"Irrational" Planting Behavior as Rational Expectations of Government Support

Dmitry V. Vedenov

Dept. of Ag. and Applied Economics
University of Georgia
315C Conner Hall, Athens, GA 30602
e-mail: dvedenov@agecon.uga.edu

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Abstract

The paper outlines an approach to estimation of rational expectations acreage response model for US soybeans that explicitly takes into account government payments. Numerical methods are used to recompute the model equilibrium at each iteration of the log-likelihood optimization routine. Estimation results allow one to measure market distortion introduced by the government support programs.

Introduction

Government farm support programs have been available to producers since late 1930s. However, major changes in the program introduced by the Federal Crop Insurance Act of 1980 and subsequent Acts of Congress significantly expanded the scope of the program. Introduction of new insurance products in mid-1990s and increasing government subsidies led to dramatic increase in program participation. In 2001, over 200 million acres were enrolled in the program, compared with only 26 million in 1980. Since 1980 total liability has increased almost ten-fold to $36.7 billion in 2001 (FCIC Summary of Business Report, 2001).

While government crop insurance programs provide a vital support to nation's producers, it also introduces market distortion. Planting decisions made by crop producers incorporate expectations of government payments and result in behavior which may seem "irrational". For example, while harvest prices of soybeans (as reported by NASS) steadily declined between 1995 and 2001 at an average rate of 3.7% a year, the acreage planted just as steadily moved in the opposite direction at an average rate of 2.7% a year. While counterintuitive at the first glance, such planting behavior makes perfect sense if one takes into account that the harvest prices during the same

period were below commodity loan rate, i.e. the latter effectively served as a price floor. Therefore, government support payments need to be taken into account in modeling acreage supply.

Various approaches to analysis of acreage supply have been presented in the literature (Gardner; Morzuch, Weaver, and Helmberger; Askari and Cummings; Chavas, Pope, and Kao; McIntosh and Shideed; Shideed and White; Parrott and McIntosh) While different models consider different factors influencing producers' decisions, the one common variable present in all models is the expected future price of the commodity. The latter is not observed at the decision time and thus has to be somehow deduced based on current information.

Several proxies have been developed for the expected output price including "naïve expectations" or lagged cash price (e.g. Shumway and Chang), various forecasts based on historical cash prices (e.g. McIntosh and Shideed), futures prices (e.g. Morzuch, Weaver, and Helberger), combinations of futures and cash prices (Chavas, Pope, and Kao), and so on. While each of the approaches above has its merits, they all share the same disadvantage that the price model is dissociated from the decision model in the sense that expected future price is an exogenous variable in the acreage supply equation.

The rational expectations approach, on the other hand, provides a way to derive the expectations of model variables as conditional forecasts based on the model itself (Muth; Fair and Taylor). Thus a rational expectations model of acreage supply would reflect the fact that while the acreage decision is based on the present expectation of future commodity price, the realization of this future price is, in turn, affected by the planted acreage. In other words, the way the expectations of future prices are formed is determined by the structure of the acreage supply model. The effect of government support programs may then be analyzed by explicitly incorporating government payments into expected future prices.

The practical applications of rational expectations models have been limited due to their computational complexity and lack of closed form solution. However, recent developments in computational techniques have made such applications a distinct possibility. Fair and Taylor suggested a numerical strategy for solution and estimation of nonlinear rational expectations models. Miranda and Glauber attempted to implement this strategy in order to estimate a commodity market model. Finally, Miranda has outlined an approach to numerical solution of rational expectations models using the collocation method.

The present paper attempts to estimate a model of acreage supply set in the rational expectations framework. The model is similar to that of Miranda and Glauber, but puss less emphasis on the dynamics of government stockholding and instead explicitly accounts for government payments to producers. Numerical approach used to recompute model equilibrium at each step of likelihood maximization routine incorporate recent advances in computational methods.

The paper proceeds as follows. The next section presents the rational expectations model of acreage supply followed by outlines of estimation procedure and numerical solution approach. Then the data to be used for estimation are described. The paper will be updated as the estimation results become available.

Rational Expectations Model of Acreage Supply

Let Q_t be the available supply of a commodity at the beginning of year[1] t, let S_t be the total stock (both government and private) at the end of the same year, and let C_t be consumption in-

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[1] Here we consider crop marketing years which for most commodities begin on September 1.

cluding domestic demand, export, and seed utilization during the year. The material balance requires that

(1)
$$Q_t = C_t + S_t.$$

Assume that the overall consumption is governed by[2]

(2)
$$C_t = \boldsymbol{a}_1 X_t^C + \boldsymbol{a}_2 P_t + u_t,$$

where P_t is the average market price, X_t^C are exogenous variables to be specified later, and u_t is a random shock.

Under the no-arbitrage assumption, the stockholding is driven by the trade-off between the current price, expected future price, and the cost of storage. Thus the current stock can be described by

(3)
$$S_t = \boldsymbol{b}_1 X_t^S + \boldsymbol{b}_2 \left(\frac{P^E}{(1+r_t)} - P_t \right) + v_t,$$

where P_t again is the average market price, r_t is a one-period discount factor, $P^E = E_t P_{t+1}$ is the expectation of the next period price conditional on current information, X_t^S are exogenous variables to be specified later, and v_t is a random shock.

Finally, assume that the decision of planted acreage is driven mainly by the price the producer expects to receive for commodity in the next year. The latter may differ from the market price if the farmer receives payments from government support programs. Due to a wide variety of such

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[2] An alternative way to specify equations (2) through (4) is to express all variables in logs. Both variant will be estimated in the final version of the paper.

programs that existed for different commodities in the past, it is impossible to incorporate them all in an estimable model. Therefore, I choose to concentrate on commodity loan programs because of its relatively simple structure and availability of relevant data. In addition historically this was the only form of government support for soybeans in the U.S. that resulted in direct payments to farmers. Thus the effect of the program on acreage decisions can be clearly identified.

While commodity loan programs have changed over the years, the basic principle remained the same. Producers can receive loans from the government at a predefined rate per unit of production by pledging future harvest as collateral. The loan has to be repaid unless the market prices at harvest are lower than the loan rate. In this case, depending on the specific program the producers can either forfeit the collateral or repay the loan at a lower rate. In either case, the net effect is that the loan rate effectively serves as a price floor because the actual price received by producers never drops below it.

Formally, the *effective price* received by producers under a commodity loan program can be expressed as $F_t = \max\{\overline{P}, P_t\}$, where P_t is the market price and $\overline{P}$ is the loan rate. It is this effective price that ultimately drives the acreage planting decisions made by the farmers. Thus the acreage response equation can be written as

(4)
$$A_t = g_1 X_t^A + g_2 \frac{F^E}{1 + r_t} + w_t,$$

where $F^E = E_t F_{t+1}$ is the current expectation of the next period effective price, r_t again is a one-period discount factor, X_t^A are appropriate exogenous variables, and w_t is a random shock.

The available supply at the beginning of the next period is then determined as

(5) $$Q_{t+1} = S_t + A_t \cdot \tilde{Y}_{t+1},$$

where $\tilde{Y}_{t+1}$ is the random yield unknown at the planting time.

Equations (2) through (4) define current market price P as well as the effective price F as functions of available supply Q and the vector of exogenous variables $\mathbf{X} = \{X^C, X^S, X^A\}$. The rational expectations principle then requires that

(6)
$$P^E(Q_t, \mathbf{X}_t) = E_t P(Q_{t+1}, \mathbf{X}_{t+1}) = E_t P(S_t + A_t \tilde{Y}_{t+1}, \mathbf{X}_{t+1}),$$
$$F^E(Q_t, \mathbf{X}_t) = E_t F(Q_{t+1}, \mathbf{X}_{t+1}) = E_t \max\{\overline{P}, P(S_t + A_t \tilde{Y}_{t+1}, \mathbf{X}_{t+1})\}.$$

Estimation Methodology

The acreage supply model is estimated using the full-information maximum likelihood method. The estimable model consists of equations (2) through (4). The random variables u_t, v_t, w_t are assumed to be normally distributed with zero mean and stationary variance-covariance matrix Ω. The material balance equation (1) can be used to eliminate the commodity stock from equations (2)–(4) so that the likelihood of observations $\{C_t, P_t, A_t\}$ can be derived from the joint density of random shocks $\{u_t, v_t, w_t\}$. Following Fair and Taylor, the corresponding full information log-likelihood function can be written as

(7) $$L = -\frac{T}{2}\log|\Omega| + \sum_{t=1}^{T}\log|J_t| - \frac{1}{2}\sum_{t=1}^{T}\hat{\boldsymbol{e}}_t'\Omega^{-1}\hat{\boldsymbol{e}}_t,$$

where $|J_t| = \boldsymbol{b}_2 - \boldsymbol{a}_2$ is the determinant of Jacobian of the transformation

$\{u_t, v_t, w_t\} \rightarrow \{C_t, P_t, A_t\}$, and

$$
(8) \qquad \hat{\boldsymbol{e}}_t = \begin{pmatrix} C_t - \boldsymbol{a}_1 X_t^C - \boldsymbol{a}_2 P_t \\ Q_t - C_t - \boldsymbol{b}_1 X_t^S - \boldsymbol{b}_2 \left(\dfrac{P_t^E}{(1+r_t)} - P_t \right) \\ A_t - \boldsymbol{g}_1 X_t^A - \boldsymbol{g}_2 \dfrac{F_t^E}{1+r_t} \end{pmatrix}.
$$

The maximum likelihood estimates can be then obtained by maximizing (7) with respect to the parameter vector $\mathbf{d} = \{\boldsymbol{a}_i, \boldsymbol{b}_i, \boldsymbol{g}_i\}$ and Ω.

The standard optimization techniques could be used to optimize the log-likelihood function (7). However, the latter includes the unknown expectations of future prices, which cannot be expressed in a closed form in terms of model parameters but instead have to recomputed at each perturbation of the optimization algorithm.

Numerical Solution of Rational Expectations Model

For any given value of the parameter vector $\mathbf{d}$, equations (1)–(6) represent a closed system of functional equations that needs to be solved for the unknown functions $P = P(Q, \mathbf{X})$ and $F = F(Q, \mathbf{X})$. This can be done by using a numerical strategy called collocation method (Miranda). The strategy involves three steps. First, the unknown functions are replaced by linear combinations of known *basis* functions $\{\boldsymbol{f}_1, \boldsymbol{f}_2, ..., \boldsymbol{f}_n\}$ with unknown coefficients

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(9) \qquad \begin{aligned} P(s) &= \sum_{j=1}^{n} c_j^P \boldsymbol{f}_j(s), \\ F(s) &= \sum_{j=1}^{n} c_j^F \boldsymbol{f}_j(s), \end{aligned}
$$

where $s = \{Q, \mathbf{X}\}$ is the vector of state variables. Second, a finite number of points or *collocation nodes* $s_1, s_2, ..., s_n$ are selected. Finally, Gaussian quadrature method (Judd) is used to discretize the continuous yield distribution by replacing it with a set of discrete values of yields

$\{y_1, y_2, ..., y_m\}$ and corresponding probability weights $\{w_1, w_2, ..., w_3\}$. The unknown coefficients c^P and c^F are then fixed by requiring (9) to exactly satisfy equations (1)–(6) at the collocation nodes.

For the practical purposes, the Chebychev polynomials (Judd) can be chosen as the basis functions. The collocation nodes are selected so that to cover the historically observed range of state variables. The number of basis function and collocation nodes is determined by the dimensionality of the problem and desired accuracy of approximation. The unknown coefficients then can be calculated by using a relatively simple iteration algorithm (Miranda).

Data Description

The presented acreage supply model is estimated using historical data for U.S. soybeans for 1970–2001. The relevant data have been collected from NASS, Analytical Database of U.S. Agriculture (APAC), Federal Reserve Bank, and U.S. Department of Labor.

The prices used in all equations are measured as season average prices in $/bu adjusted for inflation using Consumer Price Index (CPI). The one-period discount factor is measured as annualized return on 6-month commercial papers.

In the consumption equation (2), consumption is total disappearance in billions of bushels including domestic demand, export, and seed utilization. The vector of exogenous variables includes constant term, domestic livestock-poultry population index measured in grain consuming animal equivalent units, and foreign exchange rate measured as broad index of U.S. exchange rates.

In the stock equation (3), the stock variable is the total stockholding (government and private) in billions of bushels. The exogenous variables are constant term and annual time trend.

Finally, in the acreage supply equation (4), the planted acreage is total acreage under soybeans in the U.S. in millions of acres and the support price is the Commodity Credit Corporation announced loan rate inflation-adjusted by CPI. The vector of exogenous variables includes constant term, lagged acreage, and cost of production measured as the index of all prices paid for farm production also inflation-adjusted by CPI.

Expected Results and Discussion

At the writing time, all relevant data have been collected and the numerical algorithm for solving rational expectations model has been implemented. The estimation results will be available in the near future and will include elasticities of acreage supply with respect to loan rate and other relevant factors.

The model will also be estimated under a counterfactual assumption of no government payments in order to determine the degree of market distortion introduced by the support payments and subsidies. It is hypothesized that setting more realistic levels of loan rates may reduce the level of distortion introduced in the planting decisions, while at the same time providing adequate protection to farmers. The results of the paper will provide policymakers with an additional insight into the side effects of existing and proposed farm support programs. This, in turn, may help to improve the efficiency of the programs both in terms of benefits to the crop producers and taxpayers cost.

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