# Real Exchange Rate and Commodity Prices in a Neoclassical Model

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International Monetary Fund

30 June 1988

**IMF WORKING PAPER**



WP/88/55

INTERNATIONAL MONETARY FUND

Research Department

# Real Exchange Rates and Commodity Prices in a Neoclassical Model

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June 30, 1988

Abstract

This paper presents a neoclassical model that explains the observed empirical relationship between government spending and world commodity supplies and the real exchange rate and real commodity prices. It is shown that fiscal expansion and increasing world commodity supplies simultaneously lead to an appreciation of the real exchange rate and a decline in relative commodity prices. This structural model is estimated and its forecasting performance is compared to a variety of models. We find that theory and structure help in predicting commodity prices, although not the exchange rate, and that predictive ability increases as the forecast horizon is lengthened.

JEL Classification Numbers:
1320, 3210



*This paper is based on part of the author's doctoral dissertation at Columbia University. The author would like to thank Alberto Giovannini, Mohsin S. Khan, Peter Montiel, Tom Morrison, Robert A. Mundell, and Vincent R. Reinhart for helpful suggestions. All remaining errors are the responsibility of the author.

Contents

## I. Introduction

Between 1980 and 1984 commodity prices in U.S. dollars fell by about 31 percent in real terms, considerably worsening the predicament of the large number of developing economies that are primary commodity exporters. The decline in relative commodity prices was associated with a 46 percent appreciation in the U.S. real exchange rate during that same period.1/ In the post-1984 period, despite a weakening dollar and sustained growth in the output of developed countries, real commodity prices remained soft, puzzling many commodity market analysts (see Morrison and Wattleworth, 1987). Because of the central role commodity markets play in linking "developed" commodity-importing countries to "developing" commodity exporters, a more comprehensive analysis of the macroeconomic factors that drive this key relative price is a necessary and useful exercise for policymaking.

The systematic negative association between real commodity prices (in dollar terms) and the U.S. real exchange rate as seen in Figure 1 has long been recognized and, attempts at capturing it econometrically include Dornbusch, 1987, and Chu and Morrison, 1984 and 1986. Similarly, the positive co-movement of commodity prices and industrial production is well documented. The theoretical underpinnings of these studies are partial equilibrium models that focus on commodity price determination while treating industrial output and the exchange rate as exogenous. However, real commodity prices are, in reality, one of several jointly-determined relative prices. As such, they are likely to be affected by a host of macroeconomic factors and policy variables commonly excluded from a partial equilibrium framework.

This paper broadens the analysis by explicitly considering (a) the impact fiscal policy changes in industrial countries have on relative commodity prices, and (b) the significant role an "aggregate" measure of commodity supplies plays in determining commodity price trends. As Figure 2 illustrates, much of the weakness in commodity prices in the post-1984 period can be traced to a marked expansion in world commodity supplies. The acceleration in commodity output can in turn be considered a byproduct of the debt crisis, as developing commodity exporters expanded output in an attempt to service burgeoning debt obligations (see Aizenman and Borensztein, 1988).

The simple model presented here is similar to existing models of real exchange rate determination (see Dornbusch, 1987 and Mussa, 1986) but differs from these in that the production process incorporates another input besides labor--commodities.

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1/ See Table A-1 in Appendix A for definitions of all the variables used in this paper.

We examine how far a neoclassical model can take us in explaining the joint determination of the real exchange rate and real commodity prices. By introducing commodities into the framework, we bring in another potential source of variability in real exchange rates and another market price that can send a signal to policymakers. This framework also allows us to focus on the role commodity markets play in transmitting policy "shocks" to a second commodity importing country and the commodity supplier alike, as noted by Frankel, 1986, and Gianvazzi and Giovannini, 1985.

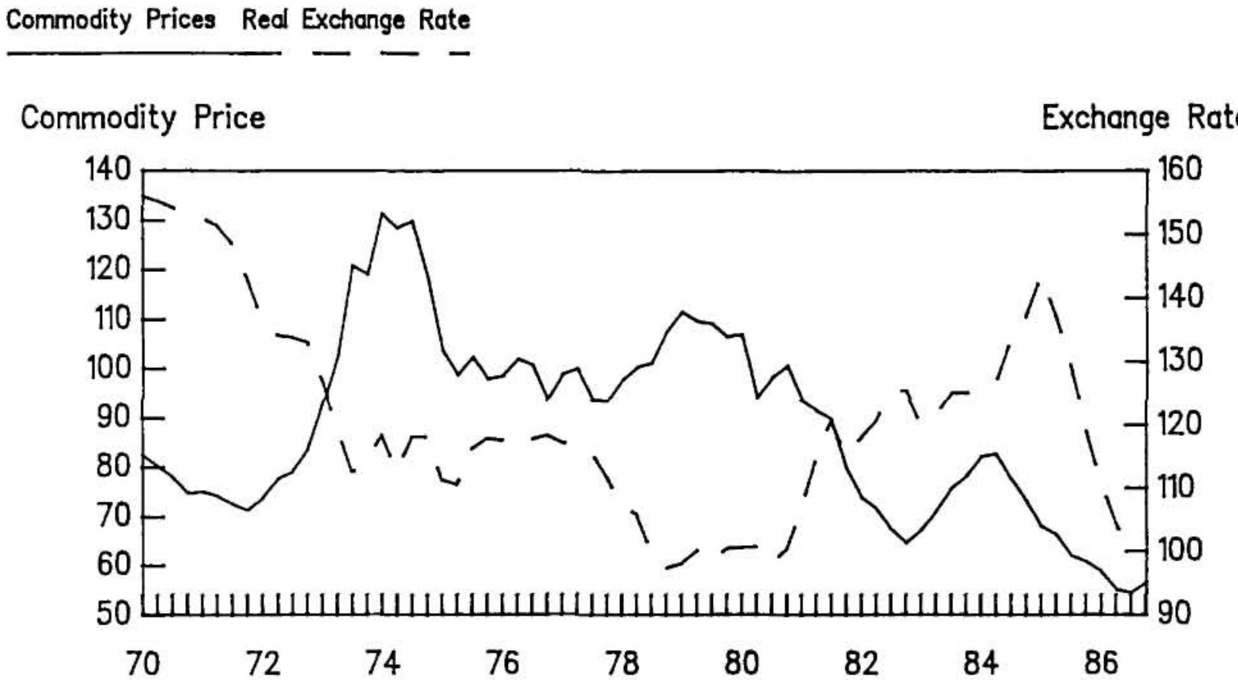
As detailed in Section III of this paper, we find that even under the assumption of price flexibility in all markets, an increase in fiscal spending in the "home" commodity-importing country leads to a simultaneous appreciation in that country's real exchange rate and a decline in commodity prices relative to the price of the home good. The conclusion that these macroeconomic variables have a systematic and predictable impact on the real exchange rate should not be interpreted as being inconsistent with microeconomic factors--such as those considered by Krugman, 1986, and Feinberg, 1986 among others--playing a significant role in relative prices, particularly at more disaggregated levels of activity. The two approaches are complementary, rather than mutually exclusive.

In Section IV the empirical linkage between the real exchange rate and commodity prices is examined, extending the work of Dornbusch, 1985 and 1986a. We find that the single equation approach adopted by Dornbusch and others (see Englander, 1985 for a review of this literature) suffers from a simultaneity bias. Subsequently, we proceed to estimate the relationship between the U.S. real exchange rate and real commodity prices in the context of the model already delineated.

This approach proves quite fruitful as the signs and magnitudes of the coefficients satisfy the priors dictated by the model. The robustness of the estimated model is confirmed by additional regressions that independently estimate a subset of the parameters of the model. This empirical exercise also allows us to scale the effects of policy and supply shocks on the real exchange rate and commodity prices.

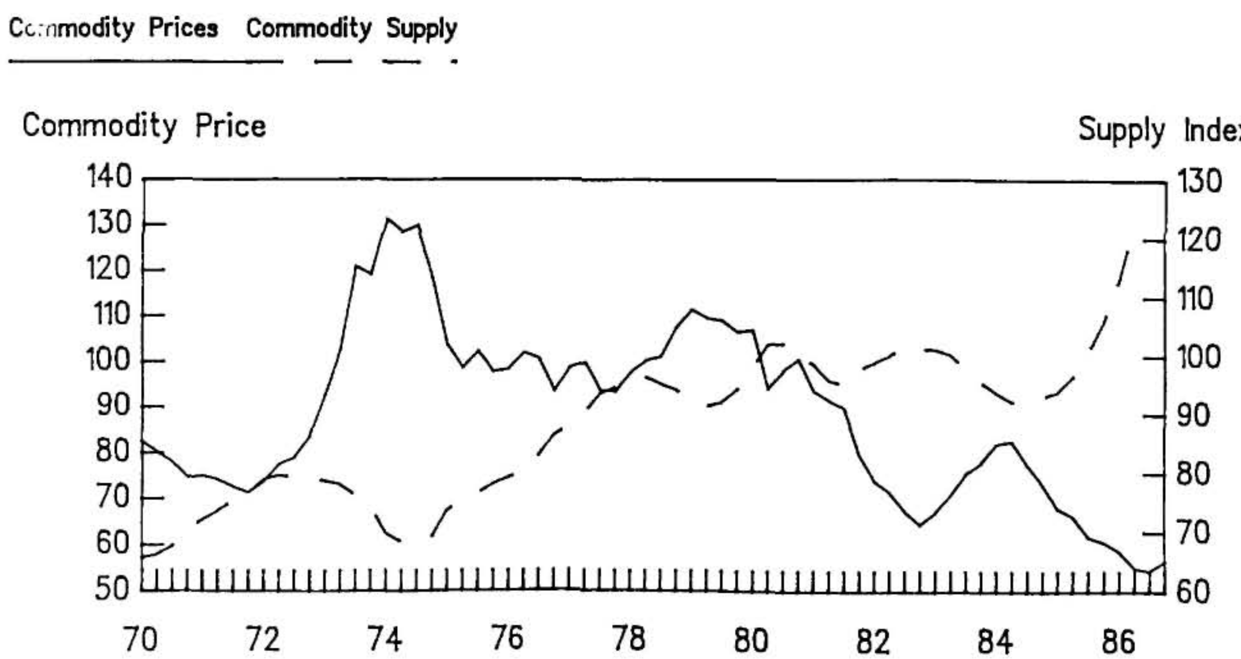
Finally, the robustness of the structural model is assesed by comparing its out-of-sample forecasting performance to a variety of "naive", ad hoc, and partial equilibrium models. Estimates using monthly data suggest that while the structural model does not predict the real exchange rate very well, as is the case with all other models, it does outperform alternative specifications for real commodity prices. As Meese and Rogoff, 1983a and 1983b, found for the real exchange rate, we find that the structural approach produces more reliable forecasts for real commodity prices the longer the forecast horizon. Section V summarizes the results.

## Figure 1
## REAL COMMODITY PRICES AND THE REAL EXCHANGE RATE




Source: Commodity Research Bureau; IMF.

## Figure 2
## REAL COMMODITY PRICES AND WORLD MATERIAL SUPPLIES




Source: Commodity Research Bureau; IMF

## II. The Theoretical Framework

In this section we examine the joint determination of the real exchange rate and real commodity prices in a simple neoclassical model. By introducing commodities into the framework, we outline an explicit link between the "developing" suppliers of commodities and the "developed" commodity-importing countries. In this framework, the commodity market adds another potential source of variability in real exchange rates and another market price that can send a signal to policymakers.

Consider a neoclassical open-economy model. Production takes place in two countries, the "Home" country, which we will refer to as Country A, and a "Foreign" country, which will be denoted by B. Both countries employ two distinct factors in the production process: labor, which is country specific, and a tradeable commodity which is imported by A and B. Following the usual neoclassical assumptions, the domestic and foreign stocks of the non-traded input, labor, are predetermined in a given period and are here denoted by the L's. Unlike Findlay and Rodriguez, 1977, and Obstfeld, 1980, who also incorporate a commodity input, the economies modelled here are capable of affecting world commodity prices. In effect, we will subsequently associate Country A with the U.S., and Country B with a "bloc" of 13 industrial countries (these are listed in Table A-1).

The supply of the traded input, commodities, can be thought of as the net exports of developing countries and is outside the system considered here: commodity supplies are fixed in a given period of time and will be denoted by C. For the sake of simplicity, we assume here that the owners of the commodities travel to the country where the resources they own are employed. Consequently, factor payments to commodity owners are considered a part of the national income of their country of residence.1/

The nominal exchange rate, e, is taken to be exogenous and is defined as the number of domestic currency units per one unit of foreign currency. The law of one price holds in commodity markets so that,

$$q^A = eq^B$$

where $q^A$ and $q^B$ represent the nominal price of commodities in the domestic and foreign currencies.

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1/ This assumption is not necessary, and it is employed only to simplify the analysis and avoid considering factor payments to the commodity supplier.

Country A produces "Good 1", while country B produces "Good 2". The prices of these two goods are denoted by $P_1$ and $P_2$ respectively. Because the manufactured home and foreign goods are assumed to be imperfect substitutes, even though purchasing power of parity may apply individually, the relative price of these two goods is given by

$$R = P_1/eP_2,$$

which defines the real exchange rate. Note that in this case the real exchange rate is the "terms of trade" for final goods.

The basic behavioral relationships are listed below for both countries. The production functions are given by:

$$Y^j = Y^j(L^j, C^j) \qquad j=A,B \qquad (1)$$

Profit maximizing behavior under perfect competition yields the following marginal conditions:

$$W^A/P_1 = Y^A_L \qquad (2)$$

$$W^B/P_2 = Y^B_L \qquad (2a)$$

$$q^A/P_1 = Y^A_C \qquad (3)$$

$$Rq^A/P_1 = Y^B_C \qquad (3a)$$

The arguments in equations (1) through (3a) have the usual signs.

There are three equilibrium conditions that must be satisfied; first,

$$C^A + C^B = C \qquad (4)$$

will clear the world commodity market. Equilibrium in the home good market (Good 1) requires,

$$\Sigma_j [D^j_1(R, Y^j - T^j) + G^j_1] = Y^j \qquad j=A,B \qquad (5)$$

where $D_1$ is a function that represents total private demand for Good 1; demand depends positively on the income terms and negatively on the real exchange rate. The G's represent government demands for the same product. Similarly equilibrium in the foreign good market requires:

$$\Sigma_j [D_2 (R, Y^j - T^j) + G_2^j] = Y^j \qquad j=A,B \qquad (6)$$

where demand for "Good 2" depends positively on the real exchange rate. For simplicity we will assume henceforth that governments purchase only their respective home products and finance their purchases by a lump sum tax levied on households, here denoted by the T's. In effect, the government alters aggregate tastes, biasing it in favor/against the home good when it increases/decreases spending. We need only ensure that two of the three equilibrium conditions hold.

Using equations (3) and (3a) and recalling that $L^A$ and $L^B$ *are assumed constant*, commodity market equilibrium, equation (4), can be expressed as a function of real commodity prices in the home currency, $q^A/P_1$, and the real exchange rate, R.

$$D_C (q^A/P_1, R) = C \qquad (7)$$

World demand for commodities will depend negatively on both real commodity prices and the real exchange rate.

Equation (7) can then be used to derive the locus of combinations of $q^A/P_1$ and R that clear the world commodity market. This locus will be called the CC schedule, and its slope is given by:

$$d(q^A/P_1)/dR = \frac{-(Y_C^A \; Y_{CC}^A)}{(Y_{CC}^B + RY_{CC}^A)} < 0$$

An appreciation in the real exchange rate increases commodity costs in the foreign country, reducing foreign demand for commodities. At the initial domestic price there is an excess supply of commodities in the world market. Consequently, real commodity prices must fall sufficiently to stimulate demand at home and abroad and bring world demand back into line with existing supply conditions. An increase in R, an appreciation in the real exchange rate, requires an accompanying decline in real commodity prices in order to maintain commodity market equilibrium, hence the negative slope of the CC schedule depicted in Figure 3. For a given real exchange rate, points above the CC schedule are associated with excess supply on the world commodity market and falling real commodity prices. Conversely, points below this line represent excess demand conditions and rising real commodity prices.

Having obtained expressions for $C^A$ and $C^B$ in terms of R and $q^A/P_1$, domestic and foreign output can now also be expressed as a function of those variables. We can thus proceed to express equilibrium in the home goods market (equation 5) in terms of the real exchange rate, real commodity prices, and the fiscal policy variable.

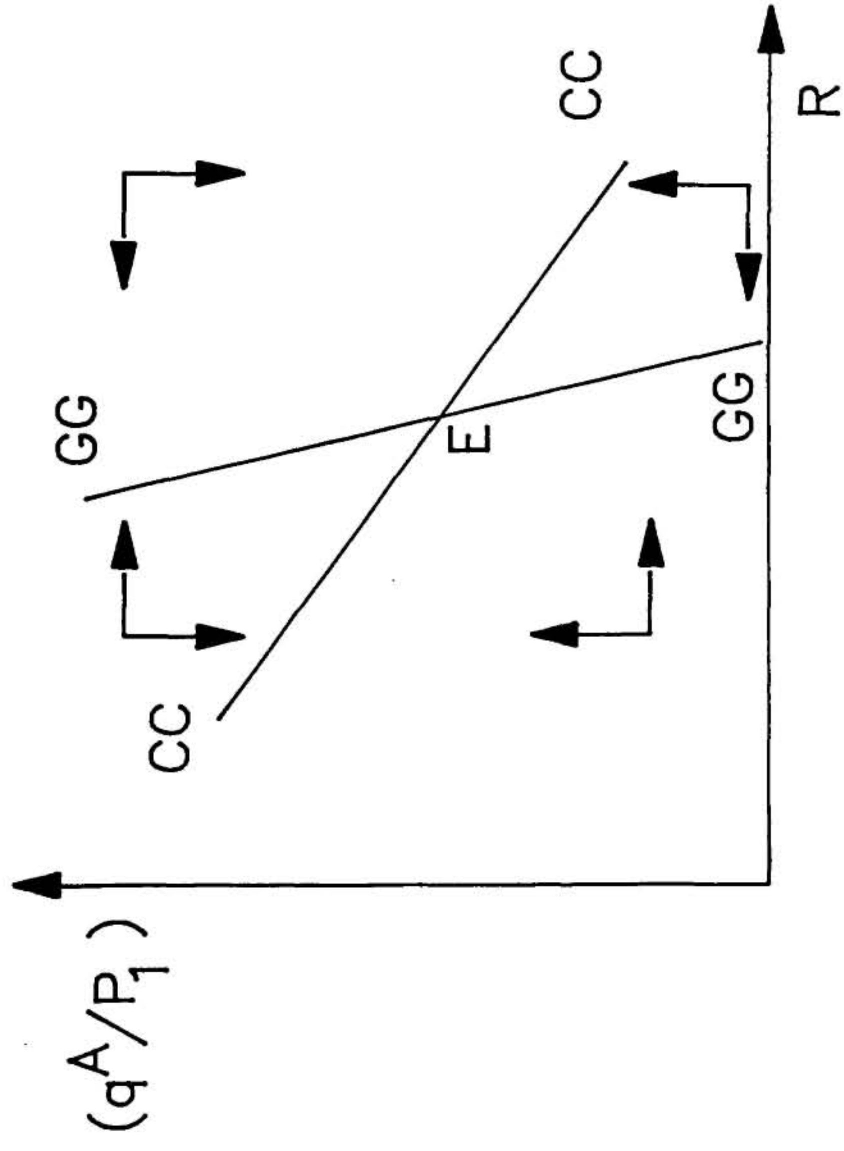
$$D_1(q^A/P_1, R, G_1^A) = Y^A(q^A/P_1) \qquad (8)$$

Assuming the home goods market is initially in equilibrium at a given real exchange rate, a rise in real commodity prices will reduce domestic output. However, the declines in domestic and foreign income also lead to falling aggregate demand for the home good. Whether the real exchange rate needs to rise or fall to clear the goods market will depend on the relative size of the shifts in aggregate supply and demand, and as such, on the parameters of the model. The GG schedule in Figure 3 represents the locus of R and $q^A/P_1$ combinations that clear the home goods market, and its slope is given by:

$$d(q^A/P_1)/dR = \frac{D_{1R} Y^A_{CC} Y^B_{CC} + D_{1Y} B Y^A_C Y^B_C Y^A_{CC}}{(1-D_{1Y} A) Y^A_C Y^B_{CC} - R D_{1Y} B Y^B_C Y^A_{CC}}$$

While the sign of the slope of the GG schedule is

Figure 3



indeterminate, for reasons detailed in Section IV of this paper, we will present the GG schedule subsequently as being negatively sloped, though nearly vertical, and as such, more steeply sloped than the CC schedule. For a given real commodity price, points to the right of the GG schedule denote excess supply in the home goods market and a depreciating real exchange rate, the opposite is true for points to the left of this line.

Combining the market clearing conditions in the commodity and home goods markets provide a solution to our model and yield the configuration illustrated in Figure 3. We can construct within this simple framework useful comparative static exercises. The next section considers two such exercises--an expansion in fiscal spending, not unlike the one observed during the early 1980's in the U.S., and a "positive supply shock" via a rise in world commodity supplies.

## III. Comparative Statics

### 1. A rise in government spending

An exogenous increase in $G_1^A$, real government purchases, will increase aggregate demand in the home goods market on impact, creating excess demand at the prevailing exchange rate. The excess demand in the home goods market will drive up the real exchange rate, R. At the initial level of real commodity prices commodity costs for the foreign country will have risen, reducing their commodity demands and output and creating excess supply in the world commodity market. Falling real commodity prices will stimulate domestic output and foreign output as well, eliminating the excess supply in the commodity market. The rise in $G_1^A$, has shifted the GG schedule to the right, and the new equilibrium point, E', is presented in Figure 4.

The new equilibrium will be characterized by a higher real exchange rate (an appreciation) and lower domestic real commodity prices. As is usually the case, the fiscal expansion will boost domestic output. However, real commodity prices will be higher for the foreign country and consequently their new steady-state level of production will be lower.

The characteristics of the new equilibrium describe the experience of the U.S. during the 1980-1985 period remarkably well, as the fiscal deficit widened, economic growth accelerated, the dollar exchange rate appreciated (in both real and nominal terms), and real commodity prices (in U.S. dollars) fell to their lowest levels since the 1930's. These trends were also independently reinforced by the fiscal policy stance adopted in that period by the rest of the OECD countries. While the U.S.

recorded a series of record deficits, other countries had begun to curtail their fiscal imbalances (see Table 1), an additional factor that could be incorporated in the model presented here without much difficulty.

Note, however, that this is a framework that lends itself better for short-run analysis. Should the long-run real exchange rate elasticity of demand for the home good be greater than its short-run values, a reasonable assumption, then the expansionary effects of fiscal policy would diminish as private demand began to shift towards the foreign good. Ultimately, there would be a loss in market share. In addition, while the assumption of fixed world commodity supplies may be adequate for short-term analysis, it is unrealistic to assume the commodity-exporting countries will not respond over time to relative price changes and international economic developments.

2. An increase in world commodity supplies

While the previous exercise dealt with a policy change, an increase in world commodity supplies will be our example of a "supply shock". Suppose world commodity supplies increase. This increase can be brought about by new discoveries (and exploitation of these discoveries) as was the case in oil, or it can be brought about by the need on the part of existing commodity exporters to increase their supplies to the world market, as was the case of many developing hard-pressed for reserves.

An increase in material supplies creates an excess supply in the world commodity market on impact. Lower commodity prices are required to clear the commodity market at all levels of the exchange rate, the CC schedule shifts downward (see Figure 5). The lower commodity prices will trigger an expansion in both domestic and foreign output. Whether the exchange rate appreciates or depreciates depends on the parameters of the system (i.e. on whether the GG schedule is positively or negatively sloped). In the case considered here, where the GG schedule is negatively sloped, although nearly vertical, a positive supply shock will be associated with a slight appreciation in the real exchange rate.

This new equilibrium will be characterized by: a) lower real commodity prices in both countries, b) an approximately unchanged real exchange rate and, c) higher output in both commodity-importing countries. The combined effects of rising commodity supplies (as shown in Figure 2) and an expansionary fiscal policy in the U.S., a mix that characterized the experience of the 1980's, suggested by this model are quite consistent with the empirical regularities observed in the last few years, as Table 2 makes evident. In the next section, estimates for the parameters of the model are presented as we attempt to scale the effects of policy and supply shocks.

Figure 4

An Increase in Government Spending in Country A

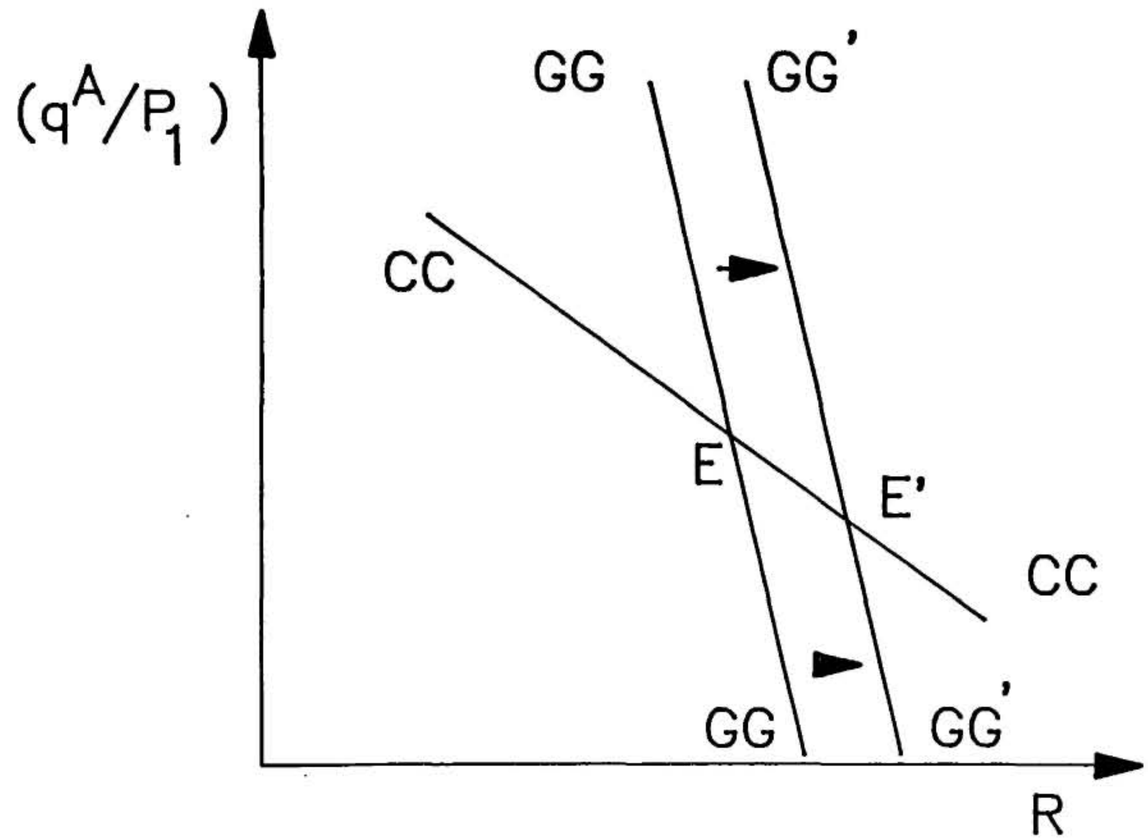


Figure 5
An Increase in World Commodity Supplies

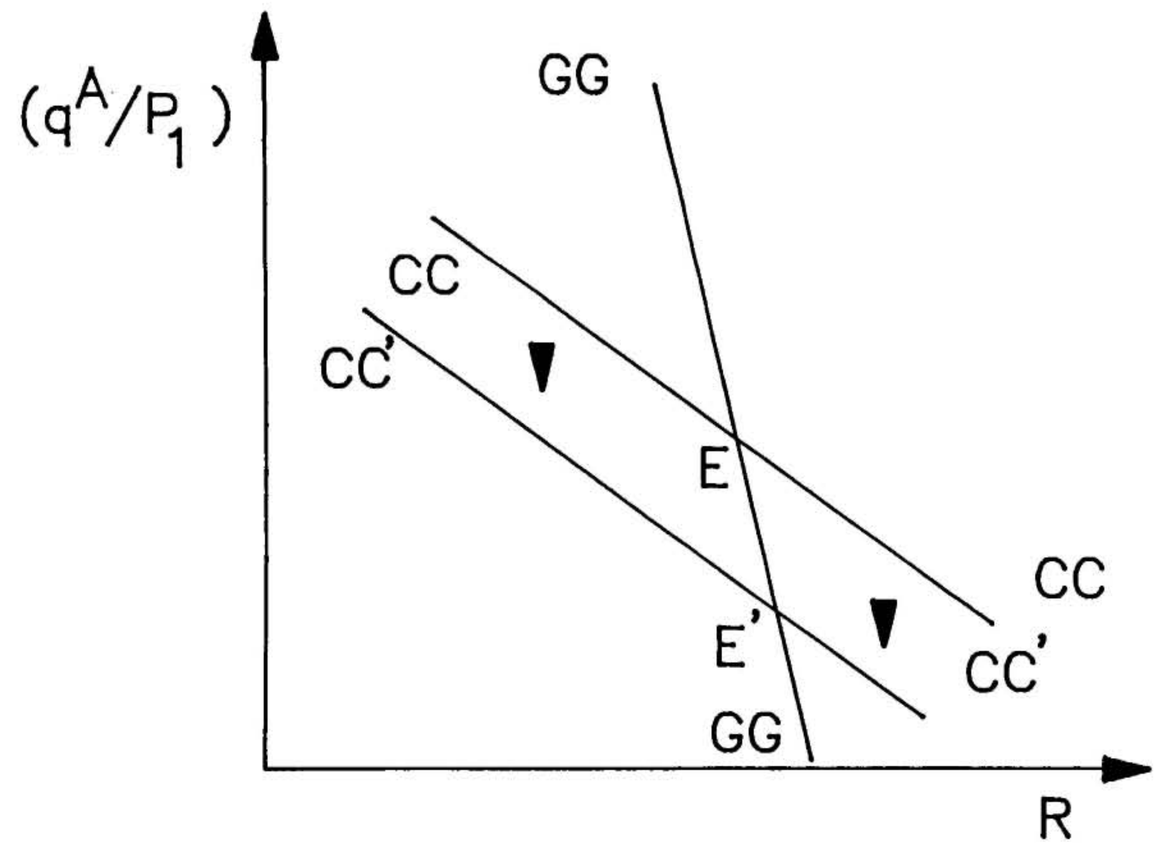


Table 1

Major Industrial Countries:
Summary of Fiscal Developments, 1980-85

(Percent of GNP\GDP)

| | Cumulative Change in the Deficit | Cumulative Structural Change in the Deficit |
|---|---|---|
| United States | 4.0 | 2.3 |
| Japan | -3.1 | -3.5 |
| France | 1.8 | -3.2 |
| Germany | -1.5 | -4.4 |
| Italy | 4.5 | -0.8 |
| United Kingdom | 0.1 | -3.8 |

Source: IMF, World Economic Outlook, 1986.

Table 2

Selected Economic Developments,1980-85

| Economic Variable | (Average Percent Change Per Annum) |
|---|---|
| Real Exchange Rate | 5.6 |
| U.S. Real Commodity Prices | -10.7 |
| Real Commodity Prices in Foreign Currency | -5.7 |
| U.S. Industrial Production | 2.4 |
| "Foreign" Industrial Production | 1.7 |

Source: IMF, World Economic Outlook, 1987.

## IV. The Joint Determination of Commodity Prices and the Real Exchange Rate

In this section we examine the empirical application of basic models of commodity price determination. The systematic negative correlation between the U.S. real exchange rate and real commodity prices seen in Figure 1 has been long recognized and among the researchers capturing it econometrically have been Dornbusch, 1987, Chu and Morrison, 1984 and 1986, and Morrison and Wattleworth, 1987. First, we replicate the basic Dornbusch equation over a new data set. Our theoretical model suggests a basic limitation to this approach: the statistical method used must recognize that commodity price and the real exchange rate are mutually determined.

We go on to examine the contemporaneous exogeneity of the real exchange rate via a Hausman test, we find that the real exchange rate is not an appropriate right-hand-side variable in an OLS regression. Given the Hausman test result, we estimate a structural explanation for these jointly determined variables.

Additionally, we use monthly data to assess and compare the forecasting ability of the basic models. These models include the structural model developed here, and this exercise will help illustrate to what extent are theory and structure useful in the prediction of commodity prices.

### 1. Modeling real commodity prices: single-equation approach

Almost all the work on commodity price determination has used a single-equation framework. The analyses differ by the indices used, estimation period and frequency, and exact set of right-hand-side variables. However, OLS is the universal technique of choice.

Consider, for example, Dornbusch's examination of the commodity price-exchange rate linkage in Dornbusch (1986a and 1987). The basic equation estimated by him is:

$$(q_1^A/P) = \alpha + \beta_0 \, IPW + \beta_1 R + u \qquad (9)$$

where Á represents a constant term and IPW in a measure of world industrial production. Using the first differences of the logs of the variables, Dornbusch estimates the coefficients for industrial production and the real exchange rate to be about 2.25 and -1.5 respectively.

These estimates, as Dornbusch relates, are troubling. Recall that the elasticity of commodity prices with respect to the real exchange rate that clears the commodity market is given by:

$$\mu_0 = -(RY^A_{CC})/[Y^B_{CC} + RY^A_{CC}].$$

If the two commodity-importing countries are equal in size and share the same technology and factor proportions, then we would expect a value closer to -0.5 rather than the -1.5 found.1/

This puzzle can be easily replicated. We estimated equation (9) using the quarterly data available from 1970 to 1985 for both the IMF world commodity index and the Commodity Research Bureau's spot index; OLS techniques yield the coefficients given in Table 3 using the variables defined in Table A-1 in Appendix A. The long-run elasticities are smaller than Dornbusch's estimate using the Economist index but are still above the dictates of theory.

The answer to this puzzle emerges from the model outlined in the previous two sections. The real exchange rate and real commodity prices are jointly determined. The inclusion of the real exchange rate in a specification such as equation (9) estimated by OLS introduces simultaneity bias. As is well known, there are two competing paradigms for identifying the exogeneity of a potential right-hand-side variable; the Granger-Sims test for temporal precedence and the Hausman test for contemporaneous correlation (for a discussion see Leamer, 1985). Our theoretical model suggests the presence of a contemporenaneous relationship, so in the following section we limit our focus to the structural test of Hausman.

2. Hausman test

The variable r can be decomposed into two parts: a prediction generated by an auxiliary regression using variables known to be strictly exogenous (and therefore uncorrelated with u) and all else. Simultaneity bias would appear as a correlation between the residuals from the auxiliary regression and the residuals of the structural equation. Or as Hausman has shown (Hausman, 1978), if the actual variable is significant in a regression that includes both the actual and the projection, then simultaneity bias is present.

The results for a subset of equations are presented in Table 4. As anticipated, the inclusion of an instrumental projection

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1/The share of the U.S. in the total trade of primary commodity exporting countries with industrial countries is about equal in size to the share of 13-country "bloc" used in the empirical work.

for r in a specification such as (9) did not eliminate the significance of the real exchange rate, thereby indicating the presence of simultaneity bias. Hence, the Dornbusch puzzle seen in Table 3 follows from an invalid inference resulting from the wrong estimation strategy. In the next section we control for simultaneity by estimating the system of equations suggested by our theoretical model.

## 3. A Model of Real Commodity Prices and the Real Exchange Rate

Our theoretical framework suggests, at the least, a two-equation model of real commodity prices and exchange-rate determination, a model that is identified and that can be estimated by two stage least squares. Other variables are determined within the model--real manufacturing and commodity outputs--but to maintain the focus on the commodity price-exchange rate link, we will account for those variables' potential endogeneity when they serve as right-hand-side variables but will not include explicit equations for them.

Commodity market equilibrium provides an equation for real commodity prices in terms of the real exchange rate, world production and commodity supplies:

$$q^A/P_1 = \alpha + \beta_0 \, IPW + \beta_1 R + \beta_2 C + u_1 \qquad (10)$$

Goods market equilibrium can be written as an equation determining the real exchange rate in terms of real commodity prices, world industrial production and the real budget deficit:

$$R = \alpha_2 + \theta_0 \, IPW + \theta_1 (q^A/P_1) + \theta_2 G^A_1 + u_2 \qquad (11)$$

Treating the fiscal deficit as exogenous, we first estimated a VAR system to create instruments for industrial production, real oil prices, and commodity supplies. While commodity supplies are taken to be exogenous at a point in time in the theoretical model, it is reasonable to assume that commodity output is endogenous over time, as commodity suppliers respond to policy changes and market conditions. For this reason the following empirical work will also employ an instrument for the supply variable. The current and two lagged values of these, along with the fiscal deficit, the lagged dependent variables, and a time trend were used in the first stage of the estimation procedure. The second-stage results are reported in Table 5.

The estimation results suggest that commodity prices have no systematic effect on the real exchange rate (the sum of the coefficients on DIMFD insignificantly differs from zero); this would make the GG schedule approximately vertical. On the other hand, the real exchange rate coefficient in the commodity price equation equals -0.4.

Together, these relationships help explain Dornbusch's "unusual" result. This is the classic identification problem. Single equation estimation does not recognize the independent influences on commodity prices and the real exchange rate and result in a coefficient that averages the effect. Equation (9) is a locus of equilibrium points satisfying equations (10) and (11), not a properly identified commodity market clearing relationship.

4. Independently assessing the parameters of the model

The small impact of commodity prices on the real exchange rate, which results in a nearly vertical GG, is disquieting. The results of Section II, in which the slope of the GG was derived analytically, allows us to independently assess our estimation results if we are willing to pass judgements on a number of structural parameters.

By the marginal conditions, we know:

$$Y_C^A = q^A/P_1 \text{ ; and,}$$

$$Y_C^B = (q^A/P_1)R.$$

Estimates for the marginal propensity to import for the Home and Foreign countries, $(1-D_{1Y}A)$ and $D_{1Y}B$ respectively, are a necessary ingredient. We estimated conventional import demand equations for the U.S. and an aggregate of 13 major foreign countries and report the results in Table 6. The implied propensities to import derived from these elasticity estimates are 0.108 for the U.S. and 0.08 for the 13-country aggregate.

If similar technology and factor shares are assumed then $Y_{CC}^A$ equals $Y_{CC}^B$ and we can express $d(q^A/P_1)/dR$ along the GG schedule (expressed in elasticity form) as

Table 3

Determinants of the Real Commodity Price, United States: Single-Equation Approach 1970:2-1985:3

| Eqn. Number | Dependent Variable: | Constant | IPW | RVADN | $R^2$ | D.W. |
|---|---|---|---|---|---|---|
| 1 | CRBD | -0.17<br>(-2.46) | 1.62<br>(3.06) | -1.05<br>(-3.62) | 0.41 | 2.04 |
| 2 | IMFD | -0.19<br>(-2.51) | 1.98<br>(3.67) | -0.96<br>(-2.91) | 0.37 | 1.72 |

Definitions for all the variables appear in Table A-1 in Appendix A. For reasons discussed in Appendix B, first differences of log levels are used for all variables. The above equations employ second degree polynomial distributed lags for IPW and RVADN. The numbers in parentheses are t-statistics.

Table 4

The Hausman Test for Simultaneity 1970:2-1985:3

| Eqn. Number | Constant | IPW | RVADN | Instrument for RVADN | $R^2$ | D.W. |
|---|---|---|---|---|---|---|
| 1a | -0.16<br>(-2.45) | 1.60<br>(3.33) | -1.45<br>(-3.92) | 0.71<br>(1.67) | 0.44 | 2.00 |
| 2a | -0.65<br>(-4.21) | 1.85<br>(6.12) | -1.00<br>(-4.29) | 1.96<br>(2.22) | 0.60 | 1.08 |

Equations 1a and 2a use the CRB commodity index (deflated) as the dependent variable. The auxiliary regression used to construct an instrument for the real exchange rate employed current and lagged values of FDD and OILD, and lagged values of RVADN and IPW. The numbers in parentheses are t-statistics.

Table 5

Estimates of the Structural Model

Equation 1: The Real Exchange Rate

| | | | |
|---|---|---|---|
| Dependent Variable | RVADN | | |
| Sample Period | 1970:1-1985:1 | | |
| Observations | 61 | Degrees of Freedom | 46 |
| $R^2$ | 0.506 | $RBAR^2$ | 0.356 |
| SSR | 0.030 | SEE | 0.026 |
| D.W. | 1.93 | | |

| Variable | Lags | Coefficient | Stand. Error | T-Statistic |
|---|---|---|---|---|
| IMFD | 0 to 2 | -0.14 | 0.22 | -0.62 |
| RVADN | 1 to 2 | 0.20 | 0.21 | 0.92 |
| IPW | 0 to 2 | -0.70 | 0.72 | -0.97 |
| EGY | 0 to 2 | 0.65 | 0.53 | 1.22 |
| FDD | 0 to 2 | -0.05 | 0.03 | -1.64 |

Equation 2: Real Commodity Prices

| | | | |
|---|---|---|---|
| Dependent Variable | IMFD | | |
| Sample Period | 1970:1-1985:1 | | |
| Observations | 61 | Degrees of Freedom | 46 |
| $R^2$ | 0.743 | $RBAR^2$ | 0.665 |
| SSR | 0.057 | SEE | 0.035 |
| D.W. | 1.82 | | |

| Variable | Lags | Coefficient | Stand. Error | T-Statistic |
|---|---|---|---|---|
| IMFD | 1 to 2 | 0.30 | 0.25 | 0.12 |
| RVADN | 0 to 2 | -0.38 | 0.36 | -1.06 |
| IPW | 0 to 2 | 2.09 | 0.48 | 4.31 |
| EGY | 0 to 2 | 0.12 | 0.07 | 1.79 |
| MATI | 0 to 2 | -0.50 | 0.29 | -1.70 |

Definitions for all the variables appear in Table A-1 in Appendix A. For reasons discussed in Appendix B, first differences of log levels are used for all variables.

$$\mu_1 = \frac{R D_{1R} Y_{CC} + D_{1Y} B Y_C^{A2}}{(1-D_{1Y} A) Y_C^{2} - D_{1Y} B Y_C^{B2}}$$

Note that the numerator is unambiguously positive. We can make the appropriate substitutions in the denominator using the following values:

$(q^A/P_1)=3.316$; $R=1.206$; $(q^A/P_1)R=4$;

$(1-D_{1Y}A)=0.108$; and, $D_{1Y}B=0.08$.

Simple calculations yield a value for the denominator of $\mu_1$ equal to -0.08; since the numerator is considerably larger, we have confirmed that the slope of the GG schedule is nearly vertical, and, thus, provide independent support for the estimates of the model.

The coefficient of our proxy of "world" commodity supplies has the anticipated sign. The estimates found in Table 5 suggest that a one percent rise in commodity supplies will reduce real commodity prices by about half of one percent on impact and by about a similar magnitude in the long run. This is somewhat surprising because the demand for commodities is generally thought to be inelastic, at least in the short run, which would suggest that prices should change by more that one-half the change in supply. A low apparent responsiveness may reflect poorly on our supply proxy or the model's failure to include inventory behavior as part of the overall demand for commodities.

## 5. Forecasting ability

A way of assessing the usefulness of the structural model described in the previous sections is to compare its forecasting abilities to alternative commodity price models. Fifteen years of experience with floating rates has taught that the exchange rate cannot be predicted. Meese and Rogoff, 1983a and 1983b, formalized this by showing that exchange rate models routinely fail to predict out-of-sample relative to the most naive of forecasts--a random walk (see also Mussa, 1986). Our goal in this section is not to evaluate exchange rate forecasts but focus on the question; Can we predict commodity prices? However, since this paper has emphasized the joint determination of real commodity prices and the real exchange rate, it is natural to examine the predictive power of the model for both variables.

Figure 6 a: Bivariate VAR

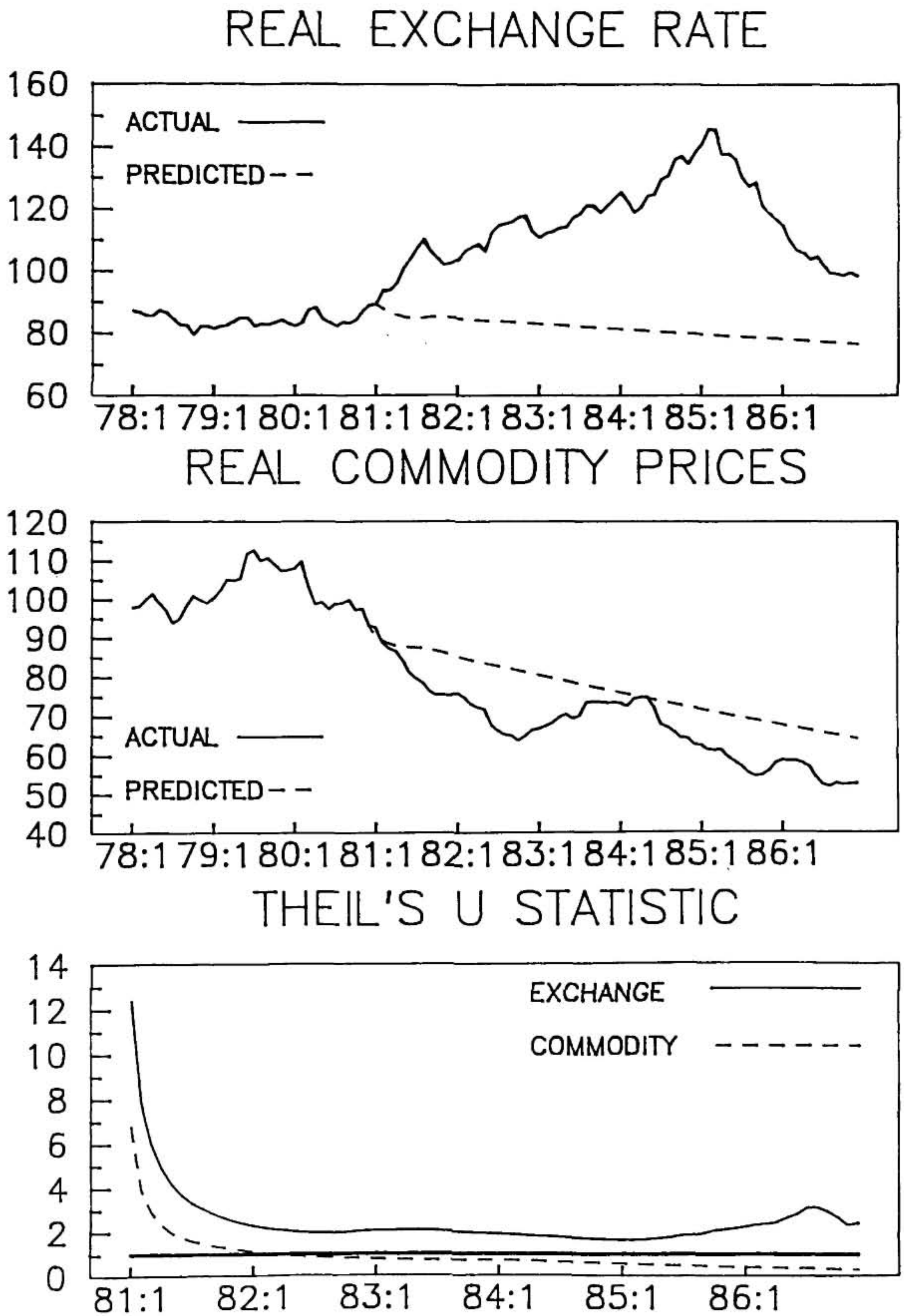

Figure 6b: EXTENDED VAR

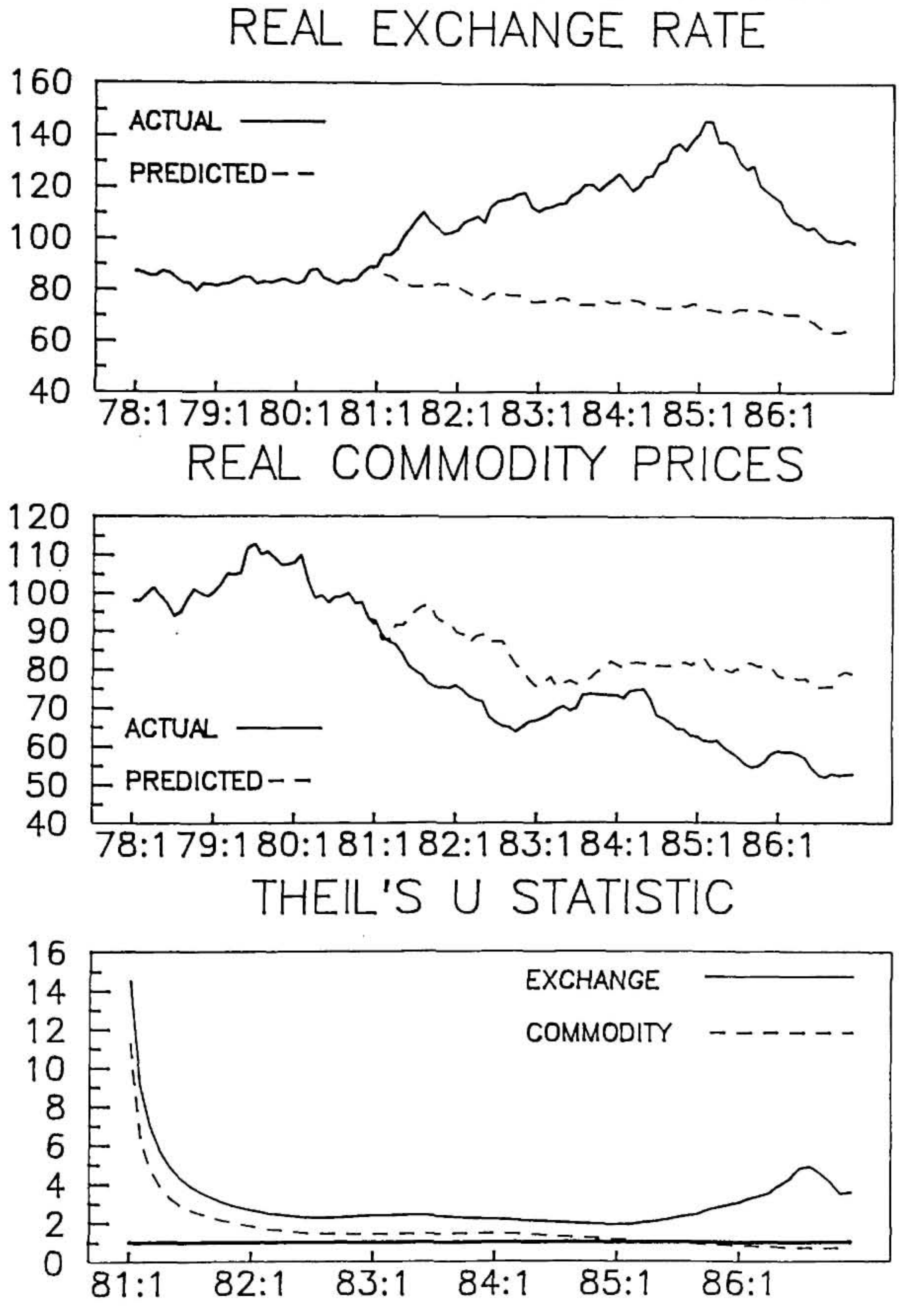

Figure 6 c: DORNBUSCH EQUATION

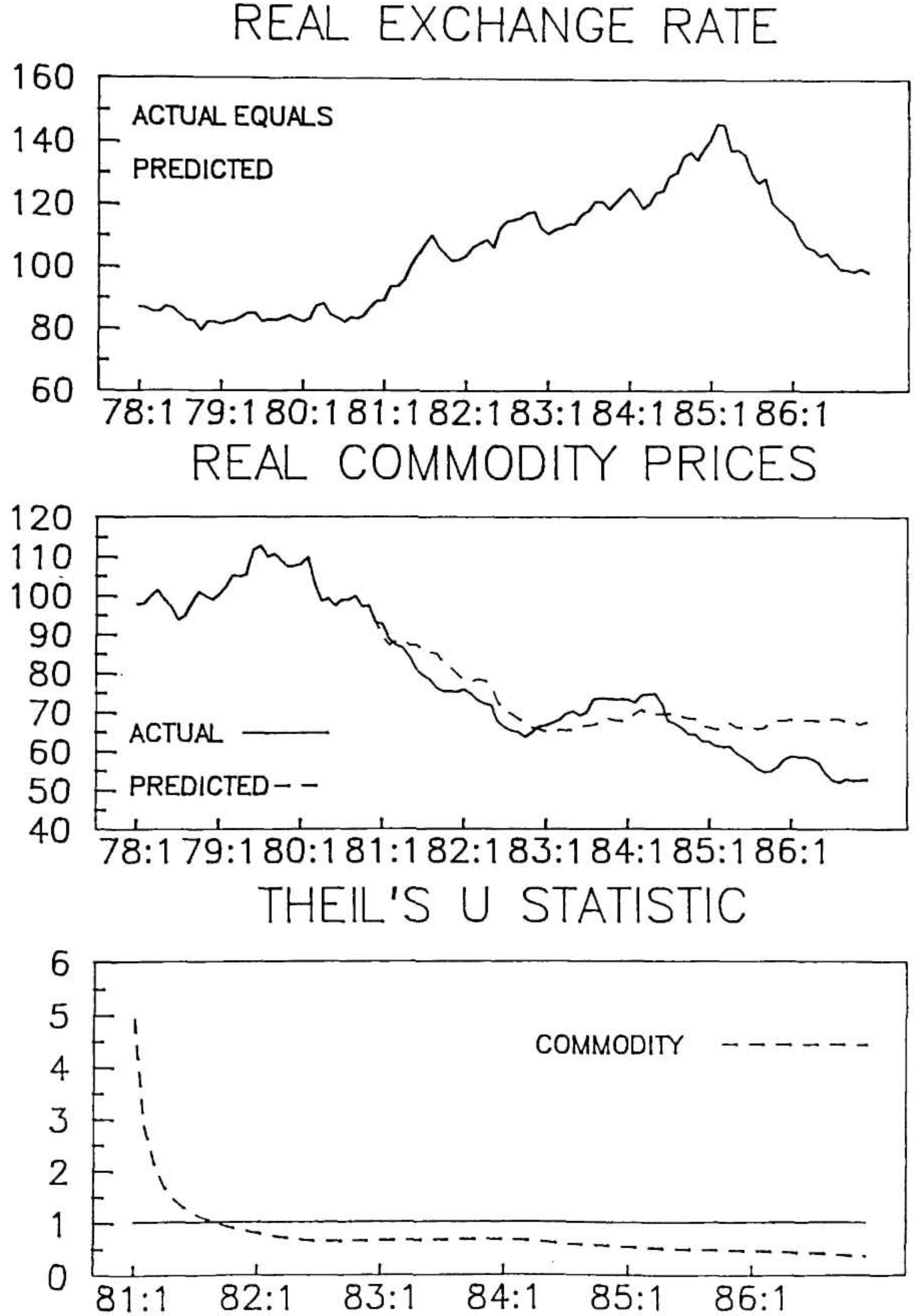

Figure 6 d: 2SLS STRUCTURAL MODEL

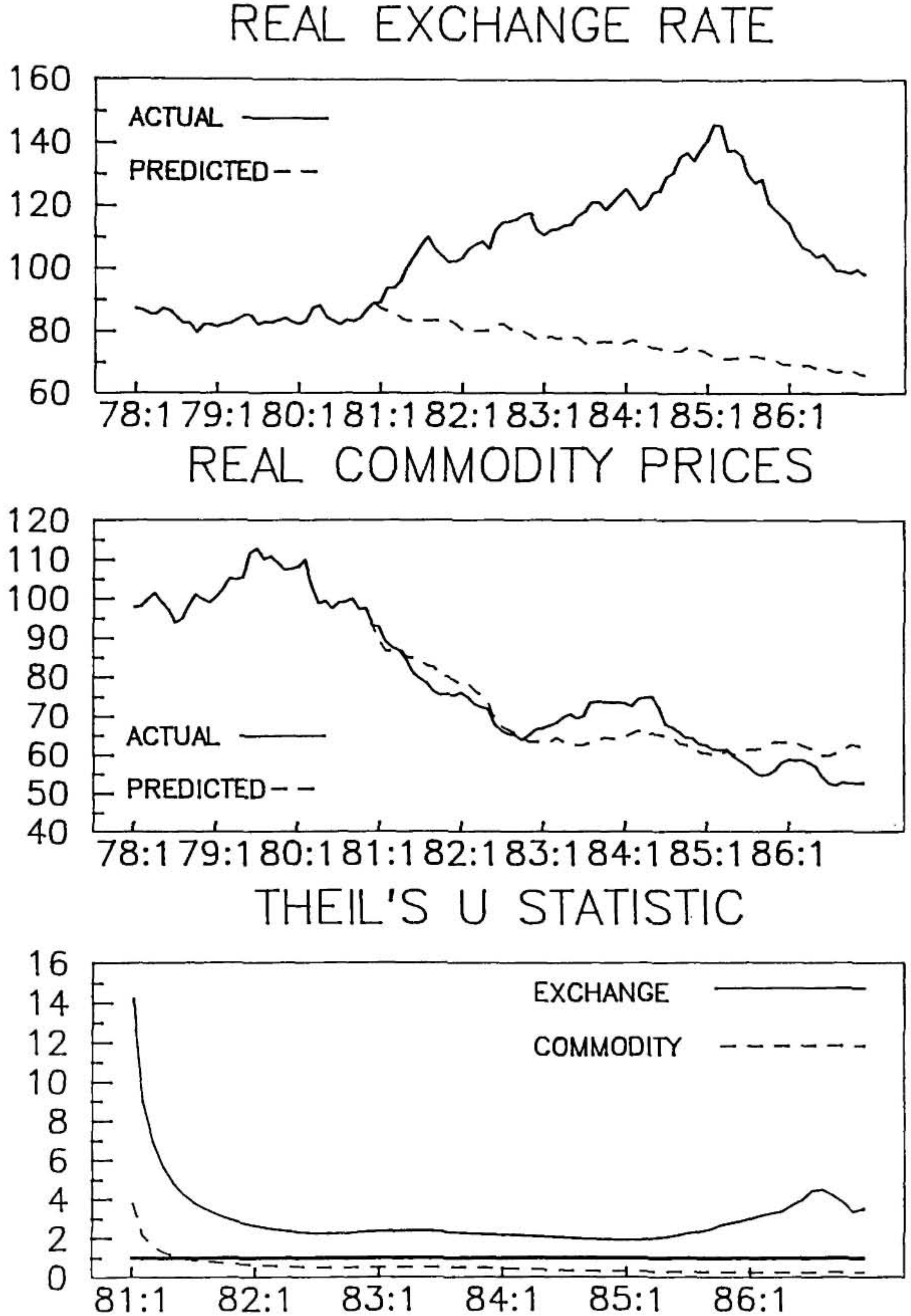

Table 6

Import Demand for Manufactured Goods for the U.S. and the Major Industrial Countries 1968:1-85:3

| Dependent Variable | Constant | IPWUS | IP13 | RVADN | RHO | $R^2$ | D.W. |
|---|---|---|---|---|---|---|---|
| RMUS | -3.58 | 1.99 | * | -0.15 | 0.85 | 0.89 | 2.42 |
| | (-2.51) | (10.62) | | (-0.87) | (8.41) | | |
| RM13 | 2.90 | * | 0.77 | -0.39 | 0.64 | 0.90 | 2.45 |
| | (2.35) | | (5.35) | (-2.59) | (6.85) | | |

All variables are in logs. Correction for first order serial correlation was made using a Maximum Likelihood Iterative Technique. The implied propensities to import for the U.S. and the "Foreign" country grouping are 0.10 and 0.08 respectively. The numbers in parentheses are t-statistics.

In order to increase our power to discriminate, we re-estimated the models of the previous sections using monthly data. This required several data re-definitions due to data availability, as well as a shift of sample period to start in 1974. To compare the forecasting accuracy of alternative specifications that contain varying degrees of structure and theory, we estimated: (a) a bivariate vector autoregression of real commodity prices and the real exchange rate, (b) an extended vector autoregression that also includes variables dictated by theory, such as commodity supplies and a measure of fiscal policy, but these are included without structure, (c) a single equation of the Dornbusch type, and (d) the 2SLS two-equation structural model.

These models were estimated using the monthly observations available from 1974 to 1980 and then dynamically simulated over 1981 to 1986. The results are plotted in Figures 6a through 6d. The bottom panel presents Theil's u-statistic for varying forecast horizons. Theil's u compares the root-mean-squared error of the model forecast to the naive forecast of an unchanged level over the whole horizon; a rightward movement along the horizontal axis in the lower panel lengthens the forecast horizon and lessens the number of observations available.

Two key points emerge from this exercise. First, unstructured modeling uniformly performs poorly. The bivariate and extended vector autoregressions predict neither the appreciating dollar nor falling commodity prices of the 1980's. Of course, those errors propagate: since commodity prices and the real exchange rate are negatively related, failure to predict the dollar's appreciation worsens the commodity price forecast performance in a dynamic simulation.

Second, structural models <u>can</u> predict commodity prices <u>and</u> that ability increases as the horizon lengthens. The Dornbusch equation (Figure 6c) tracks the decline in commodity prices through the 1980's. It may be argued that taking the exchange rate path as given bestows an unfair advantage to the structural model. Our system estimates, which predict both the exchange rate and commodity prices, do not possess that advantage and still forecast accurately (Figure 6d). In effect the structural model developed in this paper outperforms the other models in the prediction of commodity prices.

Structural models, however, are dominated by a naive forecast in high-frequency predictive ability. For one- to five-month ahead projections, a forecast of an unchanged real commodity price would result in a smaller root-mean-squared error than the structural model's predictions. For any forecast one-half year ahead or longer, knowledge of the model's structure would significantly reduce forecast error. In no case for any horizon can the exchange rate be predicted with accuracy.

## V. Implications and Shortcomings of the Model

The simple theoretical model presented here is capable of explaining much of the observed variation in real commodity prices and the real exchange rate . Even within a framework that incorporates the assumption of flexible prices in all markets, and as such, the simplifying assumption of nominal exchange rate "neutrality", real exchange rate and real commodity price volatility is observed when supply shocks or policy changes take place.

Fiscal policy changes in the large home country are capable of inducing significant variation in real exchange rates, real commodity prices at home and abroad, and domestic and foreign income growth. In particular, a rise in real government spending will induce a simultaneous appreciation in the exchange rate and a drop in commodity prices. It will tilt income growth in favor of the home country (in this case the U.S.), widening the real growth differential between the home country and its trading partners, at least in the short-run--a scenario not unlike the experience of the 1980's.

This analysis therefore indicates that policies that stimulate growth in a large country, such as the U.S., need not have positive consequences for the rest of the world, as the "engine of growth" argument would suggest. More specifically, it is not output growth that will matter for its developed and developing trading partners, per se, but how that growth is achieved, as illustrated in the case of an expansion in government purchases. For this reason, it is important to not only focus on the domestic output consequences of policy changes, but also evaluate its effects on that international channel of transmission--the commodity market--a channel frequently neglected in discussions of policies.

In the case of an increase in world commodity supplies, a positive "supply shock", it is shown that this will lower commodity prices in both the home country and abroad, and provide a stimulus to output in the developed commodity importing countries while producing an unambiguous worsening in the terms of trade of the commodity supplier.

In the empirical section of the paper the real commodity price-real exchange rate relationship was estimated using a single equation approach, following the approach of Dornbusch, 1987. This approach was shown to suffer a major drawback: simultaneity bias makes the real exchange rate an inappropriate right-hand-side variable so that the model is not identified.

A simultaneous equation approach was then adopted, yielding generally satisfactory results. As dictated by the priors of the model: (a) the elasticity of real commodity prices with respect to the real exchange rate was found to be a negative fraction; (b) a budget deficit is associated with an appreciation of the real exchange rate on impact; (c) increases in commodity supplies lead to lower commodity prices (although the coefficient appears low in absolute value); and (d) consistent with independently estimated import demand elasticities, disturbances in the commodity market will impact commodity prices and domestic and foreign income but are not likely to have a major impact on the exchange rate.

Knowledge of the model's structure significantly aids in predicting commodity prices six-months ahead or longer. The two-equation structural model out-performs the naive forecast of an unchanged level as well as the predictions from unstructured vector autoregressions and partial equilibrium models.

## Appendix A

Table A-1

Variable Definitions

| Variable | |
|---|---|
| CRBD | Commodity Research Bureau index of all commodities excluding fuels deflated by the U.S. GNP deflator |
| WAXCPI | Federal Reserve Board of Governors multilateral exchange rate index, deflated by commodity prices |
| IMFD | IMF index of all commodity prices excluding fuels deflated by the GNP deflator |
| RVAD | IMF index of the real exchange rate based on value-added deflators in manufacturing |
| IPW | Industrial production index for 14 industrial countries, including the U.S., similar in construction to the IMF index |
| IPUS | U.S. Industrial Production index |
| IP13 | Same as IPW, but excluding the U.S. |
| OILD | Saudi Arabian benchmark price for light crude deflated by the U.S. GNP deflator |
| EGY | Index of world energy prices |
| FDD | U.S. Federal budget deficit (unified budget basis) deflated by the U.S. GNP deflator |
| MATI | Commodity imports excluding oil denominated in U.S. dollars for 14 industrial countries, including the U.S. deflated by the CRB index |

Table A-1 (Continued)

Variable Definitions

| Variable | |
|---|---|
| NSA | Index of the volume of commodity exports, excluding oil, denominated in U.S. dollars for the same basket of commodites used in IMFD. |
| FUER | Fuel imports denominated in U.S. dollars for 14 industrial countries, including the U.S. |
| RMUS | U.S. imports of manufactured goods deflated by the import unit value index |
| RM13 | Imports of manufactured goods for 13 industrial countries, excluding the U.S., deflated by the import unit value index for those 13 countries |

The 13 industrial countries that make up these indices are: Canada, Japan, Austria, Denmark, France, Germany, Italy, Netherlands, Norway, Sweden, United Kingdom, Switzerland, and Belgium. A 4 at the end of quarterly data denotes a 4-quarter moving average; a 12 at the end of monthly data denotes a 12-month moving average.

## Appendix B: The Time-Series Properties of the Left-Hand-Side Variables

The models estimated in the main text use the first difference of the logs of various measures of real commodity prices and the real exchange rate as left-hand-side variables. This appendix explains why that specification was chosen. As the literature on money/income causality has taught, this decision on the treatment of apparently nonstationary economic time series can have important implications for the qualitative results (as in Stock and Watson, 1987).

Following Stock and Watson's advice, we first subject our potential dependent variables to a battery of tests. First, using the monthly observations available from 1973:8 to 1987:6, we tested if the log levels of the series had one or two unit roots. As in Engle and Granger, 1987, the following test statistics were calculated (and appear as the column headings in Table A-2a):

- Dickey-Fuller test, which is a "t-test" of the coefficient of the lagged level variable in the regression

  $$Dx(t) = a + b\, x(t-1);$$

- Augmented Dickey-Fuller test, which is a "t-test" of the coefficient on the lagged level variable in the regression:

  $$Dx(t) = a + b\, x(t-1) + \sum_{i=1}^{4} c_i\, Dx(t-i)$$

- Durbin-Watson test, which is the standard Durbin-Watson statistic of the demeaned variable.

In all cases, for all potential dependent variables, the hypothesis of one unit root is not rejected while the hypothesis of two unit roots is rejected. The presence of a unit root in the real exchange rate is unsurprising and merely replicated Mussa's more qualitative assessment (Mussa, 1986). The similar behavior of all the measures of real commodity prices supports the main contention of this paper: real commodity prices, similarly to the real exchange rate, are relative prices determined in a general equilibrium system. It would be disturbing to find sets of relative prices with differing time-series properties. (The presence of a unit root in these relative prices also tells us that nominal prices are not cointegrated--as in the Engle and Granger sense.)

Second, we examined if the differenced variable exhibits a time trend. For each potential left-hand-side variable, the first difference of the logs was regressed against a constant and a time trend and, alternatively, a constant, a time trend, and 4 lags of the dependent variable (to tighten the standard errors). As shown in Table A-2b, in no case was the time trend significant.

These tests determined the basic unit of observation in the main text: first differences of the logs of all relative prices. They also suggest that any contemporaneous correlation is not an artifact of movements in nonstationary variables but a properly identified relationship of economic (as well as statistical) significance.

Table A-2a

The Time-Series Behavior of Commodity Prices
and The Real Exchange Rate

| | --One Unit Root-- | | | --Two Unit Roots-- | | |
|---|---|---|---|---|---|---|
| | D.F. | A.D.F. | D.W. | D.F. | A.D.F. | D.W. |
| IMF, all | -0.52 | -0.74 | 0.01 | -8.62 | -5.75 | 1.22 |
| Food | -0.87 | -0.56 | 0.01 | -8.58 | -6.55 | 1.22 |
| Beverages | -0.49 | -1.26 | 0.03 | -8.23 | -5.24 | 1.15 |
| Ag. Raw Mat. | -1.34 | -2.21 | 0.03 | -9.41 | -4.12 | 1.39 |
| Metals | -0.73 | -1.03 | 0.01 | -9.53 | -5.75 | 1.28 |
| CRB, all | -0.58 | -0.70 | 0.01 | -9.30 | -5.68 | 1.33 |
| Raw Mat. | -0.84 | -1.39 | 0.01 | -7.93 | -4.94 | 1.09 |
| Real Exchange Rate | -0.95 | -1.43 | 0.02 | -10.00 | -5.04 | 1.42 |
| Critical Values | | | | | | |
| 1 percent | 4.07 | 3.77 | 0.51 | | | |
| 5 percent | 3.37 | 3.17 | 0.39 | | | |
| 10 percent | 3.03 | 2.84 | 0.32 | | | |

Table A-2b

The Trend in the Change in
Commodity Prices and the Real Exchange Rate

| | | | -----Augmented----- | |
|---|---|---|---|---|
| | Constant | Time | Constant | Time |
| IMF, all | -1.04 | -0.11 | -0.71 | -0.49 |
| Food | -1.20 | 0.12 | -0.84 | -0.33 |
| Beverages | 1.07 | -1.54 | 1.19 | -1.67 |
| Ag. Raw Mat. | -0.73 | 0.42 | -0.71 | 0.39 |
| Metals | -0.90 | 0.05 | -0.75 | -0.15 |
| CRB, all | -0.64 | -0.20 | -0.45 | -0.46 |
| Raw Mat. | -0.74 | 0.11 | -0.53 | -0.19 |
| Real Exchange Rate | 0.98 | -1.13 | 0.92 | -1.06 |

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