.4954 |
| **Seed Demand Function ($SD_{t3}$):** |  |  |
| $CON_6$ | 8.5769 | 2.1889 |
| $A_{t3}$ | 1.3122 | 18.0166 |

a. $Con_i$ is the constant where i=1,2,…6.

## 4. Validation results

Although many estimated structural parameters for the endogenous variables have the correct signs, with acceptable levels of statistical significance, the question remains whether the model as a whole is a plausible quantitative representation of the U.S.

soybean market. The 3SLS estimates were used to simulate dynamically the performance of the market over the sample period 1961-1991. Simulated performance is then compared with actual performance to see how well the model track history. The mean absolute percentage (MAP) error is calculated for each endogenous variable. The MAP errors for total domestic demand, total export demand, annual price and acreage planted are 3.5%, 8.0%, 7.6% and 8.5% respectively. These results can lead us to believe that the model can be used to analyze some impacts of EC policy changes on the U.S. soybean market.

## IV. Policy Simulation and Conclusions

### 1. Policy simulation

To estimate the EC policy impacts on U.S. soybean market, we have to know what EC oilseed production would have been without subsidy. To solve the question, EC oilseed production is estimated using a linear trend over the period 1961-1979. The resulting regression equation is then used to estimate production over the period1980-1991. Using the model estimated in the previous section, the performance of the U.S. soybean market was simulated dynamically over the sample period with and without the EC oilseed program. Table 4 provides the simulation effects of the EC oilseed subsidy on the performance of the U.S. soybean market for the five years 1987-1991.Without the EC oilseed production subsidy, quarterly and annual quantities of U.S. soybeans processed and exported tend to increase. Average annual quantities of soybeans processed and exported increased by 1.9% and 14.4.%,respectively. By the end of sample period, soybean production increased from 2,060 to 2,119 million bushels, representing a 2.9 % increase in production. On average, without the EC oilseed subsidy the annual U.S. soybean price would have been higher by 5.9%. At the end of the sample period, the annual soybean prices were $5.97 and $6.32 per bushel with and without EC oilseed program, respectively. Without the EC production subsidy, U.S. farmers would have received 9 percent more revenue than they did with the program.

**Table 4 Annual U.S. Soybean Price, Production, and Utilization, Simulated with and without EC Oilseed Subsidies, with Percentage Changes in Parentheses, 1987-1991.**

| Year | Price | Production | Processed Domestically | Exports |
|---|---|---|---|---|
| | $ / bushel | ---- 100 Million Bushels ---- | | |
| | | **With EC Oilseed Subsidy** | | |
| 1987 | 5.68 | 18.62 | 11.61 | 6.80 |
| 1988 | 7.29 | 14.91 | 11.42 | 6.79 |

|  |  |  |  |  |
|---|---|---|---|---|
| 1989 | 7.16 | 19.18 | 11.45 | 6.00 |
| 1990 | 6.43 | 20.80 | 11.69 | 6.18 |
| 1991 | 5.97 | 20.60 | 11.94 | 6.23 |

**EC Oilseed Production Trend without Subsidy** [a]

|  |  |  |  |  |
|---|---|---|---|---|
| 1987 | 6.13 (7.9) | 19.03 (2.2) | 11.97 (3.1) | 8.26 (21.3) |
| 1988 | 7.75 (6.4) | 15.34 (2.7) | 11.64 (2.0) | 7.77 (14.5) |
| 1989 | 7.47 (4.4) | 19.71 (2.8) | 11.59 (1.2) | 6.62 (10.5) |
| 1990 | 6.75 (5.1) | 21.37 (2.8) | 11.88 (1.6) | 6.98 (12.8) |
| 1991 | 6.32 (5.9) | 21.20 (2.9) | 12.13 (1.6) | 7.11 (13.0) |

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a. Percentage change is calculated by expressing the difference between the with and without subsidy values divided by the with subsidy value.

## 2. Conclusions

The major findings of this research are both methodological and empirical. As methods, the recent research on pricing and storage has, drawing on Muth’s hypothesis of rational expectations, assigned a central role to (1) price expectations, (2) an arbitrage condition that relates discounted prices to current prices and the cost of bin space, and (3) expected price function, that in part link expected prices to current values of endogenous variables. The latter have been estimated using numerical methods akin to dynamic programming. Following Choi and Helmberger (1993), this research explores the efficiency of traditional econometric procedures. As combining the storage supply and the expected price function eliminates the expected price and yields the demand function for stocks varies with the current price. The derived demand for stock is then estimated using econometric rather than numerical methods.

A second methodological advance focuses on the acreage supply function. In the econometric modeling of farm production, it has become standard practice to express acreage planted as a function of lagged prices or of the futures price, where in both cases the independent variable is proposed as a proxy for the unobservable expected price. The procedure is restrictive. The research suggests expressing acreage planted as a function of the expected gross return per unit planted output. This suggestion flows naturally from modeling farm output and input decision under conditions of uncertainty. A procedure is proposed for measuring expected gross returns and our econometric findings lend support to the proposed approach.

As to empirical results, we find that over the sample period, EC oilseed subsidies have lowered both U.S. exports to the European Community and U.S. soybean prices. The percentage declines in annual U.S. soybean prices reached their maximum at 7.9 percent in 1987. The percentage declines averaged 5.9 percent over the period 1987-1991. The U.S. soybean farmers would have received 9 percent (1 billion dollars) more without the EC subsidy than they did with the subsidy.

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