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A Generalized Uncovered Interest Parity Model of Exchange Rates

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Sticky price monetary models of exchange rates, while reasonable theoretically, have been disappointing empirically. Out-of-sample predictions have been little or no better than those from a naive model of no change. The most likely reason is that shocks to the market's expectation of the future equilibrium real exchange rate weaken the stability of the association between exchange rates and the real interest rate differentials. This study identifies three types of shocks that appear to be empirically important. These are productivity growth, which changes the relative price of traded goods at home versus abroad, government budget deficits, and the real price of oil.

These factors along with real interest rates are shown to explain at least 80 percent of the longer run variation in both the trade-weighted dollar and bilateral rates against the dollar. An error correction model that includes these factors is shown to have out-of-sample prediction errors for changes in the trade-weighted dollar that are 30 to 45 percent lower than those from a naive model of no change, at horizons of four to eight quarters. The prediction errors for bilateral rates against the dollar are almost as low.

This paper reexamines the sources of fluctuations in exchange rates between the dollar and other major currencies in the post 1973 flexible rate experience. The real values of the major currencies have fluctuated quite widely in this period. As a result, flexible-price models, which assume constant real currency values (or purchasing power parity), have not been successful in explaining their movements.[1] Sticky price monetary models, which assume that prices in markets for goods adjust to disturbances more slowly than prices in markets for financial assets, have appeared to work more satisfactorily.[2] In these models, purchasing power parity holds in the long run when prices are able to adjust fully, but deviations from purchasing power parity occur in the short run. These deviations are associated with temporary differentials between real interest rates at home and abroad. Uncovered interest parity holds in the sense that the differences between real interest rates are offset by expected changes in the real exchange rate. As a result, movements in the real exchange rate can be explained by changes in the differential between home and foreign real interest rates.

The robustness of the sticky price monetary model has been challenged in an important series of papers by Meese and Rogoff, however.[3] They showed that, while variations in interest differentials can explain some of the movements in the major currencies within the period of estimation of the model, predictions outside that period are no better than those of a naive model of no change, even when actual values of the explanatory variables are used. Meese and Rogoff further suggested that the most likely hypothesis for explaining this result is the existence of shocks to the flexible-price equilibrium of the real exchange rate. The resulting variation in the expected value of the future real exchange rate would weaken the statistical association between real interest differentials and exchange rates. Yet, it has been difficult to identify which real factors have affected equilibrium real exchange rates over what periods.

1. Studies of the U.S. dollar using data for the period 1973 to 1978 have yielded findings consistent with the flexible price model, but those incorporating more recent data have been much less favorable to that approach. See Bilson (1978) and Hodrick (1978).

2. See, for example, Dornbusch (1976), Frankel (1979), Hooper and Morton (1982), and Shafer and Loopesko (1983).

3. See Meese and Rogoff (1983a, 1983b, 1988) and also Meese (1990).

This paper identifies several important factors in addition to real interest rate differentials that have altered real exchange rates between the major currencies. These factors include productivity in traded and nontraded goods, the real price of oil, and government budget balances. We call the resulting extension of the sticky price monetary model a generalized uncovered interest parity model of the exchange rate. It is shown that exchange rates are cointegrated with these factors over time. Because of this, real exchange rates can deviate from a simple purchasing power parity relationship even in the long run. Moreover, the adjustment of currencies to the equilibrium values determined by these factors is a major part of their short-run fluctuation. In particular, out-of-sample predictions (using actual values of the explanatory variables) of both the nominal and real trade-weighted dollar, as well as of three bilateral rates against the dollar, from an error-correction form of the generalized model are shown to be significantly better than those from a naive model of no change.

Section I reviews the basic elements of the conventional sticky price model of exchange rates and previous tests of its out-of-sample predictive power. Section II develops the generalized uncovered interest parity model. In Section III it is shown that the exchange rate is cointegrated with productivity differentials, the real price of oil, government budget balances, and the long-term real interest rate differential. Then, an error correction model is estimated to capture the gradual adjustment of exchange rates to the longer-run equilibrium established by this larger combination of variables. Out-of-sample predictions from this generalized uncovered interest parity model are shown to be very much superior to those of a naive model of no change. Section IV provides a summary and some conclusions.

I. CONVENTIONAL UNCOVERED INTEREST PARITY MODEL

Much of the recent work on exchange rates has been based upon the "monetary" or "asset" view. The market rate of exchange between two currencies is seen in the short run to equilibrate the international demand for stocks of assets, rather than the international demands for flows of goods, as the more traditional view posits. However, market adjustment ensures equilibrium in the goods markets as well in the longer run. The most widely used approach has been the uncovered interest parity model.

Uncovered Interest Parity

The conventional uncovered interest parity model of exchange rates uses two basic building blocks: (1) uncovered interest parity and (2) purchasing power parity. The condition of uncovered interest parity says that market arbitrage will move the exchange rate to the point at which the expected rate of return on investments denominated in either the home or foreign currency is the same, except for a possible risk premium. Thus,

$$(1) \qquad e_t - E_t(e_{t+k}) = k({}_ki_t - {}_ki_t^*) + pr_t,$$

where

e_t = log of nominal value of home currency

$E_t(e_{t+k})$ = market expectation at time t of exchange rate at time $t+k$

${}_ki_t$ = home country interest rate on security with k periods to maturity

${}_ki_t^*$ = foreign country interest rate on security with k periods to maturity

pr_t = risk premium

If the interest rate differential times the periods to maturity, k, exceeds the expected rate of depreciation of the home currency (allowing for any risk premium, pr_t), then arbitragers would bid the value of the home currency up until the equality holds, thus equalizing expected returns at home and abroad.

A problem with using this form of the theory for predicting exchange rates is that it is difficult to model the expected value of the nominal exchange rate k periods ahead. One way around this problem is to state the uncovered interest parity condition in real terms. Given nominal uncovered interest parity, it is also true that the expected depreciation in the *real* value of the home currency equals the excess in the *real* rate of return on investments in the home country over those in the foreign country (times k):[4]

$$(2) \quad q_t - E_t(q_{t+k}) = k(({}_ki_t - {}_k\pi_t) - ({}_ki_t^* - {}_k\pi_t^*)) + pr_t$$

or

$$(3) \quad q_t = E_t(q_{t+k}) + k(({}_ki_t - {}_k\pi_t) - ({}_ki_t^* - {}_k\pi_t^*)) + pr_t,$$

where

q_t = log of real value of home currency

${}_k\pi_t$ = market expectation at time t of inflation rate at home over k periods

${}_k\pi_t^*$ = market expectation at time t of inflation rate abroad over k periods

4. The uncovered interest parity condition in nominal terms is: $e_t - E_t(e_{t+k}) = k\ ({}_ki_t - {}_ki_t^*)$. But by definition $e_t = q_t + p_t^* - p_t$ and $E_t(e_{t+k}) = E_t(q_{t+k}) + p_t^* + k_k\pi_t^* - p_t - k_k\pi_t$. Substituting these relationships into the first equation then gives $q_t - E_t(q_{t+k}) = k[({}_ki_t - {}_k\pi_t) - ({}_ki_t^* - {}_k\pi_t^*)]$.

The advantage of equation (3) is that, particularly if a long-term real rate of interest is used, the expected value of the real exchange rate k periods ahead may be assumed to be a constant, corresponding to a flexible price equilibrium of purchasing power parity. Although equation (3) as it stands predicts the real exchange rate, it can be modified to explain the nominal exchange rate. This is done by breaking the real exchange rate into its real and nominal components:

$$(4) \quad e_t = E_t(q_{t+k}) + p_t^* - p_t + k(({}_ki_t - {}_k\pi_t) - ({}_ki_t^* - {}_k\pi_t^*)) + pr_t,$$

where

p_t^* = log of overall price level abroad

p_t = log of overall price level at home

The monetary theory of exchange rates explains p^* and p in terms of the demand for money at home and abroad. Given a stable standard demand function for money, the price level in each country would vary positively with the money supply and the nominal interest rate and negatively with real income.

Making these substitutions, Meese and Rogoff (1983a) estimated equation (4) for bilateral values of the dollar against the mark, pound, and yen. They then made predictions of these exchange rates outside of the period over which the model coefficients were estimated, *using actual realized values of all the explanatory variables*. The resulting prediction errors were no lower than those from a naive model that simply assumes no change in the exchange rate. As a result, it appeared that current structural models of the nominal exchange rate do not describe stable economic relationships.

However, these results may simply have been due to instability in the demand for money functions, resulting in poor predictions of p and p^*, rather than to instability in the basic uncovered interest parity relationship. Therefore, Meese and Rogoff (1988) followed up their earlier study by making similar out-of-sample predictions from an estimate of equation (3) making the real exchange rate the dependent variable. In this version of uncovered interest parity, current price levels are subsumed in the definition of the real exchange rate, which then simply becomes a function of the real interest rate differential and the market's expectation of the flexible-price equilibrium value of the real exchange rate. The latter is assumed to be a constant given by purchasing power parity. Once again, however, out-of-sample predictions were no more accurate than those from a naive model of no change.

Note that since what is at issue is the stability of the exchange rate model as indicated by its ability to make *ex post* forecasts, rather than *ex ante* forecasts, there is a straightforward way of testing the predictive ability of the nominal version of the model that is independent of the complications introduced by money demand. This is simply to use equation (4) with the actual realized values of the price levels, p^* and p, on the right hand side to predict the nominal exchange rate. This equation relies upon the same basic building blocks of uncovered interest parity and purchasing power parity as equation (3) for the real exchange rate. Moreover, the prediction errors from the two equations will be exactly the same because p^* and p are known.[5] Obviously, however, the prediction errors for the naive model of no change would differ for real and nominal exchange rates.

Meese and Rogoff (1988) suggest that the most likely hypothesis for explaining the poor out-of-sample predictions of the conventional model of exchange rates, whether nominal or real, is the existence of shocks to the flexible price equilibrium of the real exchange rate. The resulting variation in the expected value of the future real exchange rate would weaken the statistical association between the real interest rate differential and either the nominal or real exchange rate. To assess the empirical importance of these effects, this paper expands the conventional model to include factors that alter the flexible-price equilibrium of the real exchange rate. This generalized uncovered interest parity model is then used to generate out-of-sample predictions of both nominal and real exchange rates.

II. GENERALIZED UNCOVERED INTEREST PARITY MODEL

The expected value of the flexible-price equilibrium of the real exchange rate, which serves as an anchor for the conventional uncovered interest parity model, is likely to change significantly over time in response to a number of factors. This section expands the model to include some of these factors.

Productivity Growth

The real exchange rate relevant for uncovered interest parity is measured in terms of overall price levels. But, when measured this way, the flexible-price equilibrium will tend to change over time as a result of differential rates

5. The error in predicting the log of the real exchange rate is: $q_t - \hat{q}_t$ or $e_t - p_t^* + p_t^* - (\hat{e}_t - \hat{p}_t^* + \hat{p}_t)$. But since the price levels are known, $\hat{p}_t^* = p_t^*$ and $\hat{p}_t = p$. Therefore, $q_t - \hat{q}_t = e_t - \hat{e}_t$.

of productivity growth between traded and nontraded goods. This can be seen by examining the relationship between the real exchange rate when measured in terms of overall price levels and when measured in terms of the prices of tradable goods.

The log of the real value of the home currency in terms of overall price levels is:

$$(5) \qquad q_t = e_t - p_t^* + p_t,$$

where

e_t = log of nominal value of home currency

p_t = log of overall price level at home

p_t^* = log of overall price level abroad

Next, the log of the real value of the home currency in terms of the prices of traded goods is:

$$(6) \qquad qd_t = e_t - pd_t^* + pd_t,$$

where

pd_t = log of price of traded goods at home

pd_t^* = log of price of traded goods abroad

Substituting (6) into (5), the relationship between the real exchange rates measured in these two different ways is therefore:

$$(7) \qquad q_t = qd_t + (pd_t^* - p_t^*) - (pd_t - p_t).$$

Thus, even if the real exchange rate in terms of the prices of traded goods remains constant according to purchasing power parity, the real exchange rate in terms of overall price levels varies according to whether the relative price of traded goods is changing by more or less than abroad.

Since productivity typically grows faster in the traded goods sector than in the non-traded goods sector, the relative price of traded goods typically falls over time. Should the relative price of traded goods fall faster at home than abroad, then the real value of the home currency in terms of overall prices would rise even though the real exchange rate in terms of traded goods prices remains constant. The theory of purchasing power parity suggests that the exchange rate should adjust to equalize the prices of traded goods at home and abroad in terms of the same currency. But even if purchasing power parity holds in this sense, the flexible price equilibrium of the real exchange rate in the uncovered interest parity model would vary over time according to differential productivity growth.[6]

6. This aspect of the purchasing power parity hypothesis was explored in a well-known article by Belassa (1964). A more recent treatment is Koedijk and Schotman (1990).

In empirical analysis, the wholesale price index is frequently used as a proxy for the prices of traded goods.[7] That approach is also followed here. Returning to equation (3) for uncovered interest parity with the real exchange rate, equation (7) can be substituted for the expected value of the real exchange rate, giving:

$$\begin{aligned}(8) \quad q_t = {} & B_0 + E_t(qd_{t+k}) \\ & + E_t((pd_{t+k}^* - p_{t+k}^*) - (pd_{t+k} - p_{t+k})) \\ & + B_3({}_kR_t - {}_kR_t^*)\end{aligned}$$

where

$${}_kR_t - {}_kR_t^* = ({}_ki_t - {}_k\pi_t) - ({}_ki_t^* - {}_k\pi_t^*).$$

Next, the expected difference between relative prices at home and abroad is assumed to be a linear function of the current difference, so that:

$$\begin{aligned}(9) \qquad q_t = {} & B_0 + E_t(qd_{t+k}) \\ & + B_2((pd_t^* - p_t^*) - (pd_t - p_t)) \\ & + B_3({}_kR_t - {}_kR_t^*).\end{aligned}$$

If purchasing power parity holds in traded goods, then $E(qd_{t+k})$ is simply a constant. But home and foreign-traded goods by and large are imperfect substitutes, so that purchasing power parity does not hold even for traded goods. International adjustment requires changes in the prices of home-traded goods relative to foreign-traded goods, and therefore in the real exchange rate measured in terms of the prices of traded goods.

Budget Balances

An important factor requiring such adjustment is changes in the balance between saving and investment at home relative to that abroad. A country with a high rate of investment relative to saving will tend to absorb more output than it produces, which will tend to put upward pressure on the prices of home-traded goods relative to those of foreign-traded goods. Historically, private saving has been quite stable.[8] In the last two decades, however,

7. See, for example, Koedijk and Schotman (1990), Clements and Frenkel (1980), and Wolff (1987).

8. See David and Scadding (1974). As pointed out by Feldstein (1992), private saving in the U.S. has trended down in the 1980s. However, foreign private saving rates also have declined in this period. See, for example, Bosworth (1993, ch. 3). So effects on the dollar have tended to be offsetting.

U.S. government saving has fluctuated a lot. Consequently, this paper focuses on the effects of changes in government saving.

The effects of changes in government saving on the flexible-price equilibrium of the real exchange rate can be illustrated with the aid of a simple model.[9] This assumes that traded goods produced in different countries are imperfect substitutes, so that the equilibrium price of traded goods in one country relative to that in another changes in response to shifts in supply and demand. In contrast and consistent with the notion of uncovered interest parity, financial assets as a first approximation are assumed to be perfect substitutes (this assumption will be relaxed later). Real aggregate spending at home and abroad varies inversely with the country's real interest rate; and the real trade balance moves inversely with the real value of the country's currency measured in terms of prices of tradable goods. In algebraic terms, the conditions for full employment at home and abroad are therefore:

$$y_0 = A(R) + nx(qd) \tag{10}$$

$$y_0^* = A^*(R^*) + nx^*(qd) \tag{11}$$

where

$y_0 y_0^*$ = full employment output

$A(A^*)$ = real aggregate spending, or absorption

$nx(nx^*)$ = real net exports

(R,R^*) = real interest rate

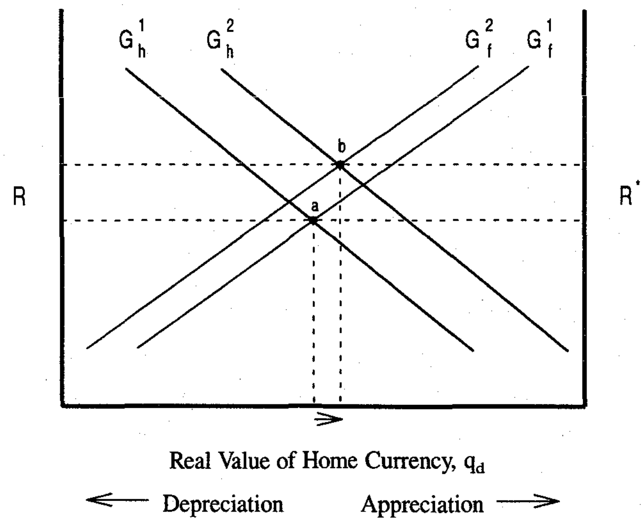
qd = real value of home currency measured in prices of tradables

Assuming a complete adjustment to full employment equilibrium, there are three unknowns (R, R^*, and qd) but only two equations. However, R can be solved as equal to R^* in the case where home and foreign assets are perfect substitutes (or equal to R^* plus or minus a risk premium in the case of imperfect substitutes).

Figure 1 provides a graphical representation of this system. The goods market equilibrium in the home country is represented by G_h. It is downward sloping because a reduction in the domestic real interest rate (left scale) must be offset by an appreciation in the real value of the home currency (qd) in order to maintain real aggregate spending equal to potential output. Conversely, the locus of the foreign goods market equilibrium, G_f, is upward sloping. A reduction in the foreign real interest rate (right scale) has

FIGURE 1

EFFECT OF FISCAL EXPANSION IN HOME COUNTRY: SHORTER RUN



to be offset by a depreciation in the real value of the home currency in order to restore a goods market equilibrium abroad. General equilibrium in the case of perfect substitutability between assets lies at point *a*, where the two schedules for goods market equilibrium intersect and the interest rates are equalized.

Consider now the comparative statics of a fiscal expansion in the home country. A fiscal expansion in the form of a larger budget deficit or smaller surplus at home increases the demand for home goods, shifting the G_h schedule up and to the right.[10] Either a higher real interest rate or higher real value of the domestic currency, or some combination of the two, is necessary to maintain the same level of aggregate spending on home goods as before.

To the extent that higher domestic spending falls on foreign goods, the G_f schedule shifts up also. But one would expect more of the increased spending to fall on home goods than foreign goods. So the G_h schedule would shift up by more than the G_f schedule, leading to a new general equilibrium at a point like *b*. At this point the world level of real interest rates will have risen, and the real value of the home currency (qd) will have *appreciated* in response to the fiscal expansion at home.

9. For earlier treatments, see Dornbusch (1983), Blanchard and Dornbusch (1984), Hutchison and Throop (1985) and Throop (1989).

10. This assumes that households do not increase their saving in order to fund the extra future tax liabilities caused by the increase in the government's larger deficit. If they did increase their saving by the full amount of the increase in these liabilities, then the G_h and G_f schedules would not change at all. On this so-called "Ricardo effect," see Barro (1974), Bernheim (1987), Brunner (1986), and Tobin (1980, ch. 3).

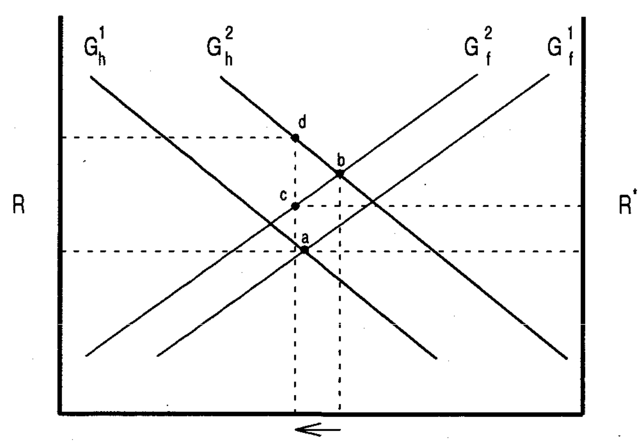
Even if the fiscal deficit were to persist, however, the value of the home currency could begin to depreciate and eventually end up lower than it was before. This would happen if there were a limit to the amount of home currency assets that foreigners were willing to absorb. Associated with the net import surplus resulting from the home currency's appreciation is a net capital inflow into the home country. As a result, as foreigners increase their holding of home country assets, the risk premium on them is likely to increase, driving a growing wedge between home and foreign country interest rates.

This process is illustrated in Figure 2. Assume for simplicity that there is no risk premium to begin with. Then the fiscal expansion shifts the G_k and G_f schedules up as before. This makes the dollar appreciate from point *a* to point *b*, as before. But now the risk premium grows with the accumulation of home country debt by foreigners. The risk premium, given by *cd* in the diagram, drives a growing wedge between foreign and home country interest rates. The risk premium will continue to grow until the exchange rate has depreciated by enough to prevent net indebtedness to foreigners from growing any further. If the budget deficit persists, this would occur when the home currency has depreciated by enough not only to eliminate the original import surplus but also to generate an export surplus sufficient to pay for servicing the debt without further capital inflows. Thus, given a persistent fiscal deficit, a stable equilibrium requires that the home currency depreciate by more than the original appreciation.

The movements in the real exchange rate that are pro-

FIGURE 2

EFFECT OF FISCAL EXPANSION IN HOME COUNTRY: LONGER RUN



duced by changes in budgetary positions in this comparative statics exercise correspond to changes in the long-run flexible-price equilibrium of the real exchange rate in the uncovered interest parity model. The actual effect of budgetary changes on the exchange rate in the short run will depend upon the character of market expectations. In particular, what matters is whether the market views changes in budgetary positions as temporary or permanent, the effective time horizon over which its expectations are formed, and the degree to which the risk premium can be expected to change as indebtedness changes. Although the very long-run effect of a persistent fiscal expansion would appear to be one of depreciation in the real value of the home currency, the market may well expect an appreciation to result over its relevant time horizon.

Real Price of Oil

The final factor that appears to have been important in affecting the flexible-price equilibrium value of real exchange rates is the real price of oil. The real price of oil rose 65 percent in the early 1970s, and then another 70 percent in the late 1970s and early 1980s as the result of the actions of the OPEC cartel. Then in the mid-1980s it dropped by 50 percent as the cartel's power started to erode.

Like the effects of budget deficits, the effects of oil price changes on the flexible-price equilibrium value of real exchange rates between currencies of the oil-importing countries depend upon the effects on the goods markets of those countries. Following oil price increases, the less developed oil-exporting countries typically have temporarily invested the proceeds of higher oil export revenues in the capital markets of the developed oil-importing countries, which in turn have lent much of these funds to other less developed countries. In this "recycling" process international capital mobility has been fairly high, so that it can be assumed real interest rates in different countries would continue to be roughly equalized in flexible-price equilibrium. As a result and similar to the effects of budget deficits, the effect of an oil price change on equilibrium exchange rates of the oil-importing countries depends upon the relative effects on aggregate demand in those countries. These effects may change over time to some degree, as the oil-exporting countries gradually increased their expenditures on the exports of oil-importing countries. However, the most important factor is the degree of dependence of the importing countries on imported oil. This can be illustrated with the aid of the model used in the previous section.

Industrialized countries differ widely in their dependence on imported oil. For instance, the U.S. imports about 40 percent of its oil, but Japan is totally dependent on imports to satisfy its oil needs. Let the home country in the model be like the U.S., which is less dependent upon oil imports than its major industrialized trading partners. The other country in the model represents those trading partners.[11]

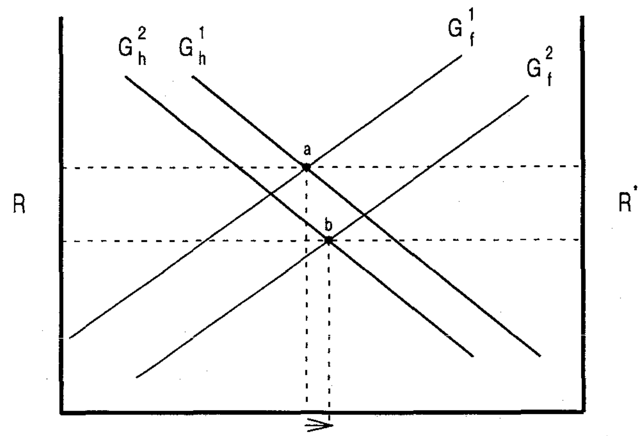
Following a price increase by OPEC, in the first stage assume that all of OPEC's oil revenues are invested abroad. If the home country is less dependent upon imported oil than its industrialized trading partners, its import bill will increase but by less than theirs. The increase in the import bill reduces aggregate demand, and so requires a reduction in the real interest rate to maintain full employment equilibrium. As shown in Figure 3, the G_h schedule for the home country therefore shifts down, but by less than the G_f schedule for the other oil importers. The result is a decrease in the world real interest rate because of the increase in OPEC's saving and a real *appreciation* of the home currency (in terms of tradable goods prices). The currency of the foreign country, which is more dependent on imported oil than the home country, depreciates so as to allow it to export more to the home country in order to pay for its oil imports more cheaply.

Over a longer run, OPEC will gradually increase the proportion of oil revenues that are spent on foreign goods and services. This increases the demand for exports of both the home country and the foreign country in the model. But so long as OPEC does not have a much stronger preference for the goods of the foreign country compared with those of the home country, the real appreciation of the home country's currency will not be undone. Thus, following an oil price increase it is likely that the market will expect an appreciation in the flexible-price value of the real equilibrium exchange rates of those countries that are less dependent on imported oil.[12] Notice also that over the longer run the upward shifts of G_h and G_f will tend to restore the world rate of interest to its previous level.

11. The exchange values of the currencies of the oil exporting countries do not enter into this analysis because oil is priced in dollars, and these "petrodollars" are either invested or spent on goods and services abroad.

FIGURE 3

EFFECT OF OIL PRICE INCREASE



Real Value of Home Currency, q_d

⟵ Depreciation Appreciation ⟶

Generalized Uncovered Interest Parity

The log of the flexible-price equilibrium value of the real exchange rate, measured in terms of the prices of traded goods, thus can be assumed to be a function of budget balances both at home (*USBB*) and abroad (*FBB*) and the log of the real price of oil (*LPOIL*). This gives:

$$E_t(qd_{t+k}) = \gamma_0 + \gamma_1\, USBB_2 + \gamma_2\, FBB_t + \gamma_3\, LPOIL_t. \tag{12}$$

Next, substituting (12) into (9) gives the generalized open interest parity condition for the *real* exchange rate as:

$$q_t = B_0 + B_1\, USBB_t + B_2\, FBB_t + B_3\, LPOIL + B_4((pd_t^* - p_t^*) - (pd_t - p_t)) + B_5({}_kR_t - {}_kR_t^*). \tag{13}$$

The presence of p_t* and p on both the left hand side (in q_t) and right hand side of (13) produces an automatic correlation between the left and right side variables. To avoid this statistical problem when estimating the coefficients of the model, the dependent variable is redefined to be the *nominal* value of the home currency by substituting (5) for q_t. Collecting terms, this gives the generalized uncovered interest parity condition for the *nominal* exchange rate as:

$$e = B_0 + B_1\, USBB_t + B_2\, FBB_t + B_3\, LPOIL + B_4(pd_t^* - pd_t) + (1 - B_4)(p_t^* - p_t) + B_5({}_kR_t - {}_kR_t^*). \tag{14}$$

The estimate of this equation is then used to make out-of-sample predictions of the nominal exchange rate, assuming the values of all explanatory variables are known. To make out-of-sample predictions of the *real* exchange, known values of p_t and p_t^* are simply added and subtracted,

12. Trehan (1986) detects a positive influence of the price of oil on the trade-weighted value of the U.S. dollar. Also see Krugman (1983) and Dunn (1979).

respectively, to the value of e predicted by the estimated form of equation (14). But as pointed out earlier, since p_t and p_t^* are known, the prediction errors for real and nominal exchange rates are the same.

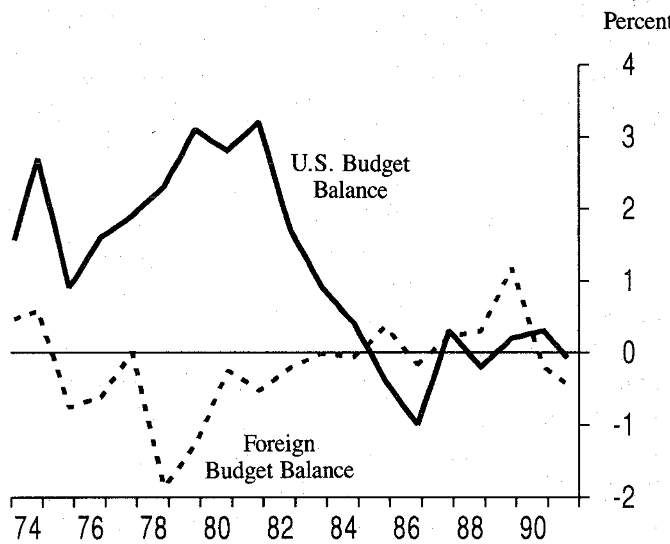
For the case of the trade-weighted dollar, e_t is measured by the multilateral trade-weighted value against 10 major industrial countries constructed by the staff of the Board of Governors of the Federal Reserve System. The interest rates, ${}_kR_t$ and ${}_kR_t^*$, are yields on 10-year government bonds less a centered 12-quarter moving average of inflation in consumer prices. The real price of oil is calculated as the ratio of the seasonally adjusted producers' price of crude petroleum to the seasonally adjusted producers' price of finished goods.

To measure anticipated budget balances, a moving average of inflation-adjusted high employment budget balances as a percent of GDP for the most recent four quarters was used.[13] The alternative of budget balances over four quarters ahead did not perform as well. Neither did flexible distributed lags on current and past budget balances. For the trade-weighted dollar, trade weights clearly should be used in aggregating the rest of the world's relative prices and real interest rates. But the effect of a foreign structural budget deficit depends upon the relative size of the foreign country as well, and the weights should reflect this. The smaller the foreign country, the larger will trade generally be as a proportion of GDP, the steeper will be its G schedule, and the less the G schedule of the home country will be changed by a movement of the foreign country's budget deficit. As a result, the smaller will be the size of the effect of its own budgetary changes on its exchange rate with the home country. Therefore, in the case of the trade-weighted dollar, foreign budget balances were weighted by GDP weights times trade weights.

Theoretically, both foreign and U.S. budget balances should be included in the model. However, while the U.S. budget balance had the expected estimated effects in all cases, the estimated effects of foreign budget balances were close to zero and sometimes of unanticipated sign. In the case of the trade-weighted dollar, the explanation appears to be that during the sample period there was relatively little variation in the weighted foreign budget balance, as shown in Figure 4. For the bilateral rates the explanation appears to be different. As discussed, the size of the effect of a foreign budget deficit on the respective dollar bilateral rate depends upon the relative size of

FIGURE 4

U.S. AND FOREIGN INFLATION-ADJUSTED STRUCTURAL BUDGET BALANCES



the foreign country. In the sample period, the largest of the three foreign economies (Japan) was only one-third of the size of the U.S. economy. So the effect of its budget deficit on the dollar bilateral rate would be much smaller than the effect of the U.S. budget deficit. The crudeness of the budget data and sharper perceptions of U.S. as opposed to foreign budget deficits also may have been contributing factors. In any case, because of a lack of significant effects, foreign budget balances were dropped from the model.

A further point with respect to equation (14) is that the coefficients on the wholesale price differential (B_4) and the consumer price differential ($1-B_4$) should sum to 1.0. Unrestricted estimates of these coefficients came close to meeting this condition, and this constraint was imposed both in the cointegrating vectors and subsequent error correction models of the exchange rate.

III. STABILITY OF THE GENERALIZED UNCOVERED INTEREST PARITY MODEL

The generalized open interest parity condition of equation (14) does not hold instantaneously. This is because perceptions of the flexible-price equilibrium of the real exchange rate evolve gradually in response to changes in the current values of their determinants. However, the variables in equation (14) are cointegrated in the long run and can be described by an error correction system in the short run.

13. These budget balances are for state and local, as well as the federal, government. The recent data was constructed from various issues of the *OECD Economic Outlook*. Back data are from Price and Muller (1984).

Cointegration

Having found that short-term movements in real long-term interest rate differentials are no better than a naive model of no change for making out-of-sample predictions of real bilateral exchange rates, Meese and Rogoff (1988) went on to examine the possibility that real exchange rates adjust slowly to real interest rate differentials. They rejected this possibility, however, because they found that real bilateral long-term interest rate differentials were *not* cointegrated with real bilateral exchange rates. Cointegration of these variables would mean that there is a long-run relationship between them.[14]

Meese and Rogoff used the Engle-Granger two-step procedure to test for cointegration. In the first step one variable is regressed against other variables that are potentially cointegrated with it. The residuals from the regression are then tested for stationarity by means of the Dickey-Fuller test. If nonstationarity of the residuals is rejected, then the combination of variables can be regarded as cointegrated.[15] Table 1 substantiates a lack of cointegration between the real exchange rate and the real long-term interest rate differential for the four exchange rates in this study using the Dickey-Fuller test.[16]

A more powerful test for cointegration is available, however. As proved by Engle and Granger (1987), any variables that are cointegrated have an error correction representation. This means, for example, that if the real exchange rate is cointegrated with the real interest rate differential, then the errors in this relationship are part of a larger error correction system. Such a two variable system would be written as:

$$(15)\ \Delta q_t = -\rho_1 EC_{-1} + \text{lagged } [\Delta q_t, \Delta ({}_kR_t - {}_kR_t^*)]$$

$$(16)\ \Delta({}_kR_t - {}_kR_t^*) = \rho_2 EC_{-1} + \text{lagged } [\Delta q_t, \Delta ({}_kR_t - {}_kR_t^*)]$$

where $EC_t = q_t - B_0 - B_1 ({}_kR_t - {}_kR_t^*)$.

In this error correction model, the short-run and long-run responses of the variables are allowed to differ, and all variables are treated as endogenous. In contrast, the Dickey-Fuller test assumes that short- and long-run responses are the same. It also ignores possible endogeneity of the explanatory variables. As a result, the Dickey-Fuller test is inefficient. A more powerful test for cointegration is obtained by maximum likelihood estimation of the complete error correction system, as developed by Johansen (1988) and Johansen and Juselius (1990).[17] Table 1 shows that, on the basis of this more powerful test, cointegration between the real exchange rate and the real long-term interest rate differential is accepted for the trade-weighted dollar and bilateral rates against the mark and pound, but is rejected for the bilateral rate against the yen.[18]

The Johansen procedure also was used to test for cointegration of all variables in (14).[19] Since the power of this

TABLE 1

TESTS FOR COINTEGRATION OF REAL EXCHANGE RATE AND REAL LONG-TERM INTEREST RATE DIFFERENTIAL, 1974.Q1 TO 1991.Q3

	AUGMENTED DICKEY-FULLER TEST	JOHANSEN PROCEDURE Maximum Eigenvalue	Trace
Trade-weighted US$	−2.41	16.3**	19.4**
Yen/US$	−2.39	4.0	7.2
Mark/US$	−1.68	12.94*	17.4*
Pound/US$	−1.78	15.5**	18.7**

**Significant at 5 percent.
*Significant at 10 percent.

14. A necessary condition for cointegration is that the variables be nonstationary and also integrated of the same order. See Charemza and Deadman (1992), ch. 5. Meese and Rogoff (1988) rejected stationarity for levels of the three real bilateral exchange rates as well as the corresponding real long-term interest differentials, but not for first differences. Stationarity can also be rejected for levels of the nominal and real trade-weighted dollar and the corresponding long-term real interest rate differential.

15. See Engle and Granger (1987) and Engle and Yoo (1987), and Charemza and Deadman (1992), Ch. 5.

16. Couglin and Koedijk (1990) and Edison and Pauls (1991) report similar results with respect to the cointegration of exchange rates and real interest rates using the Dickey-Fuller test.

17. In the case of two variables there can be only one unique cointegrating vector. In the more general case of a model with n variables, however, there can be up to n-1 unique cointegrating vectors. See Johansen and Juselius (1990) or Charemza and Deadman (1992, Ch. 6.4).

18. Two lags on the differenced variables were used. Edison and Melick (1992) also found cointegration between the real trade-weighted dollar and the real long-term interest rate spread using the Johansen procedure.

19. A necessary condition for cointegration is that the variables be integrated of the same order. As discussed in footnote 14, exchange rates and real interest rate differentials were found to be stationary in first differences but not in levels, or integrated of order one. This is also true of the other variables in equation (14), with the exception of the Japanese price levels, which were stationary in levels. However, since the U.S. price level is nonstationary in levels, all of the relative price variables were nonstationary also, and thus also integrated of order one.

test is low for cointegration vectors that are close to being nonstationary, it is reasonable to follow a test procedure that allows rejection for probability values higher than the usual 5 or 1 percent. As shown in Table 2, the Johansen procedure rejects the null of no cointegrating vectors for the trade-weighted dollar at the 1 percent level; and at that same level of significance one cointegrating vector is accepted. Similarly, for the nominal bilateral rates against the dollar, the null of no cointegrating vector is rejected at from a 5 to 20 percent level of significance, and one cointegrating vector is accepted. Thus, the data for both the trade-weighted dollar and the three bilateral rates are consistent with cointegration of the variables in the generalized uncovered interest parity model.

Estimates of the cointegrating vectors for the variables in equation (14) are given in Table 3, and the resulting contributions to longer-run changes in the value of the nominal trade-weighted dollar are shown in Figures 5 and 6. The effect of the real interest rate differential was either very small or of the wrong sign for the yen and pound bilateral rates, most likely because of the difficulty of measuring long-term inflation expectations. So in these cases the variable was dropped. Otherwise, the overall effects on the exchange rate are about as anticipated. A 1 percentage point increase in the U.S. budget deficit as a percent of U.S. GDP is estimated to appreciate the value of the trade-weighted dollar by 6 percent, with the value in terms of the pound going up by more and in terms of the yen and the mark by less. A 10 percent higher real price of oil is estimated to appreciate the trade-weighted value of the U.S. dollar by about 3 percent, but less so against the mark than the other two currencies. Also, the value of the dollar moves positively with the relative price of traded goods abroad compared with the U.S., as anticipated.

The inclusion of factors besides interest rates substantially reduces the estimated long-run response of the dollar to interest rates. Without these additional factors, a 1 percentage point change in the real interest rate differential on 10-year bonds is estimated to move the trade-weighted dollar by about 7 percentage points. But with their inclusion the estimated effect drops to about 3½ percentage points. Evidently, risk in open interest arbitrage causes the response of the dollar to fall well short of the 10 percentage point response that would tend fully to equalize expected returns on 10-year bonds.

TABLE 2

TESTS FOR COINTEGRATION OF THE EXCHANGE RATE WITH ALL VARIABLES IN GENERALIZED UNCOVERED INTEREST PARITY MODEL, 1974.Q1–1991.Q3

	Johansen Procedure		
	Number of Cointegrating Vectors	Maximum Eigenvalue	Trace
Trade-Weighted US$	0	47.3****	96.8****
	1	25.6	49.6
Yen/US$	0	35.6***	78.6****
	1	25.4	42.9
Mark/US$	0	27.8*	65.1*
	1	14.1	37.3
Pound/US$	0	30.5**	78.7****
	1	23.5	48.2

****Reject at 1 percent
***Reject at 5 percent
**Reject at 10 percent
*Reject at 20 percent

PREDICTIONS WITH AN ERROR CORRECTION MODEL

Given cointegration of the variables, the short-run adjustment of the exchange rate to generalized open interest parity can be captured with an error correction model. Estimates of such a model for changes in nominal exchange rates are provided in Table 4. The model explains nearly

TABLE 3

COINTEGRATION VECTORS FOR NOMINAL EXCHANGE RATES, 1974.Q1–1991.Q3

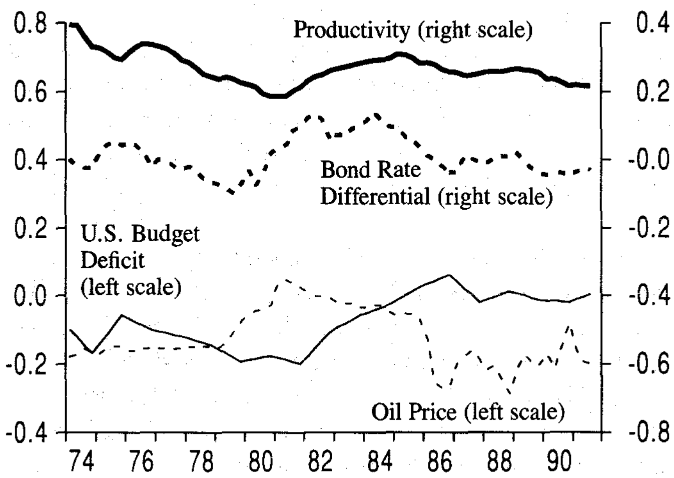
	CONSTANT	$USBB_t$	$LPOIL_t$	$(pd_t^* - pd_t)$	$(p_t^* - p)$	$(R_t - R_t^*)$	$\bar{R}^2$	S.E.
Trade-Weighted US$	4.56	−0.0625	0.281	0.985	0.015	0.0341	0.798	0.0678
Yen/US$	5.41	−0.0447	0.278	2.03	−1.03	—	0.918	0.0813
Mark/US$	0.987	−0.0469	0.165	2.89	−1.89	0.0179	0.866	0.0690
Pound/US$	−0.218	−0.111	0.225	1.55	−0.55	—	0.861	0.0666

half of the in-sample variation of changes in the trade-weighted dollar (Figure 7) and somewhat lesser proportions of changes in the bilateral rates. A full response of the trade-weighted dollar to changes in the real interest rate differential takes only one quarter, consistent with a relatively quick exploitation of arbitrage opportunities. The speed of response of the dollar to changes in the other variables is generally not as fast, suggesting a gradual formation of longer-term expectations with regard to the flexible-price equilibrium of the real exchange rate.

Out-of-sample predictions that use data other than those on which the model was estimated provide an important test of the stability of the economic relationships in the model. Therefore, the error correction model was first estimated for the period 1975.Q2 to 1981.Q4. Then predictions for one, four, and eight quarters ahead were made using the actual values of the explanatory variables. Predictions of the change in the nominal exchange rate were made with the estimated error correction equation, while the predictions of the change in the real exchange rate were obtained by subtracting off changes in logs of the price levels. The estimation was then updated to include successively more quarters, allowing additional out-of-sample predictions to be made. The root-mean-squared error (RMSE) for (non-overlapping) predictions of the error correction model was then calculated and compared with that of a naive model of no change. F tests indicated the lack of significance of lagged changes in the U.S. budget balance and the price of oil in most cases, suggesting that only the error correction part of the model is important for the short-run response to these variables. Consequently, two sets of predictions were examined, one including these variables and the other excluding them.

FIGURE 5

CONTRIBUTIONS OF ALL ECONOMIC FACTORS TO VALUE OF TRADE-WEIGHTED DOLLAR



NOTE: In logarithms.

FIGURE 6

TRADE-WEIGHTED DOLLAR AND VALUE PREDICTED BY ALL ECONOMIC FACTORS

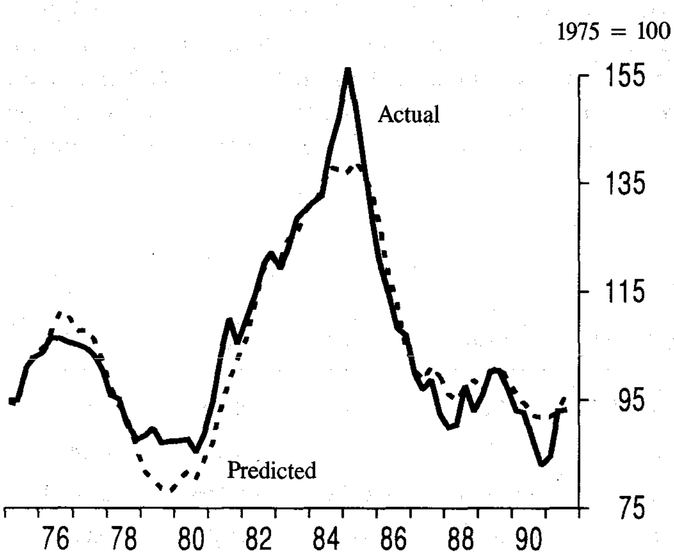
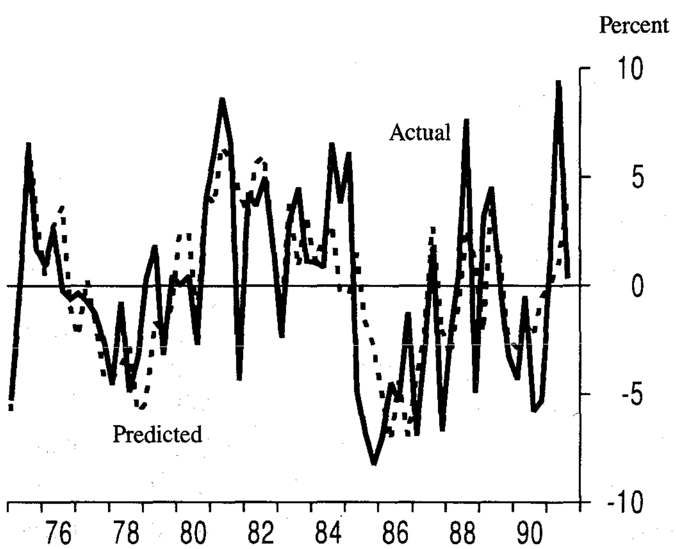


FIGURE 7

QUARTERLY CHANGE IN TRADE-WEIGHTED DOLLAR AND VALUE PREDICTED BY ALL ECONOMIC FACTORS



As discussed earlier, the RMSEs for predictions of the real and nominal exchange rates are the same in this exercise, and only the RMSEs for predictions from the naive model of no change differ. As shown in Table 5, the RMSEs for out-of-sample predictions of the nominal trade-weighted dollar from the full model are about 10 percent lower than those of the naive model of no change for one or two quarters ahead. Then, for four and eight quarters ahead the RMSE is about 30 and 45 percent less than for the naive model, respectively. Also, the partial model that drops lagged changes in the U.S. budget balance and the price of oil reduces the RMSE by significantly more at horizons up to four quarters. Thus, not only does the generalized uncovered interest parity model fit the in-sample data for the nominal trade-weighted dollar better than the simple uncovered interest parity model does, but it also performs significantly better out of sample as well.

The results for the bilateral rates are almost as good. In the work of Meese and Rogoff, the RMSEs for the out-of-sample predictions of bilateral rates from the simple uncovered interest parity model were no lower than for those from the naive model. In contrast, the partial generalized

TABLE 4

ESTIMATED ERROR CORRECTION MODEL OF SHORT-RUN ADJUSTMENT FOR THE NOMINAL EXCHANGE RATE, 1975.Q2–1991.Q3

	VARIABLE			
	TRADE-WEIGHTED US$	YEN/US$	MARK/US$	POUND/US$
$\Delta USBB_{t-1}$	−0.00444	−0.0421	−0.0411	−0.0156
	(−0.156)	(−0.934)	(−1.01)	(−0.333)
$\Delta USBB_{t-2}$	−0.0174	0.0209	−0.0186	−0.0401
	(−0.646)	(0.486)	(−0.479)	(−0.904)
$\Delta LPOIL_{t-1}$	0.0237	0.0852	0.0306	−0.0165
	(0.572)	(1.32)	(0.551)	(−0.239)
$\Delta LPOIL_{t-2}$	0.00768	−0.0474	0.0874	0.000806
	(0.181)	(−0.723)	(1.58)	(0.0115)
$\Delta(pd^*_{t-1}-pd_{t-1})$	−0.297	0.149	0.553	0.354
	(0.666)	(0.335)	(0.953)	(1.22)
$\Delta(pd^*_{t-2}-pd_{t-2})$	1.15	−0.0443	0.103	0.220
	(2.56)	(0.460)	(0.180)	(0.763)
$\Delta(p^*_{t-1}-p_{t-1})$	1.29	0.851	0.447	0.646
	(2.91)	(1.91)	(0.772)	(2.23)
$\Delta(p^*_{t-2}-p_{t-2})$	−0.150	1.04	0.897	0.780
	(−0.333)	(2.27)	(1.57)	(2.71)
$\Delta(R_{t-1}-R^*_{t-1})$	0.0190	—	0.0269	—
	(2.58)		(3.03)	
$\Delta(R_{t-2}-R^*_{t-2})$	−0.00158	—	−0.00143	—
	(−0.210)		(−0.143)	
Δe_{t-1}	0.227	0.397	0.116	0.182
	(1.90)	(2.57)	(0.923)	(1.10)
Δe_{t-2}	0.0228	−0.0901	−0.109	−0.0119
	(0.195)	(−0.561)	(−0.860)	(−0.069)
EC_{t-1}	−0.234	−0.166	−0.188	−0.268
	(−2.87)	(−0.166)	(1.94)	(−1.76)
S.E.	0.0330	0.0552	0.0468	0.0558

NOTE: t statistics are in parentheses.

TABLE 5

OUT-OF-SAMPLE RMSE FOR SHORT-RUN ADJUSTMENT TO GENERALIZED UNCOVERED INTEREST PARITY, 1982.Q1 TO 1991.Q3

	HORIZON	NAIVE MODEL		ERROR CORRECTION (Nominal and Real)	
		Nominal	Real	Full	Partial
Trade-Weighted US$	1	0.048	0.050	0.045	0.041
	2	0.081	0.083	0.072	0.060
	4	0.135	0.138	0.093	0.082
	8	0.235	0.223	0.135	0.133
Yen/US$	1	0.059	0.059	0.066	0.064
	2	0.100	0.097	0.084	0.080
	4	0.154	0.145	0.105	0.097
	8	0.263	0.236	0.190	0.189
Mark/US$	1	0.057	0.055	0.058	0.051
	2	0.094	0.090	0.086	0.069
	4	0.156	0.144	0.117	0.097
	8	0.271	0.244	0.149	0.139
Pound/US$	1	0.057	0.066	0.066	0.060
	2	0.089	0.111	0.111	0.085
	4	0.159	0.153	0.153	0.120
	8	0.205	0.125	0.125	0.150

model reduces the RMSE for bilateral rates by 5 to 30 percent for a horizon of two quarters and by 25 to 50 percent for horizons of four or eight quarters.

The RMSEs for the naive model of no change are approximately the same, whether predictions are made for nominal or real values of the dollar. Therefore, the marked superiority of the generalized uncovered interest parity model over the naive model holds up for the real exchange rates as well.

IV. SUMMARY AND CONCLUSIONS

Sticky price monetary models of the real exchange rate, while reasonable theoretically, have been disappointing empirically. These models imply that real exchange rates should vary significantly with real interest rate differentials, according to the principle of uncovered interest parity. But while some statistical association between exchange rates and interest rates has been found, predictions of real exchange rates using data other than those on which the model is estimated have not been satisfactory. The most likely reason is that shocks to the market's expectation of the future equilibrium real exchange rate weaken the stability of the association between the real exchange rate and the real interest rate differential.

This study has identified three types of factors that appear to be empirically important. These are productivity growth that causes changes in the relative prices of traded goods at home versus abroad, government budget deficits, and the real price of oil. These factors along with long-term real interest rate differentials account for at least 80 percent of the longer-run variation in both the trade-weighted dollar and bilateral rates against the dollar. However, taking these additional factors into account reduces the estimated effect of interest rates on the dollar. The estimated response of the trade-weighted dollar to a 1 percentage point change in the differential between 10-year real bond rates drops from about 7 percent to 3½ percent in the complete model.

An error correction model, based on this expanded form of uncovered interest parity explains nearly half of the in-sample variation in *changes* in the trade-weighted dollar and has out-of-sample prediction errors that are 30 to 45 percent lower than those from a naive model of no change over horizons of four or eight quarters. Moreover, prediction errors for bilateral rates are almost as low as for the trade-weighted dollar.

These results have important implications for monetary policy. Most macroeconometric models stress the role of real interest rate differentials between the U.S. and abroad in determining the real value of the dollar. However, this study has shown that productivity growth, the real price of oil, and budget deficits also play important roles. Moreover, taking these additional factors into account reduces the estimated effects of interest rates on the dollar. As a result, the influence of monetary policy on the international sector of the economy, operating through interest rates, probably is lower than generally thought.

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