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DYNAMIC WELFARE ANALYSIS AND
COMMODITY FUTURES MARKETS OVERSHOOTING

by

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I. INTRODUCTION

Much of the analysis conducted on commodity futures markets focuses on partial equilibrium frameworks (Fama, 1970, and Stein, 1981). However, linkages among markets implied by general equilibrium representations show that such analyses can suffer from serious limitations (Walraven and Rausser, 1986). In particular, studies of futures market efficiency which search for single series martingale or random walk processes cannot be expected to classify markets correctly.

Linkages among markets forces inefficiencies in one market to be transmitted to related markets. Nowhere is this more likely to be evident than in commodity futures markets. Since these markets reflect price expectations, differential information flows in the various markets will generally result in varying speeds of adjustment to causal forces.

Varying speeds of market adjustment have been used by Dornbusch (1976) and others to show that exchange rates can overshoot as a result of such market behavior. In this work, and the subsequent work by Frankel (1979), exchange rates overreact to a monetary shock in order to compensate for the disequilibrium arising in a more slowly adjusting goods market. In the Dornbusch formulation, the long-run steady state remains unchanged while the exchange rate equates (temporarily) demand and supply in both the exchange and goods markets. For an expansionary monetary shock, the exchange rate moves to a level higher than that implied by the new long-run equilibrium and falls gradually as the sticky goods market adjusts. Prices in the efficient market overshoot the eventual equilibrium levels in order to clear the relatively inefficient goods market.

The basic Dornbusch model will be extended in this paper to examine the linkages among three groups of markets: interest rates, exchange rates, and commodity markets. Price expectations, as represented by futures markets, will be emphasized. Unlike the Dornbusch model, in which all goods prices except exchange rates are presumed to be sticky, interest rates and agricultural prices will be allowed to be "flexible." Futures contracts for agricultural commodities are homogeneous, frequently traded, and (mostly) storable and, thus, are presumed to be flexible and governed by instantaneous arbitrage.

Allowing flexibility in some markets with less flexibility in other markets admits the possibility of overshooting, in spot markets for interest rates, exchange rates, and commodity markets. To the extent that this overshooting exists, does it carry over to the formation of expectations as reflected by futures markets? If resource allocation decisions

are based on these expectations, what are the welfare implications of overshooting? These questions are investigated by quantifying the dynamic linkages among U. S. Treasury bills (T-bills); the British pound; the Canadian dollar; the German mark; the Japanese yen; and three agricultural commodity markets, corn, cotton, and wheat.

A vector autoregressive moving average model is empirically estimated for a specific period of tight monetary policy, viz, 1980 through the spring of 1982. Based on the dynamic adjustment paths, pricing efficiency is examined, accuracy and speed of convergence measures are calculated, and dynamic welfare measures are computed. The accuracy measure is the total absolute deviation from final equilibrium levels of each price series during the adjustment period. The speed measure is the number of trading days required for some percentage of the total deviation to occur.

II. BASIC SPECIFICATION

The existence of differential responses to monetary shocks among markets can lead to "overshooting." More specifically, price stickiness in some markets is a necessary but not a sufficient condition for overshooting. Hence, whether pricing inefficiencies in one market leads to overshooting and allocative inefficiencies in another market is an empirical question. To demonstrate this result, a basic model specification linking interest rates, exchange rates, sticky price, and flexible price markets is advanced. The formulation is based on an open economy and allows for endogenous output responses to dynamic price adjustment paths.

The sticky-priced or manufactured goods sector is represented by

$$y_m^s = y_m^d \quad (1)$$

$$y_m^d = a_0(p_c - p_m) - a_1(i - u - \bar{r}) + a_2 y_m^s + a_3(p_m^* + e - p_m) \quad (2)$$

$$\bar{y}_m^p = (a_0/1 - a_2)(\bar{p}_c - \bar{p}_m) - (a_1/1 - a_2)\bar{r} \quad (3)$$

where $0 < a_2 < 1$; y_m^s denotes output supply; $\bar{y}_m^p$ defines potential output; y_m^d denotes demand for manufactured goods; p_c denotes the price of commodities, with $\bar{p}_c$ its long-run equilibrium counterpart; p_m denotes the price of manufactured goods, with $\bar{p}_m$ its long-run

equilibrium counterpart; p_m^* denotes the foreign price of manufactured goods; i denotes the nominal rate of interest; u denotes rate of inflation; $\bar{r}$ denotes the long-run equilibrium real rate of interest; and e denotes the exchange rate. All variables are defined in logs.

The rational expectation for commodity prices are generated by the arbitrage condition

$$\dot{p}_c^* = i + sc \quad (4)$$

where sc represents the storage costs associated with holding the flexible commodity stock from one period to another. For the money market, a standard money demand equation is assumed with the following equilibrium condition

$$m - p = \phi y - \lambda i \quad (5)$$

where m is the logarithm of the money supply, p is the logarithm of the general price index, y is the logarithm of income, and λ is the interest rate semi-elasticity of demand for real balances. This specification presumes that the money market clears at each moment in time.

Under the above specifications, manufactured goods are produced and imported; agricultural commodities are exported but not imported, with agricultural exports normalized to be zero; domestic and foreign manufactured goods are perfect substitutes; and, for the agricultural commodity market, purchasing power parity is assumed to hold in the long run. However, deviations from purchasing power parity occur in the short run due to differential adjustment speeds in exchange rates and manufactured goods prices. Note also that the small country assumption is presumed to hold.

For the price index (p), the underlying utility functions are assumed Cobb-Douglas, so that the prices are weighted by their expenditure shares, i.e.,

$$p = \alpha_1 p_m + \alpha_2 p_c + (1 - \alpha_1 - \alpha_2)(p_m^* + e) \quad (6)$$

In the short run, uncovered interest parity is presumed to hold

$$i - i^* = \dot{e} \quad (7)$$

where i^* is the foreign short-term nominal interest rate and $\dot{e}^*$ the expected rate of depreciation or appreciation of domestic currency. Since the small country's assumption is imposed, the nominal interest rate adjusted for expected appreciation is always equal to the (given) foreign rate. Implicitly, the specification assumes perfect substitutability between domestic and foreign interest-bearing instruments (a one bond world), absence of risk premia, and perfect capital mobility.

Since the manufactured goods market is presumed to be sticky in the short run, the price adjustment process is specified to be some distributed lagged of excess demand, i.e.,

$$\dot{p}_m = \Pi (y_m^d - \bar{y}_m^p) + u. \quad (8)$$

For the flexible price commodity market, expectations are presumed to be rational,

$$\dot{p}_c^* = \dot{p}_c. \quad (9)$$

Finally, for the case of exchange rate expectations, two alternative specifications are evaluated. One is based on rational expectations,

$$\dot{e}^* = e, \quad (10a)$$

while the other is based on regressive expectations,

$$\dot{e}^* = -\delta (e - \bar{e}), \quad (10b)$$

For the second specification (10b), the expected rate of appreciation or depreciation is assumed to be proportional to the gap between the exchange rate and its long-run equilibrium value ($\bar{e}$). Hence, if the spot rate exceeds its long-run value, these investors expect the rate to gradually appreciate a speed of adjustment equal to δ .¹ Finally, the normalization imposed is $\bar{p}_m = \bar{p}_c$, $\bar{y}_c = 0$ where y_c is the level of commodity output.

Combining equations in the basic model specification, the following price dynamic equations are obtained for the case of rational expectations (10a):

$$\begin{aligned}\dot{p}_c = & \frac{\alpha_1 - b_0\phi - b_3\phi}{\lambda + b_1\phi}(p_m - \bar{p}_m) + \frac{\alpha_2 + b_0\phi}{\lambda + b_1\phi}(p_c - \bar{p}_c) \\ & + \frac{1 - \alpha_1 - \alpha_2 + b_3\phi}{\lambda + b_1\phi}(e - \bar{e}) + u + \bar{r} + sc - \frac{1}{\lambda + b_1\phi}\varepsilon\end{aligned}\quad (11)$$

$$\begin{aligned}\dot{e} = & \frac{\alpha_1 - b_0\phi - b_3\phi}{\lambda + b_1\phi}(p_m - \bar{p}_m) + \frac{\alpha_2 + b_0\phi}{\lambda + b_1\phi}(p_c - \bar{p}_c) \\ & + \frac{1 - \alpha_1 - \alpha_2 + b_3\phi}{\lambda + b_1\phi}(e - \bar{e}) + u + \bar{r} - i^* - \frac{1}{\lambda + b_1\phi}\varepsilon\end{aligned}\quad (12)$$

$$\begin{aligned}\dot{p}_m = & \Pi \left[b_0 - \frac{b_1(\alpha_2 + b_0\phi)}{\lambda + b_1\phi} \right] (p_c - \bar{p}_c) \\ & - \Pi \left[b_0 + b_3 + \frac{b_1(\alpha_1 - b_0\phi - b_3\phi)}{\lambda + b_1\phi} \right] (p_m - \bar{p}_m) \\ & + \Pi \left[b_3 - \frac{b_1(1 - \alpha_1 - \alpha_2 + b_3\phi)}{\lambda + b_1\phi} \right] (e - \bar{e}) + u + \frac{\Pi b_1}{\lambda + b_1\phi}\varepsilon\end{aligned}\quad (13)$$

where

$$b_0 = \frac{a_0}{1 - a_2}, \quad b_1 = \frac{a_1}{1 - a_2}, \quad b_3 = \frac{a_3}{1 - a_2}.$$

From the above price dynamic equations, commodity price determination equations can be analytically derived. These equations for the commodity price path are

$$\bar{p}_c = \bar{m} - \phi\bar{y} + \lambda(\bar{r} + u) - \frac{1}{\theta_1}(i - u - \bar{r}), \quad (14)$$

and

$$\Delta p_c = \frac{1 + \theta (\lambda + \phi b_1)}{1 - \alpha_1 + \theta \lambda + \phi (b_0 + b_3 + \theta b_1)} \Delta m + \frac{\lambda + \lambda \theta (\lambda + \phi b_1)}{1 - \alpha_1 + \theta \lambda + \phi (b_0 + b_3 + \theta b_1)} \Delta u \quad (15)$$

where $-\theta$ is the negative root of the solution obtained by solving equations (11), (12), and (13) ($\Delta s_c = \Delta \bar{r} = \Delta \bar{y}_m (= \Delta \bar{y}) = \Delta p_m^* = 0$, and $m = \bar{m}$ are assumed in this derivation). Note that the results for the regressive and rational expectations of exchange rates collapse to the same outcome when $\delta = \theta$.

For equation (15), overshooting is only one of three possible outcomes. This can be seen from

$$\frac{\Delta p_c}{\Delta m} = 1 + \frac{\alpha_1 - \phi (b_0 + b_3)}{1 - \alpha_1 + \theta \lambda + \phi (b_0 + b_3 + \theta b_1)} \quad (16)$$

Hence, given that the denominator of the second term is positive, whether overshooting, undershooting, or neutrality results from a particular monetary shock depends upon the numerator of the second term in equation (16). More precisely,

$$\alpha_1 \begin{cases} > \frac{\phi (a_0 + a_3)}{1 - a_2} & \text{overshooting} \\ < \frac{\phi (a_0 + a_3)}{1 - a_2} & \text{undershooting} \\ = \frac{\phi (a_0 + a_3)}{1 - a_2} & \text{neutral} \end{cases} \quad (17)$$

The mixed results of (17) reflect the possibility that the output and demand responses to prices ($a_0 + a_3$), appropriately modified for the effect of output on money demand (ϕ) and the dynamic output adjustment ($1 - a_2$), can swamp the initial moves in flexible price commodity markets that would otherwise result. Hence, it depends empirically on the relative size of the expenditure share of the sticky price markets (α_1) and the responsiveness of output to prices and, in turn, the responsiveness of demand for real money balances to changes in output levels.

If the overshooting result occurs, its degree will depend upon four key parameters: the relative share of the sticky price markets in the domestic economy (α_1); the responsiveness of money demand (λ); the effect of output response on money demand; and the speed of adjustment (θ). The length of time overshooting will last is a negative function of θ . This parameter plays a major role in the speed of convergence to any new

long-run equilibrium resulting from a monetary shock. The remaining parameters dictate the magnitude of Δp_c during any particular period. The accuracy of any particular level of price relative to the long-run equilibrium level (Δp_c) and the speed of convergence (θ) are the major components of the appropriate dynamic welfare measure.

III. A DYNAMIC MULTICOMMODITY WELFARE MEASURE

The allocative efficiency loss during the joint adjustment of all prices to new equilibrium levels resulting from shocks requires the development of general equilibrium specifications welfare measures (Rausser and Just, 1981). Dropping the distinction between flexible and inflexible prices, consider the following system:

$$S_t = A_0 + A_1 \hat{p}_t, \quad A_1 \geq 0 \quad (18)$$

$$D_t = B_0 - B_1 p_t, \quad B_1 \geq 0 \quad (19)$$

$$\hat{p}_t = A^{-1}(L)B(L)Z_t, \quad Z_t \sim N(0, \sigma^2) \quad (20)$$

$$S_t = D_t \quad (21)$$

where p_t is the price of the commodity at time t ; $\hat{p}_t$ is the expected value of p_t at time $t-1$; A_0 , A_1 , B_0 , and B_1 are positive parameters of the supply and demand relationships; and $A(L)$ and $B(L)$ are polynomials in the lag operator and are assumed to be stationary and invertible.

The price expectation substitute for $\hat{p}_t$ in equation (18) will be determined by the vector ARMA representation of the dynamic interactions of the price series (19). If the vector ARMA model represents adequately the price series, then this approach approximates a rational expectations formulation of expectations, with the error in the approximation caused by transactions costs, risk aversion of agents, etc. (Rausser and Carter, 1983).

Equations (18) through (21) yield a price path as a function of structural parameters and expected prices

$$p_t = B_0/B_1 - 1/[B_1(A_0 + A_1\hat{p}_t)] \quad (22)$$

Assume that an initial steady-state level of prices, $\bar{p}$ exists and there is a shock, Z_0 , at time 0. Since $\bar{p}$ represents the net effect of all past adjustments, $\hat{p}_t$ for any time after time 0 is:

$$\hat{p}_t = \bar{p} + Q_t Z_0 \quad (23)$$

where

$$Q_t Z_0 = \sum_{j=0}^{t-1} (A^{-1}(L)B(L))_j Z_0.$$

In other words, assuming that there are no subsequent shocks, the effect of Z_0 at any time may be expressed as the initial steady state, $\bar{p}$, plus the net effect of Z_0 to that time. The deviation of prices from the eventual long-run equilibrium changes over time; therefore, the amount of welfare loss also changes over time.

To determine the welfare loss in a market at any time during the adjustment period, consider the static welfare analysis depicted in Figure 1. The long-run steady state is p_e following the shock, and y_e is the corresponding quantity. Given a stable and invertible model, $A(L)p_\infty = B(L)Z_\infty \rightarrow p_e$; that is, given no other shocks, the price path converges to its new equilibrium level. The expected level of prices for t periods following the shock is $E p_t = (Q_t Z_0 + \bar{p})$.

It is clear that the welfare loss at p_t relative to p_e is given by triangle abc. This area is given algebraically by halving the product of the base and height of abc:

$$WL_t = \frac{1}{2} (S(\hat{p}) - S(p_e)) (\hat{p} - D^{-1}[S(\hat{p})]) \quad (24)$$

Substituting from the demand and supply relationships and adding and subtracting $S(p_e) = D(p_e)$, the welfare loss at any time t is

$$WL_t = \frac{1}{2} \frac{A_1}{B_1} (B_1 + A_1) (\hat{p} - p_e)^2 \quad (25)$$

Note that this measure depends on the squared deviation of prices from the eventual equilibrium level and slope parameters of the supply and demand functions. This result is

Figure 1. Static Welfare Analysis

similar to the partial equilibrium measure of Stein for welfare losses due to futures market price inaccuracies. Because A_1 and B_1 represent $\partial S/\partial p$ and $-(\partial D/\partial p)$, respectively, the welfare loss expressed in terms of the supply and demand elasticities at (p_e, y_e) is:

$$WL_t = \frac{1}{2} \frac{y_e}{p_e} \frac{\eta_s}{\eta_d} (\eta_d - \eta_s) (\hat{p} - p_e)^2. \quad (26)$$

The total consumer and producer surplus at (p_e, y_e) is given by the area of triangle deb in Figure 1 which, when expressed in terms of elasticities, is

$$TS = \frac{1}{2} p_e y_e \left[\frac{A_1 \frac{p_e}{y_e} + B_1 \frac{p_e}{y_e}}{B_1 \frac{p_e}{y_e} A_1 p_e y_e} \right] = \frac{1}{2} p_e y_e \left[\frac{\eta_d - \eta_s}{\eta_s \eta_d} \right]. \quad (27)$$

Dividing equation (26) by equation (27) gives the percentage of total surplus lost as a result of the deviation of futures prices, i.e.,

$$\frac{WL}{TS} = \eta_s^2 \left(\frac{1}{p_e} \right)^2 (\hat{p} - p_e)^2. \quad (28)$$

Representation (28) has several advantages. First, the expression is solely in terms of the elasticity of supply, the new steady-state price, and the squared deviation of prices during the adjustment period. The last two variables are known for each market; therefore, the percentage welfare loss may be expressed in terms of one parameter, the elasticity of supply. Another advantage is the lack of scale for this loss measure. This allows various markets to be compared regardless of their size.

The form of this welfare measure depends upon several assumptions of the model, (18) through (21). First, the linear supply and demand allow the manipulations necessary to obtain the simple expression (28). The results hold only to the extent that the linear representation approximates the proper supply and demand relationships. The dependence of (28) on the supply elasticity rather than both supply and demand elasticities occurs because of the linear structure and because $\hat{p}$ in the supply equation (18) determines the quantity in any period. Once one component of the supply and demand relationships determining the surplus measure is fixed (i.e., the supply elasticity at (p_e, y_e)), any change in the other component has offsetting effects on total surplus and welfare loss. That is, rotating the demand curve clockwise around (p_e, y_e) in Figure 1 proportionately increases

both the welfare loss (26) and the total surplus (27), leaving their ratio unchanged. The supply elasticity becomes the scaling factor in (28) because the expected price determines the quantity via supply.

Of course, to obtain the total welfare loss for the adjustment period, one should discount losses at future dates by some discount rate. Specifying the number of periods for an arbitrary amount of the total adjustment to occur, the total welfare loss due to the deviation of prices is a function of the discount rate, elasticities of the supply and demand functions, the number of periods for the adjustment to occur, the new steady-state level of prices and quantities, and the squared deviations of futures prices from the new steady state following a shock. The first three parameters are assumed to be constant over the adjustment period, so welfare loss may be viewed as a function of the dynamic adjustment path of prices. In other words, the welfare loss depends on the accuracy (squared deviations) and the speed of convergence of the price series.

A crucial assumption for this view of the efficiency of observed price series is the nature of the long-run equilibrium in an environment of slowly adjusting prices. Futures markets clear each day, and allocative decisions involving futures prices may be made during the adjustment of prices to their new equilibrium levels. If the final equilibrium is affected by the series of temporary equilibria of all related markets, any measure of welfare loss based upon the final equilibrium which it obtains must be incorrect. The long-run equilibrium which would exist in the absence of lagged adjustment of prices is unobservable; so the new efficiency measures developed in this paper, while correcting for some of the possible misspecification of previous studies, may remain only partial evaluations of total efficiency.

Although the loss measure in equation (28) provides a convenient comparison of the relative efficiency of various markets, the absolute levels of welfare loss remain informative. The measurement problem that arises for the absolute welfare loss (27) is the absence of observations of y_e , the equilibrium quantity. Although some approximations of y_e are used in the empirical section, the approximations may be crude. A loss measure consisting of the forecast error weighted by the particular market's importance to the economy is both easily determined from available data and useful in assessing the total welfare loss in each market.

Dividing both sides of equation (26) by (y_e, p_e) yields

$$\frac{WL}{y_e p_e} = \frac{1}{2} \frac{\eta_s}{\eta_d} (\eta_d - \eta_s) \left[\frac{\hat{p} - p_e}{p_e} \right]^2. \quad (29)$$

This value expresses the welfare loss scaled by the total sales in the market or, in other words, the welfare loss per unit of revenue. An attraction of this quantity is the absence of unobserved equilibrium quantities from the right-hand side of the expression. The scaled welfare measure depends only on the elasticities of supply and demand, the steady-state price level, and the squared deviation of prices.

IV. METHODOLOGY, DATA, AND EMPIRICAL RESULTS

To capture empirically the dynamic price linked paths, a multivariate time series model is specified for an eight-market system. This model incorporates the relationships of T-bills and exchange rates (British pound, Canadian dollar, German mark, and Japanese yen--all in cents per unit of foreign currency) with corn, cotton, and wheat prices. As mentioned earlier, the dynamic interactions of the price series depend on the structural relationships of the underlying supply and demand functions. The existence of these interactions among agricultural commodities, as well as the relationship of agricultural commodities to interest and exchange rates, has been documented in numerous studies (Rausser, 1985).

The accuracy of the estimated efficiency for each market and for the system depends critically upon expressing the dynamic interactions adequately by identifying a suitable time-series representation. We chose vector ARMA representations because of their parsimony relative to the more widely used vector autoregressive models. Nevertheless, large-vector ARMA models still fall into the general class of overparameterized models, implying that some sort of restrictions other than identifying the order of the autoregressive and moving average polynomials may become necessary (Sims, 1980).²

The data used to estimate the vector ARMA consist of 205 observations for the March, 1981, delivery contracts of the eight variables mentioned above and 195 observations for March, 1982. These data span the period beginning in the spring of 1980 through the spring of 1982, a period during which financial markets adjusted to the new Federal Reserve (Fed) policy of targeting the money supply rather than interest rates. The two sets of observations provide estimates of pricing and allocative efficiency immediately following the Fed policy change (1981 delivery contracts) and much later (1982 delivery contracts).

The choice of the steady-state vector of prices used in the dynamic analysis influences all of the subsequent results. The welfare measures developed in section III depend on the steady-state level of prices. In addition, since the models all have

autoregressive terms, the new equilibrium price levels, as well as the dynamic adjustment paths, depend upon the initial steady state chosen.

The initial equilibrium of each series is obtained by forecasting from the end of the time series until no further change in the variables is observed. This approach, of course, provides only one of many possible steady-state levels for the vector of series. At any point in the sample, one could assume that there are no further shocks and find a different steady-state level. Any one of these steady states is preferable to some ad hoc level, such as the mean for each series, because the simultaneous observation of all series at their mean level may be highly unlikely. Since there is no definite trend in the price series, the choice of the last observation rather than another simultaneously observed set of prices will not affect the results.

The degree of correlation among the series in this study may be highly positive or negative, so a simultaneously observed set of prices was chosen--the last observation vector. Then, assuming no further disturbance, the estimated parameters are used to compute successive forecasts until there is no change in the forecast price. The estimated models are stable and invertible, so the forecasts converged to the equilibrium level, p_* --usually in about 25 periods.

The proper type of shock to consider when calculating the multipliers is an interesting question relating to the selection of the initial steady state. Most authors who construct vector autoregressive models analyze the dynamic properties of their models by using one standard deviation of a single series as a shock. In other words, one element of the shock vector is the standard deviation of the corresponding error series, and all other elements are zero. The probability of observing this particular shock may be extremely low, especially when the residual error terms are correlated. For example, given positive expected correlation of interest rate and the costs of storage, one might not expect to see large positive shocks both in T-bills and all commodity prices. Even if all the series are positively correlated, adjustment by the correlation matrix will reflect the relationships among errors.

The plausibility of the shock is very important since the resulting dynamic patterns are used to construct empirical measures. As mentioned earlier, positive shocks in one market or set of markets might be associated with a particular type of shock in a related market. An arbitrary choice of a particular shock might obscure this empirical relationship in the efficiency measure.

Consideration of a large positive shock in one leading market and none in an other should yield a different adjustment pattern than a simultaneous shock in several markets. If some particular type of shock rarely occurred and, therefore, hardly affected the estimated

relationships among the price series, then one should not use it to calculate the efficiency measure for the entire sample. In other words, the most likely shock during the sample period should be used to summarize the relative efficiency of the markets. Accordingly, a multi-market shock is employed here. It is generated by a one-standard deviation vector of errors from the fitted ARMA model multiplied by the empirical correlation matrix of the errors. This procedure yields the best estimate of the signs and relative magnitudes of the elements of the shock vector given the observed data. Multiplication by the correlation matrix adjusts each standard deviation by its correlation with all other series times the standard deviation of that particular series. This perturbation helps to demonstrate the dynamic interactions of the series and allows calculation of the empirical efficiency measures resulting from the single shock.

Fitting an (AR(1) MA(6,13,18)) model to the differenced, 1981 data, and an (AR(1) MA(5,6,8,14,15)) model to the differenced, 1982 data, yield the parameter estimates necessary for constructing the efficiency measures. Graphs of eight markets in terms of these efficiency measures, accuracy and speed, are given in Figures 2 and 3. Figure 2 effectively summarizes the previous comparison of the dynamic behavior of each market from the perspective of the absolute deviation measure of accuracy. Figure 3 displays a similar summary for a total deviation measure. In both graphs, the furthestmost point on the left for each series represents the number of periods following a shock required for 50 percent of the total response to occur. Similarly, the furthestmost point on the right represents the number of periods required for 75 percent of the total fluctuations to occur. The 1981 Canadian dollar series in Figure 2, for example, achieves 50 percent of the total adjustment by period 7 and 75 percent by period 17. The German mark, in contrast, achieves both 50 percent and 75 percent of its adjustment at period 18. When the deviation measures for two series overlap, parentheses indicate differing values of the speed measure. To illustrate, in Figure 3, the British pound and Canadian dollar have total deviation values of -1.28 and -1.05, respectively, which are too close to distinguish on the graph. The parentheses surrounding the symbol for the pound indicate that its speeds for 50 percent and 75 percent adjustment were 9 and 15 days, respectively. The vertical axes for Figures 2 and 3 measure the total absolute deviation and the total deviation, respectively. The values of these deviations are printed along the right side of each group.

These results indicate that agricultural markets for 1981 delivery tended to adjust more quickly and to deviate more than either interest rate or exchange rate markets. As shown in Figure 2, the agricultural markets achieved 50 percent of the total absolute deviation by period 7 in 1981. Furthermore, 75 percent of the total absolute adjustment occurred by period 7 for cotton, period 10 for corn, and period 14 for wheat. In contrast,

Figure 2. Accuracy in Terms of Total Absolute Deviations and Speed 1981

Accuracy in Terms of Total Absolute Deviations and Speed 1982

i denotes T-bills, b the British pound; % of the Canadian dollar; d the German mark; y the Japanese yen; c = corn; f = cotton; and w = wheat.

Figure 3. Accuracy in Terms of Total Deviation and Speed 1981

Accuracy in Terms of Total Deviation and Speed 1982

both interest rates and exchange rates generally took much longer to reach either 50 percent or 75 percent adjustment.

The total deviation values in Figure 3 show that the agricultural series dropped to their final levels while the other markets oscillated about their initial levels. The combination of large negative total deviations and large positive absolute deviations of the agricultural markets suggests that they generally fell after the period 0 reaction to the shock. The agricultural markets overshoot to the greatest degree followed by exchange rates. The empirical results indicate that agricultural markets exhibited both greater net overshooting and a faster speed of convergence in 1980-1981.

For March, 1982, delivery contracts, the German mark continued to show little deviation and to adjust slowly. The agricultural markets continued to deviate substantially more in absolute value than exchange rates or interest rates, but the speed was much more similar to the financial markets than previously. Indeed, the British pound achieved both 50 percent and 75 percent of its total adjustment faster than any other series, while the speed for the agricultural series was similar to that of the Japanese yen and T-bills.

The total deviation measures in 1982 are markedly different from 1981. In contrast to the -.05 to -30 range for 1981, the total deviation varied from 4.2 for T-bills to -11.2 for wheat; and the distinct difference between agricultural and financial contracts observed in 1981 is less clear.

The empirical dynamic adjustment paths can be used to compute the welfare measures developed in section III. Figures 4 and 5 express the percentage of total welfare lost as a result of the dynamic path of prices for 1981 and 1982, respectively. The percentage of total welfare lost as a function of squared elasticity of supply are represented along the vertical axis in these figures.

The figures show clearly that a much greater percentage of total welfare in the cotton and Japanese yen markets is lost in both 1981 and 1982. The other series have values markedly smaller, suggesting that, relative to total trade of the commodities, the cotton and Japanese yen markets were inefficient allocatively. Of course, this observation depends upon an assumption that the elasticity of supply for yen and cotton is nonzero and not drastically different from the other exchange rates and agricultural commodities, respectively.

The elasticity of supply for both yen and cotton in 1981 must be approximately $\sqrt{.25}$, while the elasticity of supply for the other commodities must be approximately $\sqrt{3}$ for there to be a roughly comparable percentage welfare loss in all the markets. Although there are no empirical estimates of daily supply-and-demand elasticities, general assumptions regarding relative elasticities may be made. It seems reasonable to assume that there is

Figure 4. 1981 PERCENTAGE WELFARE LOSS

Figure 5. 1982 PERCENTAGE WELFARE LOSS

some degree of price responsiveness, even on a daily basis. The difference in the loss measure becomes more pronounced if all series have roughly similar elasticities of supply. The similarity of the relative values in 1981 and 1982 suggests that greater welfare loss may be endemic to the yen and cotton markets.

Daily quantities supplied or demanded are necessary to calculate the welfare loss. Quantities supplied are readily available for agricultural markets, and the Federal Reserve Bulletin reports average daily trade in T-bills. The only source of data regarding the volume of spot market currency transactions seems to be a sampling done by the New York Federal Reserve Bank every three years. The last available data, sampled for the month of April, 1983, are given in Table 1. These monthly trade volume numbers provide an estimate of the daily volume which may be used to estimate the total welfare loss in the exchange markets.³

The welfare measure can be rearranged to be an expression involving two multiplicands, specifically:

$$WL_t = \left[\frac{\eta_s}{\eta_d} (\eta_d - \eta_s) \right] \left[\left(\frac{p_e y_e}{2} \right) \left(\frac{\hat{p} - p_e}{p_e} \right)^2 \right]. \quad (30)$$

The first term, involving elasticities of supply and demand, shall be denoted subsequently as the elasticity multiplicand. The second term, hereinafter called the deviation multiplicand, consists of the squared forecast error, constants, market revenues, and the squared equilibrium price.

The deviation multiplicand and its components are given in Table 1. The deviation multiplicand indicates that the loss due to deviations in the agricultural markets is miniscule compared to the losses in the T-bill, German mark, and Japanese yen markets if the elasticity multiplicands are of similar magnitudes across markets. That is, if the elasticity multiplicand, $\eta_s/\eta_d(\eta_d - \eta_s)$, is roughly comparable, the welfare loss is much less in the agricultural markets. The greater deviation of prices for agricultural series are more than counterbalanced by the large volume of trade in the financial markets.

The deviation multiplicand indicates that the Japanese yen, followed by T-bills and the German mark, should exhibit the greatest daily welfare loss due to slowly adjusting prices. The relatively small squared deviations of T-bill prices are offset by its enormous size, causing any deviation of prices to cause a great welfare loss. The Japanese yen exhibits the highest squared deviations among the financial markets, and its relatively large volume gives it a large welfare loss. Agricultural markets have squared deviations about

Table 1.--Welfare Loss Measure

Series	Squared deviation		Yearly volume ^a		Steady state		Yearly value		Deviation multiplicand	
	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982
	dollars				dollars		billion dollars		million dollars	
U. S. Treasury bills	.27	.56	3707.0	4618.0	.851	.869	3155.0	4013.0	.515	.634
British pound	.64	.04	b		2.21	1.84	861.0	861.0	.060	.003
Canadian dollar	.02	.04			.838	.810	318.0	318.0	.004	.006
German mark	.04	.02			.468	.416	1929.0	1929.0	.147	.078
Japanese yen	1.22	.93			.469	.421	1006.0	1006.0	3.14	1.56
Corn	2.71	1.85	8.3	9.2	3.50	2.54	29.0	23.5	.002	.001
Cotton	4.11	4.52	10.7	15.2	.847	.628	4.3	4.6	.010	.008
Wheat	6.61	2.80	3.8	4.0	4.40	3.51	16.7	14.0	.001	.0005

^aDollars for Treasury bills; million bushels for corn and wheat; and thousand bales for cotton.

^bBlanks indicate no data available.

ten times greater than the financial markets, but their trade value makes them have a relatively low welfare loss.

Figure 6 depicts the trade-off between elasticities of supply and demand for the elasticity multiplicand. For welfare losses in agricultural markets to be as large as in the T-bill market, the elasticity multiplicand (k in Figure 6) must be roughly 100 times greater for agricultural markets than for T-bills.

V. CONCLUSION

Allowing for varying flexibility among exchange rates, interest rates, and commodity markets and dynamic linkages among these various markets, overshooting is revealed as a common empirical phenomenon. For the eight futures markets investigated (T-bills, the British pound, the Canadian dollar, the German mark, the Japanese yen, corn, cotton, and wheat), overshooting occurs in formation of expectations for each market.

Although interest rate, exchange rate, and commodity markets are all shown by the estimated vector autoregressive moving average model to overact to an initial shock, commodity markets (corn, cotton, and wheat) do so to a much greater degree than either exchange rate or short-term interest rate markets. However, the period length of this overaction, for a major portion of the degree of disequilibrium, is much shorter for the agricultural commodity markets. In the context of resource allocation decisions, the dynamic welfare measures reported suggest that the cotton and yen markets have the greatest loss as a proportion of the total consumer and producer surplus in each. For comparable elasticities of supply and demand, the total welfare losses are found to be the largest in the short-term interest and Japanese yen exchange rate markets.

Figure 6. Elasticity Multiplicand Tradeoffs

FOOTNOTES

¹It can be shown that this expectation scheme is characterized by perfect foresight (Dornbusch, 1976).

²One Option is to use t-tests to set individual elements of parameter matrices to zero (Tiao and Box, 1981), reducing the degree of overparameterization. The undesirable decrease in statistical power due to the extra coefficients, therefore, may be reduced by constraining particular values to zero. The increase in power is achieved, of course, at the risk of biasing the remaining parameter estimates. Since there is little prior information concerning parameter values used in the vector ARMA models (in particular, whether or not to include variables in certain equations), the possibility of biased parameter estimates is high. One should, thus, avoid selecting extremely low significance levels for any tests. The major concern in this study is not hypothesis testing, but in reflecting as much of the dynamic adjustment as possible.

³The exchange rate volumes presented in Table 1 may overstate actual volume by up to 25 percent due to double counting.

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