Corn - Marketing

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AN ECONOMETRIC ANALYSIS OF THE FORWARD PREMIUM IN THE INTERNATIONAL CORN MARKET

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SUMMARY

This study investigates the linkage between world macroeconomic factors and prices of an internationally traded commodity by explicitly accounting for the role of futures markets in stockholding behavior. Using a portfolio model, the empirical analysis is carried out with quarterly data of a storable, international traded commodity- corn- for the 1973I-1983IV period. The empirical findings show that a substantial variation in the corn forward premium can be explained by current and expected future values of macroeconomic variables such as industrial production, interest rates, and exchange rates.

1. Introduction

Much of the past theoretical and empirical literature on commodity spot and futures prices is largely concerned with the impact of futures trading on the variability of cash prices. Notable examples of the theoretical work on the subject are Peck (1976), and Turnovsky (1983). The empirical work which stretches back almost one hundred years (Emery, 1896), includes studies by Working (1960), Gray (1963), Cox (1976), Tomek (1971), Powers (1970), Taylor and Leuthold (1974). While this literature yields useful information on the subject, little empirical work has been done on the factors which contribute to the simultaneous determination of spot and futures prices or the adjustment burden the latter carry in response to various market phenomena[1]. The theoretical foundations for the simultaneous determination of cash and futures prices have been laid earlier by Stein (1961) and recently recast by Bond (1984) within the framework of rational expectations.

The purpose of this paper is to build upon the theoretical insights provided by Stein (1961) and Bond (1984) and provide an empirical model to analyze the adjustment of cash and futures prices for an agricultural commodity with futures trading. The operational model is a short-run, demand-oriented portfolio model which considers both real and monetary factors in the simultaneous determination of spot and futures prices under the assumption of rational expectations. Following the work of Chu and Morrison (1986), we apply the portfolio model to a single aggregate international commodity market. We therefore abstract from interest rate differentials, reserve currencies, and a number of other portfolio aspects of international markets.

An underlying hypothesis of this paper is that, in light of the presence of a well-integrated world capital market (Dornbusch, 1983, 1985; McCalla, 1982; Pagoulatos, 1983; Schuh, 1976,1981; Stallings, 1986), the determination of commodity futures and spot prices is not independent of the macroeconomic disturbances transmitted via flexible exchange rates. This hypothesis received some support from empirical studies (Hwa, 1979) that have found traditional factors alone, such as the level of income, inventories, and production, unable to explain commodity spot price movements in the seventies.

Our approach to the problem is motivated by three observations. First, futures markets are regularly supplied with news on current as well as expected supplies of commodities world-wide. Second, agricultural markets are no longer isolated from the gyrations in global financial markets (Chambers, 1979; Lawrence and Lawrence, 1981; Van Duyne, 1979). Movements in interest rates emanating from financial markets not only have repercussions for carrying costs of commodities, but also for capital flows which affect exchange rates and which, in turn, influence demand. Third, erratic price movements are often attributed to "herd" behavior in financial markets with no plausible economic reason (see Pindyck and Rotemberg, 1988). If that is true, one should expect fundamental economic variables to do little in explaining the adjustment burden carried by spot and futures prices in response to real and monetary phenomena.

The organization of the paper is as follows. Section I presents the structural model used to derive the equation for the margin between cash and futures prices. In section II we apply the model to the international corn market. Section III presents the conclusions.

2. Model specification

This section presents a simple world market model of a storable agricultural commodity that explicitly accounts for the presence of commodity futures. Following Bond (1984), the model consists of relationships describing consumer and inventory demand and the supply of and demand for futures contracts. The model also reflects the working of a competitive international commodity market in which the commodity price is quoted in dollars and consumption is synonymous with the quantity traded in the world market. The supply of the commodity is treated as exogenous, and the interest rate is assumed not to affect other macroeconomic variables such as industrial production in the short run.

Consumer Demand

The quantity of the commodity consumed at time t by importing countries, C_t, is a negative function of the real spot price of the commodity P_t, a positive function of the real price of substitute commodities, S_t, a negative function of the real exchange rate (relative to consuming countries' currencies), X_t, and a positive function of aggregate economic activity in consuming countries, Y_t:

$$C_t = -aP_t + bS_t - cX_t + dY_t \qquad (1)$$

This specification is similar to that used by Chu and Morrison (1986) in deriving a price equation for internationally- traded commodities and can also be considered as an import demand function for the commodity. The theoretical justification for including the exchange rate as a separate regressor is that simple use of own price adjusted by exchange rate may lead to a downward bias on estimates of exchange rate impacts as well as an associated upward bias on own price-elasticity estimates and income-elasticity estimates (see Chambers and Just, 1979). Examples of empirical studies using the exchange rate as a separate regressor in commodity demand analysis can be found in Fletcher, Just and Schmitz (1981), and Meilke and de Gorter (1978).

Inventory Demand

The level of inventory demand depends positively on the difference between the marginal return on stockholding, $R(f)'_t$, and the *ex ante* real interest rate, r_t:

$$I_t = e\{R(f)'_t - r_t\} \tag{2}$$

The marginal return on hedged stock $R(f)'_t = F_t - P_t - h$, where F_t is the futures price, P_t is the spot price, and h is the marginal holding cost. This assumes a holding cost function of the form $H(I_t) = 1/2h(I_t)^2$, where $H(I_t)$ is the cost of storing inventory I_t for one period (Bond, 1984).

The Supply of Futures Contracts

Assuming that for every unit of the commodity that is hedged there is a forward contract supplied, the supply of contracts by inventory dealers, B_t, will be equal to the level of inventory demanded in equation (2); therefore,

$$B_t = e\{R(f)'_t - r_t\} \tag{3}$$

The assumption that all stocks are hedged is probably unrealistic for internationally traded commodities. The proper approach would be to add a relationship describing the nonspeculative demand for commodity inventories. However, since the nonspeculative component of inventory is a function of the real interest rate and total flow demand for the commodity, its exclusion from the model does not alter the final reduced form equation for the commodity price.

<u>The Demand for Futures Contracts</u>

The quantity of contracts demanded by speculators, G_t, is a positive function of anticipated profit on each futures contract purchased:

$$G_t = f(E_t P_{t+1} - F_t) \tag{4}$$

where $E_t P_{t+1}$ is the spot price expected to prevail at time $t+1$, and F_t is the price of the futures contract.[2]

<u>Equilibrium Conditions</u>

To close the model, we introduce equilibrium conditions for the futures and spot markets, respectively:

$$B_t = G_t, \tag{5}$$

and

$$C_t + I_t = I_{t-1} + Q_t, \tag{6}$$

where Q_t is the exogenously determined supply available at time t.

Price Determination

By substituting the relevant relationships into equations (5) and (6) and solving simultaneously for P_t and F_t, one obtains the following expressions:

$$P_t = \{(e+f)M_t + efR_t - efE_tP_{t+1}\}/J \tag{7}$$

$$F_t = \{eM_t - aeR_t - f(a+e)E_tP_{t+1}\}/J \tag{8}$$

where $M_t = (I_{t-1} + Q_t - bS_t + cX_t - dY_t)$, $R = (r_t + h)$, and $J = -(ae + af + ef) < 0$.

Under the assumption of rational expectations, the model is solved for the expected spot price E_tP_{t+1} by leading equation (7) forward one period, taking expectations, and substituting the result in equations (7) and (8). The procedure gives:

$$\begin{aligned} P_t = \frac{e+f}{J}M_t - \frac{e^2f(e+f)}{J(J+ef)}(F_t - P_t) - [\frac{ef}{J} + \frac{e^2f(e+f)}{J(J+ef)}]R_t \\ - \frac{ef(e+f)}{J(J+ef)}E_tN_{t+1} - \frac{e^2f^2}{J(J+ef)}E_tR_{t+1} \end{aligned} \tag{9}$$

$$\begin{aligned} F_t = \frac{e}{J}M_t - \frac{ef(a+e)(e+f)}{J(J+ef)}(F_t - P_t) - [\frac{ae}{J} - \frac{ef(a+e)(e+f)}{J(J+ef)}]R_t \\ - \frac{f(a+e)(e+f)}{J(J+ef)}E_tN_{t+1} - \frac{ef^2(a+e)}{J(J+ef)}E_tR_{t+1} \end{aligned} \tag{10}$$

where $N_t = Q_t - bS_t + cX_t - dY_t$. Note that, Given the short term horizon of the model, no attempt was made to eliminate the cash price expectation term through a repeated solution of (7) and (8). Instead, we maintained that all $E_tP_{t+n} = E_tP_{t+1}$ for $n > 1$. This implies stationarity of the cash price n periods ahead.

Substracting (9) from (10) and solving for the forward premium $(F_t - P_t)$ results in the follwing relationship:

$$F_t - P_t = \alpha_1 M_t + \alpha_2 R_t + \alpha_3 E_t N_{t+1} + \alpha_4 E_t R_{t+1} \tag{11}$$

where

$\alpha_1 = \frac{f}{a(e+f)+2ef} > 0$

$0 < \alpha_2 = \frac{ae+2ef}{ae+af+2af} = 1 - a\alpha_1 < 1$

$\alpha_3 = \frac{-f}{-J+ef} = -\alpha_1 < 0$

$\alpha_4 = \frac{ef^2}{(e+f)(J-ef)} = \frac{-ef}{e+f}\alpha_1 < 0$

By substituting for M_t and N_{t+1}, equation (11) can also be written as

$$F_t - P_t = \beta_1(I_{t-1} + Q_t) + \beta_2 E_t Q_{t+1} + \beta_3 S_t + \beta_4 E_t S_{t+1} + \beta_5 X_t + \beta_6 E_t X_{t+1}$$
$$+ \beta_7 Y_t + \beta_8 E_t Y_{t+1} + \beta_9 R_t + \beta_{10} E_t R_{t+1} \tag{12}$$

where

$\beta_1 = \alpha_1 > 0$	$\beta_2 = -\beta_1 < 0$
$\beta_3 = -\alpha_1 b < 0$	$\beta_4 = -\beta_3 > 0$
$\beta_5 = \alpha_1 c > 0$	$\beta_6 = -\beta_5 < 0$
$\beta_7 = -\alpha_1 d < 0$	$\beta_8 = -\beta_7 > 0$
$0 < \beta_9 = \alpha_2 = 1 - a\alpha_1 < 1$	$\beta_{10} = \alpha_4 < 0$

Note that, given the estimates of the β_i's in equation (12), the structural coefficients a, b, c, d can be easily recovered. The estimates for e and f can be calculated as follows:

$$e = \frac{1 - \beta_9 - 2\beta_{10}}{-(\beta_{10}/\beta_1)}$$

$$f = -\frac{\beta_1}{\beta_{10}} \frac{(1 - \beta_9 - 2\beta_{10})^2}{\beta_9 + 2\beta_{10}}$$

Equation (12) identifies major variables affecting the forward premium or equivalently the marginal returns on hedged stocks. An increase in current supply (Q_t) results in a widening forward premium. By increasing the quantity of stocks available, the increase in current supply depresses spot prices. A fall in spot prices encourages consumption, and given the price of futures, makes storage profitable. Since hedged stocks translate into a larger supply of contracts, the futures price also falls to maintain equilibrium in the futures markets. Since the forward premium widens the fall in the spot price is larger than that in the futures price. This implies increasing marginal returns to encourage carrying stocks to future periods. On the other hand, an expected increase in future supplies, while also having a depressing effect on both the current spot price and the futures price, narrows the forward premium or marginal returns on hedged stocks. Inventory holders do not require the same incentive to carry stocks forward during periods of ample production.

A shift in the demand for a commodity brought about by an increase in the price of its close substitute increases both the current spot price and the futures price. The forward premium, however, narrows as the magnitude of the rise of the spot price is higher than that of the futures price. The reason is that as consumption rises and inventories decline, the futures price must rise to keep equilibirum in the futures market. Other things remaining equal, an expected increase in the price of the substitute has the opposite effect on the forward premium. The marginal return on the hedged stock must increase to encourage carrying inventories forward to meet increased demand in the next period.

The behavior of the forward premium under an increase in current or expected income is the same as that under an increase in the price of the substitute commodity. On the other hand, the direction of the forward premium under a current or expected appreciation of the dollar is the same as that under an increase in current or expected increase in production.

By making financial instruments more attractive than commodities, an increase in current interest rates increases the opportunity cost of holding inventories. Hence, depressed commodity prices and the prospect of less carryover to the next period lead to futures price increases to widen the marginal return on hedged stocks. Note, however, the rise in the marginal return on hedged stocks will match exactly the rise in the interest rate only if current consumption does not respond to price, i.e., where $a = 0$

An expected increase in the interest rate depresses both the spot and the futures price and narrows the forward premium. Underlying this behavior is the impact of the expected increase in the interest rate on the expected spot price. Since the latter will unambiguously fall, the speculators' profit expectations will also fall and hence their demand for futures contracts. To maintain equilibirum in both the spot and futures markets, both the spot price and the futures price must fall. The narrowing of the forward premium implies a much larger decline in the futures price compared to the cash price.

3. Empirical results and model evaluation

Having outlined the theoretical framework, we now apply it to a study of a major internationally traded crop: corn. The sample data consist of quarterly observations over the 1973I-1983IV period . Detailed description of the data and their sources are presented in the Appendix . While in our theoretical discussion the price of substitutes was treated in generic terms, in the empirical testing of the theoretical model, we considered soybeans as the closest substitute.

Since expression (12) explicitly shows that the forward premium depends not only upon current levels of supply, price of substitutes, exchange rates, income, and interest rates, but also upon their expected values, some mechanism is needed to forecast their future levels. The method we adopt here is standard time- series analysis, based on the proposition that all useful information pertaining to the future levels of exogenous variables is contained in past observations (Wallis, 1980). The specification used to describe the time series properties of observed levels of an explanatory variable, Z_t, is as follows:

$$Z_t = constant + \alpha t + \sum_{i=1}^{T} \lambda_i Z_{t-i} + \epsilon_t$$

where α is the coefficent of the time trend t, and the λ_i's are autorogressive parameters. This specification captures both long term behavior as well as short term fluctuations of the time series. One step-ahead forecasts were generated for all the exogenous variables.

Finally, We treat h, the marginal holding cost, as a constant and replace R_t by r_t, the real rate of interest; hence an intercept term is added to the model. The final estimating model is as follows:

$$F_t - P_t = \beta_o + \beta_1(W_t - E_tQ_{t+1}) + \beta_3(S_t - E_tS_{t+1}) + \beta_5(X_t - E_tX_{t+1})$$
$$+\beta_7(Y_t - E_tY_{t+1}) + \beta_9 r_t + \beta_{10}E_t r_{t+1} \qquad (13)$$

where $W_t = (I_{t-1} + Q_t)$.[3] The expected signs for the parameters are listed after equation (12).

Table 1 summarizes the estimation results. Generally speaking, the results are satisfactory. All the explanatory variables have the theoretically-expected signs and are statistically significant at or above the 10 percent level. The only exceptions are the coefficients on the intercept and the supply variable which are not statistically different from zero. We suspect the weak results for the supply variables may be associated with the data limitations due to unavailability of quarterly production figures and stocks for countries other than the United States.

The model confirms the strong influences of the current and expected values of the price of soybeans and current and expected level of interest rates. These variables are statistically significant at or above the 5 percent level. The results for the interest rates are consistent with the findings of other commodity studies (Chu and Morrison, 1986). The role of the real dollar exchange rate and income in the determination of the forward premium, is also significant, but not to the extent of soybean prices and interest rates. Perhaps this is more a consequence of the periodicity of the model rather than their unimportance as economic variables. Price response to exchange rates may take longer lags than the ones considered in this study. Moreover, the volume of exports/imports may be more reflective of commitments made prior to the current quarter. Along the same lines, because it is largely an input into livestock production, corn may be affected by rising income only after longer lags.

To evaluate the forecasting performance of the forward premium equation, an ex-post simulation was conducted for comparing the difference between actual and simulated values of the dependent variable. The measure used to evaluate the ex-post simulated was the decomposed Theil Inequality Coefficient. The latter consists of a bias proportion which accounts for systematic error in the model, a variance proportion which measures the model's ability to replicate the variability in the dependent variable, and a covariance proportion which accounts for the unsystematic error. The results of the decomposition are as follows: Bias=.090; variance=.115; and covariance=.795; It is evident that the model has virtually no systematic error and is capable of replicating the degree of variability of the corn forward premium over the sample period.

4. Conclusions

This paper investigates the linkage between world macroeconomic factors and primary commodity prices in international markets by explicitly accounting for the role of futures markets in stockholding behavior. The empirical analysis is carried out with quarterly data of a storable, internationally traded agricultural commodity: corn. A reduced-form relative price equation for the corn forward premium is derived from a global market model that combines both futures and current markets along the lines suggested by Bond (1984), and is estimated over the 1973I-1983IV period.

The empirical findings provide evidence that world macroeconomic factors, in addition to traditional market variables, have an important influence on relative price movements for an individual internationally traded agricultural commodity. More specifically, the empirical analysis indicates that the cyclical movements of the corn forward premium are readily explainable by fundamental economic variables.

The empirical part of the model can be improved in two ways. First, greater emphasis should be placed on accounting for supply-side and policy factors underlying the fluctuation of world agricultural prices. Second, better estimates of quarterly world supplies and stocks for agricultural commodities are needed for a more complete understanding of market behavior.

In conclusion, this study serves as a reminder of the necessity to think more globally in setting agricultural policy price objectives and in forecasting agricultural prices. Since the results of this study provide evidence that international commodity market variability can, to an extent, be explained by world macroeconomic factors, such policies as commodity agreements, reductions of trade barriers, food security schemes, and government schemes to purchase and hold stocks alone will be inadequate to dampen price fluctuations or adjust price levels. Therefore, it is essential to clearly understand the linkage between world macroeconomic forces and agricultural commodity markets for the purpose of establishing appropriate agricultural policy alternatives.

Notes

[1] A notable exception is the work by Subotnick and Houck (1982). However, the authors concentrated on purely domestic factors.

[2] Whether the futures price is a useful predictor of spot prices is subject to debate. For our purposes, futures prices reflect the costs of carrying inventory (Hwa, 1979).

[3] The estimated forecasting equations are as follows:

$$E_t Q_{t+1} = 7.895 + .018t + .941 Q_{t-3}$$

$$E_t S_{t+1} = -.031 - .002t + .859 S_t$$

$$E_t X_{t+1} = 4.530 + .007t + .924 X_t$$

$$E_t Y_{t+1} = 4.330 - .008t + 1.080 Y_t - .217 Y_{t-2}$$

$$E_t r_{t+1} = 1.787 + .010t + .882 r_t$$

Appendix

P_t = Index of the real price for the U.S. No. 2 yellow corn , f.o.b. Gulf ports, export price base. The price is deflated by the consumer price index for 21 industrial countries. The countries are: the United States, Canada, Australia, Japan, New Zealand, Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. Source: *International Financial Statistics* (International Monetary Fund, Washington), various issues.

F_t = Index of the Real futures price of corn calculated on a quarterly basis. It represents an average of weekly futures-closing-prices delivered the subsequent quarter for Chicago no. 2 yellow. It is also deflated by the consumer price index for the 21 industrial countries. Source: *Grain Market News* (Consumer and Marketing Service, USDA, Washington); *Statistical Annual*: Chicago Board of Trade (Board of Trade, Chicago), various issues.

I_{t-1} = Carry-over stock of corn in 1000 metric tons from the previous quarter. Since quarterly data on carry-over stock at the global level are not available, quarterly data of the U.S. stocks of the commodity are used as proxies. Source: *Feed Situation* (Economics, Statistics, and Cooperatives Service, USDA, Washington).

Q_t = World production of corn in 1000 metric tons. Production of major producing countries of the commodity was allocated on a quarterly data basis by using the world harvesting calendar. Source: *FAO Production Yearbook* (Food and Agriculture Organization of The

United Nations, Rome), various issues.

S_t = Index of the Real price of Soybeans. This is the U.S. c.i.f Rotterdam price and deflated by the consumer price index of 21 industrial countries. Source:*International Financial Statistics* (International Monetary Fund, Washington), various issues.

X_t = Corn-specific Index of the real effective bilateral U.S. dollar exchange rate at time (quarter) t defined as:

$$Index_t = 100 exp \sum_{i=1}^{n} w_i log_e(E_{it} \frac{DF_t^{US}}{DF_{it}}).$$

Where E_{it} = (Base period exchange rate of currency i)/(Exchange rate of currency i at time t), with all exchange rates expressed in U.S. cents per unit of foreign currency; DF_t^{US} and DF_{it} are indices of consumer price levels at time t for the United States and country i respectively; and w_i represents the share of the ith country in U.S. exports of corn (1972-1976 average). The data were obtained from the I.M.F., *International Financial Statistics* tape. The bilateral weights w_i used for computing the trade-weighted indices for the commodity are as follows: W. Germany, .1732; Japan, .2900; France, .0384; England, .0546; Canada, .0341; Italy, .1231; Netherlands, .1807; Belgium, .0260; Spain, .0799.

Y_t = Index of industrial production for 18 major industrial countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom and the United States). Seasonally adjusted industrial production indices are averaged for the 18 countries (base year 1975 = 100). Source: I.M.F., *International Financial Statistics*, various issues.

r_t = Real world interest rates (in percent). The three-month London Eurodollar interest rate is used as a proxy for the nominal world interest rate. The three-month London Eurodollar interest rate minus the expected world inflation rate is used as the real world interest rate. The weighted average of the consumer price index in the 21 industrial countries was used to generate the world inflation rate. Sources: *Bank of England Quarterly Bulletin* (Bank of England, London); *International Financial Statistics* (International Monetary Fund, Washington); *OECD Financial Statistics* (OECD, Paris); *Federal Reserve Bulletin* (Board of Governors of the Federal Reserve System, Washington), various issues.

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Table 1. Least squares estimates of the forward premium equation (13)[1]

Coefficient	Estimate	t-ratio
β_o	.129	.220
β_1	.025	.511
β_3	-.132	2.425**
β_5	.324	1.658*
β_7	-.717	1.430 *
β_9	.034	3.193**
β_{10}	-.346	2.897**
R^2	.56	
D-W	1.51	

[1] R^2 denotes the coefficient of multiple correlation; D-W denotes the Durbin-Watson. The double asterisk (**) denotes significance at the 5 percent level; the single asterisk (*) denotes significance at the 10 percent level. Sample period 1973I-1983IV.

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