A Continuous Time Disequilibrium Model for the World Soybean Meal Market

by

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Abstract

The dynamic characteristics of the world soybean meal market were analysed under a continuous time model framework. Monthly observations of spot and futures prices, production, consumption, and stocks were utilized in the analysis. Stocks appeared to slowly adjust to price changes while consumption adjustment was rapid, and demand was inelastic in the short-run.
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Significant changes have characterized world agricultural markets during the last two decades. Several factors have contributed to these changes. One of these factors has been the rapid increase in competitive supplies available from other agricultural exporting countries such as Brazil and Argentina, which have negatively affected U.S. exports (Rausser). Exchange rate fluctuations, which have resulted in shifts of the volume of exports and have created a relative split between export and domestic use of agricultural commodities, have been another important factor in world trade (Chambers and Just).

Domestic policies of other countries also affected the structure of world markets. Brazilian domestic policy, for example, helped this country to become a major exporter of soybean meal and oil (Hillman and Faminow; Williams and Thompson). Finally, the introduction of new technologies in the agricultural sector of developing countries, double cropping, and switching of cropping production, all have had an impact on the world export markets (Mielke).

The main objective of this study is to analyze the dynamic characteristics of the world soybean meal market and its interrelationship with the markets of major soybean meal producers. In particular, adjustment rates for consumption, futures and spot prices are estimated, a short-run elasticity of soybean meal demand is calculated, and stability conditions for both the world and the major producer countries are evaluated.

Before identifying the analytical framework, some preliminary background information on the behavior of production and exports of the
major producers of soybean meal is appropriate. Over the period included in this analysis (1978-86), production of soybean meal in the U.S. remained stable, while exports declined by 26 percent. On the other hand, Brazilian production increased by 37 percent, while its exports rose by 55 percent. Although Argentina accounted for only a small part of the world soybean production in 1978, its production by 1986 accounted for about one third of Brazil's annual output, achieving an increase of 650 percent. These figures indicate that structural changes took place in the world soybean meal export market during these eight years.

The econometric model used here, which analyzes the dynamic characteristics of the world soybean meal market, is described in the next section. Data estimation and testing procedure are described in the third section. Empirical results are discussed in the subsequent section, while concluding remarks and some limitations on the model are pointed out in the final section.

The Econometric Model

The model used in this study is an approximation of a continuous time model, first proposed by Koopmans. The first empirical application of such a model was employed by Bergstrom. Wymer by using similar methodology studied the characteristics of the financial market of the United Kingdom (1973) and the dynamic behavior of the world sugar market (1975).

The basic assumption underlying this analysis is that production and consumption adjust to excess supply and demand, given that producers have some desired level of stocks. This is expressed by the following relationships:
where $D$ is the differential operator, $\hat{C}(t)$ and $\hat{Q}(t)$ are the desired levels of consumption and production, and $C(t)$ and $Q(t)$ are their corresponding actual levels. It is further assumed that spot prices as received by producers, adjust to both excess stocks and the rate of change in stocks. This is given by,

\begin{equation}
Dp(t) = f_3[\hat{S}(t) - S(t), Q(t) - C(t)],
\end{equation}

where $\hat{S}(t)$ and $S(t)$ are the desired and actual level of stocks, respectively. Futures prices are assumed to be endogenously determined in the model. Specifically, they are a function of the difference between expected spot and actual prices, such that

\begin{equation}
Dq(t) = f_4[p(t) - q(t)].
\end{equation}

To complete the theoretical model, the following identity ensures equality between change in stocks and the difference between production and consumption,

\begin{equation}
DS(t) = Q(t) - C(t).
\end{equation}

Since one of the major objectives of the present study is to determine adjustment rates to futures and spot prices, the way in which price expectations are formed should be specified. The expectation scheme employed in this study was the first order adoptive expectations specification (Nerlove),

\begin{equation}
Dp(t) = f_1[p(t) - \hat{p}(t)].
\end{equation}
The adjustment of futures prices \( q(t) \) to expected spot prices \( \hat{p}(t) \) is given by:

\[
(2b) \quad Dq(t) = \beta_2[\hat{p}(t) - q(t)].
\]

A first-order adjustment process is also assumed for the determination of spot prices:

\[
(2c) \quad Dp(t) = \alpha_1[S(t) - S(t)] - \alpha_2[Q(t) - C(t)].
\]

Finally, a second order adjustment process was assumed for consumption:

\[
(2d) \quad D^2C(t) = \gamma_1\gamma_2[C(t) - C(t)] - \gamma_1DC(t),
\]

The (derived) demand for the desired level of stocks is a function of both spot and futures prices, while the (derived) demand for the desired level of consumption is a function of spot prices. These two functions have the following form,

\[
(3a) \quad S(t) = a_0 - a_1p(t) + a_2q(t),\\
(3b) \quad C(t) = b_0 - b_1p(t) + b_2t.
\]

Equation (2c) describes the adjustment process of spot prices. Totally differentiating (2b) and substituting (2a) into it results in the derivation of the futures price equation. Finally, the consumption equation is derived by substituting (3b) into (2d).

These three equations, along with the previously specified identity (1e) form the following system:

\[
(4a) \quad Dp = \alpha_2a_2q - \alpha_1S - \alpha_2(Q-C) - \alpha_1a_1,\\
(4b) \quad D^2q = - (\beta_1+\beta_2)Dq + \beta_1\beta_2(p-q) + \beta_0,\\
(4c) \quad D^2C = - \gamma_1DC - \gamma_1\gamma_2b_1p - \gamma_1\gamma_2b_2t + \gamma_1b_0,\\
(4d) \quad DS = Q - S.
\]
This is the final form of the model which is estimated in the present study.

Data, Estimation, and Testing Procedure

Soybeans, by themselves, are an intermediate product while soybean meal and soybean oil are final products. Vandenborre specifies two export markets for soybeans: one for oil and one for meal. Since meal accounts for about 80 percent of the total quantity of crushed soybeans, it was considered as an appropriate representative of the world soybean market.

Monthly observations covering the period October 1978 to September 1986 were used in the current study. Spot prices and quantities for production, consumption and stocks were obtained from the Foreign Agriculture Circular, Oilseeds and Products (USDA, 1986). Futures prices were obtained from Dunn & Hargitt Investment Management Inc. (1986).

Three countries were considered to be major producers of soybean meal: the U.S., Brazil, and Argentina. In addition to the world model, models corresponding to the domestic markets of the U.S. and Brazil, were considered. Total world consumption was defined as consumption in individual countries plus exports to other countries, the last being justified by the fact that exports of soybean meal are directed to consumption, since stocks were assumed to be held only by producers. In contrast, exports were substracted from production for country models, since the major purpose of these models was to capture the domestic behavior of consumption and stocks.

To render the system (4a)-(4c) estimable, several modifications had to be made. First, a stochastic error term was additively appended to each equation. These disturbance terms are assumed to possess statistical
properties consistent with the optimization procedure of such models (Wymer 1972; Phillips 1972, 1974; Sargan; Bergstrom 1984). Second, time trend was added to the third equation to capture income shifts and other possible effects. The inclusion of the time trend reflects the structural form of the demand equation representing desired levels of consumption. Finally, the differential operator D, which has been defined in a continuous time sense, was replaced by the discrete approximation $(y_t - y_{t-1})$, where $y$ corresponds to the variable on which D operates. $D^2$ has been defined in a similar fashion.

Demand elasticity can be derived by partially differentiating (3b) with respect to $p$. In order to check for stability, (4a)-(4c) was transformed to a system of first order differential equations as follows,

$$(5) \quad DY(t) = AY(t) + BX(t) + u(t).$$

Calculation of the characteristics roots of the matrix $A$ allows checking for system stability.

Iterated seemingly unrelated regressions (SAS package) were used to simultaneously estimate the parameters of each model. Since the covariance matrix was iterated to convergence, the parameters were consistent and asymptotically equivalent to full information maximum likelihood estimates (Hausman). Preliminary Durbin-Watson statistics indicated severe presence of autocorrelation, thus the transformation of the data set was deemed necessary. The transformation technique developed by Parks was employed. Details about that technique can be found in Judge et al.
Empirical Results

Point estimates for the world model are reported in table 1, while estimates for the models related to the individual producer countries (the U.S. and Brazil) are reported in tables 2 and 3. The calculated eigenvalues of the adjustment matrix of each model are reported in table 4. Since the first and third equations are exactly identified, the structural parameters can be fully recovered. However, the parameters of the second equation cannot be identified individually, but only on a pair-wise basis.

By cursory inspection of the coefficients of the first equation (world model), it can be concluded that changes in spot prices adjust very slowly to stocks and changes in stocks of soybean meal. This may be attributed to the nature of the data. Stocks are usually held in the form of beans by the producers, so there is no significant variation in stocks which are held in the form of meal. This may also be supported by the fact that the estimated coefficients are insignificant in most cases (including the other models).

Since the coefficients of the second equation can be identified only pair-wise, a problem of identification arose for the adjustment process of futures prices. All the coefficients had almost the same absolute value and the same sign, for all models. This result should be expected since prices from the Chicago Board of Trade were used for all models. For the world model, the adjustment rate of futures prices was either 0.636, which indicates an adjustment period of 1.6 months, or -.241, which gives an adjustment period of about 4.2 months. This inconclusive result adds a factor of instability to the model but it could not be avoided since it
was assumed that producers form their expectations by utilizing some adaptive expectations process.

Finally, the third equation, which specifies how consumption levels are adjusted to their desired levels, indicates adjustment periods of 5 months. Similar result holds for the U.S. model. This is to be expected because most part of the world soybean production comes from the U.S. The Brazilian model exhibited very low adjustment coefficient, indicating a 12 month adjustment period.

As previously stated, the price elasticity of demand can be recovered from the third equation. Demand elasticities of soybeans in general and soybean meal in particular have been the subject of several studies (Knipscheer et al; Meilke and Griffith). The value of the demand elasticity for the world model, calculated at sample means, was found to be -0.07 in this study. For the U.S. and Brazilian model the values of demand elasticities were found to be -0.08 and -1.99 respectively. These are acceptable values (except the Brazilian model), since they can be considered as a short-run values, as the dynamic nature of the model and the incorporation of monthly observations suggest.

In order to check for stability, the model was transformed to a first order system of stochastic differential equations, as it was suggested in (5). Stability conditions require that all eigenvalues are non-positive. Table 4 indicates that for the world model this condition is violated only by one positive value while the U.S. and Brazilian models violate this condition with two positive values.

Since soybean meal is used predominately in livestock feeds, the demand for protein meal is derived from domestic agricultural policies that have consistently supported diary, livestock, and poultry producers. Governments have protected their farmers from international competition.
leading to steady growth in the demand for protein meal during the eighth-year period. These protectionist policies thus shift domestic instability into world markets (Shei and Thompson; Bale and Lutz; Sarris and Freebairn).

Concluding Remarks

This study is a preliminary attempt to specify how world prices, stocks, and consumption of soybean meal are determined. The world model advanced in this study exhibited very slow adjustment of stocks and changes in stocks to changes in spot prices. The same result holds for the country models as well. The futures price adjustment for the world model can be interpreted as either close to unity or very low. This inconclusive result has to do with the non-identification of the second equation. Finally, the short-run demand elasticity of soybean meal was found to be rather inelastic for the world and U.S. models and elastic for the Brazilian model.

However, some limitations of the model can be accounted for. The first limitation has to do with the completeness of the data set. Data limitations with respect to monthly observations in the European Community prevented its inclusion as a major producer, although it accounts for about 10 percent of the world soybean meal production (most of it imported in the form of beans). Another limitation was related to the stocks variable. The inclusion of another variable can be used for that purpose as a better approximation. Holdings of beans for example, could be substituted in the model, for stock adjustment purposes. That might explain the low adjustment rates derived from the first equation. Of course, the possibility of mispecification of the first equation is not
excluded. Although limitations of this analysis are recognized, results can contribute to the understanding of the world soybean market and indicate directions for future research.
Table 1: Parameter Estimates for World Model

\[ Dp = 0.102p - 0.075q - 0.001S + 0.001(Q-C) - 5.236 \]
\[ (0.148) (0.162) (0.002) (0.001) (8.14) \]

\[ D^2q = -0.396Dq - 0.152(p-q) + 1.978 \]
\[ (0.104) (0.082) (1.894) \]

\[ D^2c = -0.202DC + 0.316p - 0.202C + 0.522t + 537.2 \]
\[ (0.139) (0.317) (0.057) (0.447) (197.2) \]

Table 2: Parameter Estimates for U.S. Model

\[ Dp = 0.122p - 0.079q - 0.001S - 0.039(Q-C) - 6.097 \]
\[ (0.146) (0.158) (0.001) (0.029) (7.988) \]

\[ D^2q = -0.397Dq + 0.150(p-q) + 1.939 \]
\[ (0.105) (0.082) (1.894) \]

\[ D^2c = -0.203DC + 0.311p - 0.201C + 0.520t + 536.5 \]
\[ (0.139) (0.317) (0.057) (0.446) (197.2) \]

Table 3: Parameter Estimates for Brazilian Model

\[ Dp = 0.106p - 0.074q + 0.001S + 0.001(Q-C) - 5.572 \]
\[ (0.141) (0.147) (0.005) (0.012) (9.007) \]

\[ D^2q = -0.406Dq - 0.152(p-q) + 1.966 \]
\[ (0.108) (0.084) (1.914) \]

\[ D^2c = -0.089DC + 0.259p - 0.473C + 0.068t + 67.80 \]
\[ (0.299) (0.293) (0.186) (0.359) (114.8) \]

\[ a/ \] Standard errors are in parentheses.
Table 4: Eigenvalues for all Models

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References


Dunn & Hargitt Investment Management Inc. 22 N. 2nd St. P.O. Box 1100. Lafayette, IN 47902.


