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Introduction

Numerous papers have been presented which analyze the relationship between monetary variables and agricultural commodity prices. It has been demonstrated that due to unique characteristics of agricultural commodities and markets, domestic monetary shocks may have real and nominal effects on agricultural commodity prices (Saunders, Devadoss and Meyers, Frankel, Chambers, Lombra and Mehra, and Barnett, Bessler, and Thompson). Schuh (1984, 1986), Edwards, Chambers and Just (1981) and Kost suggest that exchange rate movements may be the reason for the notable increase in commodity price variance since 1973; McKinnon, Khan and Heller's analysis suggests that foreign monetary shocks are important in explaining price movements -- particularly agricultural commodity prices. Previous theoretical models, however, do not allow for government intervention in the commodity markets nor consider the impact of different assumptions regarding expectations.

In this paper we investigate the monetary factors on agricultural commodity prices and stocks within the context of a model which explicitly models government behavior. This model is an adaption of the model Kouri used to analyze the dynamic behavior of the exchange rate and later Van Duyne used to analyze the macroeconomic effects of commodity market disruptions. In addition, using structural VAR
models which take into consideration government intervention, we also take an empirical look at the impact of foreign and domestic monetary shocks on commodity prices and analyze whether the relationship between monetary aggregates and commodity prices changed with the advent of floating exchange rates.

Theoretical Model

Stock Demand for Agricultural Commodities as Assets

We follow the portfolio balance approach to asset price determination. Under this approach, the prices of assets adjust to equilibrate asset demand with the given supply of assets at all points in time. In our model, an aggregate agricultural commodity (C) is held in portfolios along with three financial assets: domestic money (M), domestic bonds (B), and foreign bonds (F). The agricultural commodity is included as a form of portfolio investment because, as Bosworth and Lawrence note, "commodities may be attractive as an asset both because of expectations about their own future prices and because of their usefulness in a portfolio to diversify the risks of holding other assets" (p. 66).

We specify two economic agents who hold commodity stocks: private agents (producers, consumers and merchants) and the domestic government acting through the Commodity Credit Corporation (CCC). As opposed to private agents, the
CCC does not have a speculative demand for commodity stocks. The level of CCC commodity stocks at any point is determined by the past history of CCC flow demand. The stock equilibrium condition for the commodity market depends on private asset demand:

(1) \[ PC = c(r, r^* + \pi, r_c, W), \]

where

\[ W = PC + EF + M + B, \]

\[ r = \text{nominal yield on domestic bonds}, \]

\[ r^* = \text{nominal yield on foreign bonds}, \]

\[ \pi = \text{expected rate of change in the domestic currency price of foreign assets, E}, \]

\[ r_c = \text{expected nominal yield on commodities}, \]

The equilibrium conditions for the three financial assets are as follows:

(2) \[ M = m(r), \]

(3) \[ B = b(r, r^* + \pi, r_c, W), \]

(4) \[ EF = f(r, r^* + \pi, r_c, W) . \]

We endogenize \( r^* \) by including a foreign money demand equation in our model:

(5) \[ M^* = m^*(r^*), \]

where \( M^* = \text{foreign money supply}. \)

The partial derivatives of the above specified asset demand functions are assumed to have the following signs:

\( c_1, c_2, m_1, b_2, b_3, f_1, f_3, m_1^* < 0 \) and \( c_3, c_4, b_1, b_4, f_2, f_4 > 0 \).

Furthermore the following relationships are assumed to hold among the partial derivatives of the asset demand functions:
\[ c_1 + m_1 + b_1 + f_1 = 0, \quad c_2 + b_2 + f_2 = 0, \]
\[ c_3 + b_3 + f_3 = 0, \text{ and } c_4 + b_4 + f_4 = 1. \]

When all prices, stocks, and returns, other than \( P \) and \( C \) are given (exogenous), desired (actual) holdings of commodity stocks are a decreasing function of the price of commodities with elasticity: \( (dC/dP)(P/C) = -1 \).

This relationship is illustrated in figure 1 as schedule c.

**Flow Excess Supply for Commodities**

The home country (U.S.) produces and consumes two goods: an aggregate agricultural commodity with "flex" price \( P \) and an aggregate manufacture with "fixed" price \( P_m \). "Flex" means to mean that the agricultural commodity price can jump instantaneously to clear the asset market. The aggregate manufacture is best thought of as containing heterogeneous traded goods and nontraded goods for which the law of one price does not hold. The U.S. flow supply and demand functions for the agricultural commodity are respectively \( S_c = s(P, p) \) and \( D_c = \phi(P, P_m, Y) \), where \( Y \) is the level of demand through which monetary shocks affect domestic flow demand; i.e., \( Y(M) \).

The foreign country produces only the manufacture and imports the agricultural commodity from the U.S. Therefore its demand function for the agricultural commodity is \( D_c^* = \phi^*(P, E, P_m^*, Y^*) \), where \( * \) denotes the foreign counterpart of the domestic variable. Note that we are
Figure 1. Equilibrium in Flow and Asset Markets
assuming that foreign import demand responds differently to exchange rate changes than to export price changes (see Chambers and Just (1979) and Niehans). The CCC's flow demand is assumed to be a function of the difference between the spot price \( P \) and the underlying long-run or steady-state price \( \bar{P} \). The CCC stabilizes prices by selling commodities when the spot price is above its steady-state and buying commodities when the spot price is below its steady-state. Therefore, CCC stocks adjust according to:

\[
g = - \delta (P - \bar{P}), \quad \delta > 0.
\]

Following a shock that moves \( P \) away from its steady-state, the larger is \( \delta \), the faster \( P \) adjusts back to its steady-state. The steady-state price of the commodity \( \bar{P} \) is determined by the behavioral condition that private excess supply equals zero:

\[
0 = s(P, P_m) - \phi(P, P_m, Y) - \phi^*(P, E, P_m^*, Y^*). \tag{3}
\]

Given the specification of government behavior, the rate of change of private stocks is as follows:

\[
\dot{C} = s(P, P_m) - \phi(P, P_m, Y) - \phi^*(P, E, P_m^*, Y^*) + \delta (P - \bar{P}).
\]

For convenience we will write this expression as

\[
\dot{C} = h(P, E, Z, X)
\]

where \( X = x(M, M^*) \), the channel through which domestic and foreign monetary shocks affect flow demand, and \( Z = z(P_m, P_m^*) \), the channel through which changes in domestic and foreign manufacture prices affect flow demand. The signs of
the partial derivatives of the $h$, $x$ and $z$ functions are posited to be as follows:

$h_1', x_1', x_2', z_1', z_2 > 0$ and $h_2, h_3, h_4 < 0$.

It is important to note that $h_1 = s_1 - \phi_1 - \phi_1^* + \delta$.

For given $X$, $Z$ and $E$, $h$ is a function of the nominal price of commodities $P$ with slope $1/(s_1 - \phi_1 - \phi_1^* + \delta)$. as illustrated in figure 1 as schedule $h$. Note that the larger is $\delta$, the flatter is the $h$ schedule.

**Comparative Statics and Dynamics under Static Expectations**

In this section we analyze the model under the assumption that expectations in the commodity market are static -- $r_c = 0$. Let us consider an exogenous dollar appreciation (a decrease in $E$). Our model -- described above by equations (1), (2), (5), and (6) -- yields the following comparative statics in this case:

$$\frac{dP}{dE} = \frac{c_4F}{C(1-c_4)} > 0,$$

$$\frac{dC}{dE} = h_2 + h_4\left(\frac{dP}{dE}\right).$$

The immediate effect of the dollar appreciation on the commodity price is certain: As a result of the decrease in domestic wealth, asset demand for commodities falls which causes an immediate decrease in $P$. Of course if the law of one price and the small country assumption holds, $\frac{dP}{dE} = 1$. However, whether excess supply or demand emerges is unclear as can be seen from examining $\frac{dC}{dE}$. One
possibility is illustrated in figure 2a. Here adjustment in the asset market so depreciates the spot price that even given the decrease in foreign import demand, there will exist excess demand and the commodity price will rise over time. In figure 2a this is illustrated as a movement from a to b and then to d. If the initial jump in the commodity price (shift in c schedule) would have been modest relative to adjustment in the flow market (shift in the h schedule), the commodity price would have continued to adjust down after its initial jump downward. Therefore, although the initial movement in the commodity price following a dollar appreciation is unambiguous, the dynamics are ambiguous: nominal price overshooting may or may not occur.

Still considering the case of a dollar appreciation, let us assume that the CCC is very aggressive in limiting the fall of the commodity price (a larger \( \delta \) and hence flatter h schedule). This case is illustrated in figure 2b. As above, the excess supply function shifts down and portfoliо adjustment by private agents causes the asset demand function to shift left. But because of CCC intervention the h schedule is flatter. Consequently adjustment to the new steady-state is faster: the commodity price moves from b' to d along \( \hat{h}' \) rather than from b to d along h'. If \( \delta \) were sufficiently large, the commodity price would jump immediately to the new steady-state.
Figure 2a. Dollar Appreciation (Initial Excess Demand)
Figure 2b. Dollar Appreciation (CCC Intervention)
Comparative Statics and Dynamics
Under Rational Expectations

Assuming rational expectations (perfect foresight) in the commodity market implies that \( r_c = \dot{P}/P \). This assumption changes our model defined by equation (1) - (6) by making \( r_c \) endogenous. The steady-state properties of this model are equivalent to the static expectations case. The dynamics and comparative statics, however, are different. To analyze the model under rational expectations, a phase diagram is derived from equations (1) and (6) and illustrated in figure 3. It can be shown that the the larger is \( \delta \), the flatter is the phase path.

The analysis of the response of the system to exogenous disturbances depends upon whether the disturbance is anticipated or unanticipated. First consider an unanticipated dollar appreciation. The dynamics of this case are illustrated in figure 4a. The dollar appreciation causes both the hand and c schedules to shift down, the latter because of the fall in wealth. The exact behavior of the commodity price and stocks depends upon the magnitude of the two shifts. If the respective shifts are to \( h' \) and \( c' \) then the spot price falls immediately following the appreciation from a to b where it then continues to fall along the rational expectations path to d. In this case rational expectations lead to stabilizing speculation — the price moves to its new equilibrium more rapidly than with static
Figure 3. Phase Diagram (Exogenous Exchange Rate)
Figure 4a. Unanticipated Dollar Appreciation
expectations. If the asset demand shift is to c", then the commodity price falls immediately to e and then adjusts upward along the rational expectations path to f. Hence, in this instance rational expectations also leads to stabilizing speculation -- the price moves more rapidly to the new equilibrium than would have occurred with static expectations.

Consider now the case where the dollar appreciation is anticipated as illustrated in figure 4b. Let T₀ be the point in time when the dollar appreciation becomes anticipated and T₁ be the point in time of the actual appreciation. Between time T₀ and T₁, the movement of commodity prices and stocks is described by an unstable path of the system corresponding to the initial equilibrium. Since stocks cannot jump upon the "announcement" of the coming dollar appreciation and commodity prices can, the system will move to a point like b from a upon such an announcement. Commodity prices and stocks will then both fall along this unstable path until the actual appreciation. This scenario offers the paradox of dwindling stocks occurring simultaneously with falling commodity prices. After time T₁, the system is described by the saddle path corresponding to the new equilibrium -- point e. Hence at the moment of actual appreciation (point d) the system switches from the unstable path (corresponding to steady
Figure 4b. Anticipated Dollar Appreciation
state a) to the saddle path corresponding to the new steady state. After time $T_1$, commodity stocks increase and prices fall.

To analyze the impact of CCC intervention policy in the presence of rational expectations, consider a domestic monetary contraction. This particular shock would cause a change in both flow and asset demand. To single out the impact of CCC intervention, let us assume that only asset demand is affected as illustrated by the upward shift in the $c$ schedule as illustrated in figure 5. Without CCC intervention, the commodity price will immediately jump up from $a$ to $b$. However, since CCC intervention flattens the phase path, with CCC intervention the initial increase in the commodity price is smaller -- from point $a$ to point $b'$ rather than to $b$. If CCC intervention were sufficiently strong (flat phase path), the commodity price would not move at all. The impact of the monetary shock would show up completely as a change in CCC stocks.

This last example brings up an important point to consider when empirically looking at the relationship between monetary variables and agricultural commodity prices: The historical effects of monetary may show up as movements in CCC inventories rather than as movements in commodity prices themselves. Thus in addition to including price and monetary variables in the empirical models below,
Figure 5. Domestic Monetary Shock with CCC Intervention
CCC inventories are included as an additional important measure of the effects of monetary shocks on commodity markets.

Empirical Model

In this section we empirically look at the impact of monetary factors on agricultural commodity prices and test whether the relationship between monetary variables and agricultural commodity prices has changed over time -- specifically going from fixed to floating exchange rates; i.e., is agriculture more subject to monetary shocks under the current regime as some have concluded (Rausser 1985, 1986, 1988 and Schuh 1974, 1984). To look into this issue four variable VARs are estimated which include the variables first difference in nominal grain price index (P), log difference in international reserves (R), log difference in U.S. M2 money supply (M), and log difference in CCC inventories (g). The variables were found not to contain a unit root nor to be cointegrated. (For the relevancy of unit roots and cointegration to VAR models see Engle and Granger.)

What we call model A is used to construct variance decomposition to investigate the differing impact of monetary variables on commodity prices and CCC inventories in the two separate sample periods: 1962:2 - 1972:4 and 1974:2-1988:2, i.e., pre-1973 and post 1973. This
contemporaneous structural model (see Bernanke and Orden and Fackler) has the following form:

\[ P(t) = r_1 R(t) + r_2 M(t) + \epsilon_1(t) \]
\[ R(t) = \epsilon_2(t) \]
\[ M(t) = \epsilon_3(t) \]
\[ g(t) = r_3 R(t) + r_4 M(t) + \epsilon_4(t) \]

For what we call model B, we substitute \( P \) into the equation for \( g \) and write

\[ P(t) = r_1 R(t) + r_2 M(t) + \epsilon_1(t) \]
\[ g(t) = \delta_4 P(t) + \epsilon_4(t) \]

with the other two equations the same as above. The last equation of this structural model is interpreted as the CCC reaction function and gives a measure of the contemporaneous response of CCC inventories to commodity price shocks. The VAR models underlying these structural models include four lags of each variable in the equations for \( P \) and \( g \) while \( M \) and \( R \) are modeled as autoregressive processes of order two.

The variance decompositions associated with model A for the two different sample periods are reported below in table 1. When the role of CCC inventories is considered, there is an interesting difference in the effects of monetary shocks on commodity prices between the two sample periods. In the pre-73 period the effects of money shocks on commodity markets showed up more as movements in CCC inventories rather than as a movement in prices: monetary
Table 1. Summary of Selected Variance Decompositions:
Percent of Forecast Error Variance of the Dependent Variable Attributable to Innovations in Column Variable (4 qtr forecast horizon)

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>PRE-73</th>
<th></th>
<th>POST-73</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>M</td>
<td>R</td>
<td>M</td>
</tr>
<tr>
<td>P</td>
<td>5.68</td>
<td>.60</td>
<td>6.28</td>
<td>14.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.41</td>
<td>17.31</td>
</tr>
<tr>
<td>g</td>
<td>15.35</td>
<td>9.25</td>
<td>24.60</td>
<td>2.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.53</td>
<td>11.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30.88</td>
<td>28.79</td>
</tr>
</tbody>
</table>
variables (R and M) account for 24.60 and 6.28 percent of the forecast variance (one year horizon) of CCC stocks and prices respectively for this period. Since 1973 the reverse is true. Monetary shocks account for more of the forecast variance of commodity prices than stocks: 17.31 percent versus 11.48 percent. Hence, if just the impact of monetary variables on agricultural commodity prices is considered, there appears to be a larger impact post-73 than pre-73. But when consideration is given to the stabilizing role of CCC stocks the opposite conclusion could be reached: 30.88 percent and 28.79 percent of the forecast error variance in commodity prices and stocks can be attributed to monetary shocks pre-73 and post-73 respectively -- approximately the same amount.

It is also interesting to compare the size of the CCC intervention parameter from model B for the two sample periods. For pre-1973 we have \( g(t) = -4.45P(t) \) (t-statistic of -1.84). For the post-1973 sample it was estimated to be \( g(t) = 2.70P(t) \) (t-statistic of 2.35). Thus it appears that the CCC may have taken a somewhat more active role in the commodity markets in the pre-73 period.

Conclusions

Our theoretical analysis illustrates that monetary shocks -- through changes in interest rates and wealth -- affect commodity prices via adjustments in the asset
markets. Furthermore as determinants of domestic and foreign import demand, monetary shocks also affect commodity prices through adjustments in goods markets. The dynamics of commodity prices following a monetary shock depend upon the relative impact of the particular shock on stock versus flow demand.

We find that monetary shocks have a significant impact on agricultural commodity markets. For the pre-1973 period, monetary shocks account for 24.60 percent of the forecast variance in CCC inventories versus only 11.48 percent for the post-1973 period. For comparison, monetary shocks account for only 6.28 percent of the forecast variance in commodity prices for the pre-1973 period versus 17.31 percent for the post-1973 period.

These variance decomposition and estimates of the CCC intervention parameter suggest that the noted increase in nominal agricultural commodity price variance since 1973 may be due to a change in the CCC intervention policy rather than in the exchange rate regime.
References


Footnotes

1. The cost of storing commodities is assumed to be zero. As long as explicit storage costs are constant, this assumption will not affect the analysis.

2. Note that we are assuming that $r$ and $r^*$ are determined in their separate, respective money markets and are independent of wealth and the returns on the other assets in the model. This is a standard assumption in portfolio balance models (see Branson and Henderson).

3. This is similar to Van Duyne's model. The differences are that in his model supply is fixed and foreign import demand depends only on P/E.

4. Note that we are assuming that $(d\phi/dy)(dY/dM = (dh/dX)(dX/dM) = h_4x_1$ and similarly for the foreign variables.

5. It is assumed that the dollar appreciation is exogenous ($r$, $r^*$, $M$, and $M^*$ are held constant). One can think of the capital inflow being a result of "safe haven" considerations.
6. Data for the grain price series were taken from various issues of *Wholesale Prices and Price Indexes*. The international reserves series was constructed from data reported in Heller and from various issues of *IFS* (line 15, all countries, 010). Domestic money supply data were taken from Gordon and various issues of the *Federal Reserve Bulletin*. CCC inventory data were obtained from various issues of *Agricultural Statistics*. All data are available from the authors on request.