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*RE-EXAMINING THE EMPIRICAL PERFORMANCE OF THE
MONETARY MODELS OF THE EXCHANGE RATE:
A PROBLEM OF STRUCTURAL CHANGE*

BY

Michael D. Goldberg
and
Roman Frydman

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**NEW YORK UNIVERSITY
FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF ECONOMICS
WASHINGTON SQUARE
NEW YORK, N.Y. 10003**

**Re-Examining the Empirical Performance of the Monetary Models of the Exchange Rate: A
Problem of Structural Change**

Michael D. Goldberg

The Whittimore School of Business and Economics
The University of New Hampshire
Durham, New Hampshire 03824

and

Roman Frydman¹
Department of Economics
New York University
New York, NY 10003

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Abstract

This paper arrives at two major conclusions. First, macroeconomic fundamentals do matter for exchange rate dynamics, but in a nonstandard way. They matter in that different sets of fundamental variables are significant during different time periods. Second, the basic (semi-reduced-form) assumptions of the sticky-price monetary models of the exchange rate are consistent with the data. Both of these conclusions stem from incorporating the problem of structural change on the part of reduced-form parameters explicitly into the analysis in a way that is objective and allows us to distinguish periods of time in the data characterized by relative parameter constancy. Our analysis indicates that the monetary models experience structural instability on more occasions over the modern floating rate period than previously documented, giving rise to three periods of relative parameter constancy. Within each period of stability we find that: 1) Many of the fundamental variables of standard theory are significant and enter with correct parameter signs, although different sets of fundamental variables are significant during different time periods; 2) These sets of significant variables are cointegrated, implying that there are longer-run relationships operating in the foreign exchange market; and 3) All of the structural models examined outperform the random walk model in out-of-sample forecasting by considerable margins (in some cases by a margin of 70 percent in root mean square error), indicating that the large forecasting errors reported in Meese and Rogoff [1983] are the result of allowing the forecasting experiment to run past the end of one exchange rate regime and into the next. In order to reconcile the structural change results and the finding that different sets of fundamental variables are significant during different time periods with exchange rate theory, we make use of an alternative expectational hypothesis called the theories consistent expectations hypothesis (TCEH), recently proposed in Frydman and Phelps [1990] and developed in Goldberg and Frydman [1991a,b]. We find that the empirical results of this study are generally consistent with the TCEH.

Re-Examining the Empirical Performance of the Monetary Models of the Exchange Rate: A Problem of Structural Change

1.0 Introduction

It has been apparent for some time now that the standard asset market models of the exchange rate do not accord well with the post-Bretton Woods era of floating exchange rates. The list of anomalies documented in the literature is long and includes the following: 1) Parameter estimates that are either insignificant or significant and of the wrong sign (see Dornbusch [1980] and Frankel [1983,1984]); 2) An inability on the part of structural models to outperform the random walk model in out-of-sample fit (see Meese and Rogoff [1983,1984]); 3) A lack of cointegrating relationships among the set of supposed fundamentals (see Meese and Rogoff [1988] and Meese and Rose [1989]); 4) Persistent movements in nominal and real exchange rates when the supposed set of fundamentals point in a direction contrary to current movements (see Frankel and Froot [1990]); and 5) A failure of the uncovered interest rate parity (UIP) condition, even when allowance is made for a standard risk premium (see Frankel and Meese [1987]). In reviewing the evidence, two of the leading researchers in the field conclude that "exchange rates are moved by factors other than the obvious, observable, macroeconomic fundamentals. Econometrically, most of the action is in the error term (Dornbusch and Frankel [1987], p.10)."

The purpose of this paper is twofold. First, we investigate whether structural change on the part of reduced-form parameters helps to explain the poor empirical performance of the monetary models of the exchange rate with respect to the first three anomalies cited above. In order to accomplish this, we use structural change tests that search the data recursively for points of structural instability (rather than using tests that impose break points a priori). We use these break points to distinguish

periods in the data characterized by relative parameter constancy and then examine within each regime the in-sample and out-of-sample fit of the standard monetary models of the exchange rate and whether any cointegrating relationships exist. The idea is that although no one linear exchange rate model explains the entire period of floating rates, it may be that a series of successive linear models fit the data reasonably well. We find that this is in fact the case.

Our findings can be summarized as follows: 1) The monetary models of the exchange rate experience structural instability on more occasions over the modern floating rate period than previously documented, giving rise to three periods of relative structural stability; 2) Many of the fundamental variables of standard theory are significant and enter with correct parameter signs within the separate regimes of stability, although different sets of fundamental variables are significant during different time periods; 3) These sets of significant variables are cointegrated, implying that there are longer-run relationships operating in the foreign exchange market; and 4) All of the structural models examined outperform the random walk model in out-of-sample forecasting by considerable margins (in some cases by a margin of 70 percent in root mean square error) within the separate regimes of stability, indicating that the large forecasting errors reported in Meese and Rogoff [1983] are the result of allowing the forecasting experiment to run past the end of one exchange rate regime and into the next.

The second objective of this paper is to explore the broader macroeconomic issues raised by the empirical analysis. We examine the following three related questions: 1) What are the causes of the structural change findings?; 2) Is the Rational Expectations Hypothesis (REH) consistent with the data?; and 3) Can any of the standard monetary models of the exchange rate be reconciled with the findings of the structural change and in-sample regression analyses? In particular, can the standard approaches be reconciled with the finding that different sets of fundamental variables are significant

during different time periods?

It is clear that structural change can arise in a linear setup through one of two channels, either there is a change in the structure of the semi-reduced form characterizing the economy (the structural channel) or there is a change in the way market agents form exchange rate expectations (the expectations channel). Although the empirical findings of this study are consistent with the view that both channels may be important for explaining the structural change findings, they tend to point more strongly to the expectations channel. There are two results important in this regard. First, the finding that different sets of fundamental variables are significant during different time periods is consistent with the view that market agents focus on different sets of fundamental variables during different time periods when forecasting future exchange rate movements. In contrast, use of the structural channel as an explanation of this finding would require an extreme degree of instability on the part of the semi-reduced form. For example, such an explanation would require instability involving a different set of money demand determinants over time or a long-run real exchange rate that is constant during one period and then a function of cumulative trade balances in another. There is nothing in the literature indicating the plausibility of such changes in the underlying structure of the economy.

The second finding pointing to changes in expectations as a more important cause of the instability findings is that all of the break points line up very closely with time periods involving major changes in policy. The standard explanation for such instability relies on what is known as the "Lucas critique." According to the critique, in the standard RE framework, shifts in expectations functions and the reduced form are tied in a rigid way to changes in policy and the associated changes in the stochastic processes underlying the driving variables. However, it seems implausible that such changes in policy would lead to shifts in rational expectations such that the resulting

reduced forms would contain different variables at different time periods. Hence, reconciling the standard RE approach with our empirical findings requires the implausible view that extreme instability on the part of the underlying structure of the economy occurs on a regular basis.

In two recent papers (Goldberg and Frydman [1991a,b]) we show that under an alternative expectational hypothesis — the theories consistent expectations hypothesis (TCEH), which was originally proposed in Frydman and Phelps [1990] — the monetary models of the exchange rate provide a plausible explanation of our empirical findings based on changes in expectations. The TCEH endows market agents with a number of leading theories, all of which inform agents as to the algebraic signs of the weights attached to the fundamental variables, rather than the true parameter magnitudes as in the standard RE approach. With the TCEH, the monetary models generate exchange rate dynamics that are characterized by persistent movements away from established equilibrium values (e.g., PPP and/or current account balance). Furthermore, the direction of these persistent exchange rate movements depends on the set of variables used by agents in their "theories consistent" forecast functions. An important and surprising implication of this result is that switches by agents from one set of fundamental variables to another can be associated with changes in the direction of movement of the exchange rate. Such switches by agents between the sets of variables also imply that different sets of variables enter the reduced form at different periods of time. Thus, the monetary approach with the TCEH provides a theoretical rationale for our empirical findings that different sets of fundamental variables matter during different time periods and that the break points are proximate to the major changes in direction of the exchange rate.

In terms of the other broader macroeconomic issues, the analysis of this paper also generates the following results: 1) The data are unambiguously consistent with the assumption of sticky-prices; 2) The data cannot unambiguously distinguish between the assumptions of perfect and imperfect capital

mobility; 3) There is evidence that money matters, although not always in a standard way; and 4) There is evidence that not only do agents switch expectations functions, but they also use subsets of the variables contained in any one particular theory and they use more than one theory at a time. The overall implication of the results in this paper is that the monetary approach with sticky prices and the TCEH provides a reasonable macroeconomic framework in which to examine exchange rate dynamics.

It should be noted that the issue of structural instability as an important characteristic of empirical exchange rate models and as a potential factor in explaining the poor empirical performance of standard exchange rate theory is not new. There are several studies which document that the standard asset market models experience structural instability during the late 1970s, precisely when a major change in U.S. monetary policy occurs.¹ Meese [1990] observes that the set of fundamental variables relevant for exchange rate movements depends on the sample period analyzed and he argues that in the 1980s researchers (and presumably market agents as well) shifted their focus from real interest rate differentials in the early 1980s to U.S. budget and current account deficits beginning in the mid-1980s. Finally, there are several studies that account for the problem of instability in testing for out-of-sample fit by allowing for time-varying regression parameters. These studies find little improvement in out-of-sample forecasting ability.² The positive results in this paper, however,

¹See Meese [1986], Boughton [1987], and Meese and Rogoff [1988]. Hamilton and Engle [1990] examine structural changes of the univariate exchange rate process and show that the mean of the process is unstable. Meese [1990] suggests that one explanation for the lack of a stable exchange rate equation is the Lucas critique.

²Alexander and Thomas [1987] and Wolf [1987] allow for time-varying parameters using the Kalman filtering technique and all find results which basically substantiate the original findings of Meese and Rogoff [1983]. Meese and Rogoff [1983] also report experimenting with the Kalman filter with little success. Schinasi and Swamy [1989] allow for time-varying parameters using a technique based on the work of Swamy and Tinsley [1982], which encompasses as special cases the Kalman filtering technique, the method of Hildreth and Houck [1968] and the ARCH models of

indicate that the techniques which have been used in modeling time-varying parameters are not general enough to capture a piece-wise linear data generating process. Furthermore, the recursive approach of locating periods of relative structural stability used in this paper has the advantage of not only providing for an examination of a number of the documented anomalies in the literature, but it also allows for an examination of the broader macroeconomic issues.

The structure of the paper is as follows. Section 2 sets out the composite monetary model and shows how with the TCEH, the model not only allows for different sets of fundamental variables to matter during different time periods, but it also generates testable restrictions that can be brought to the data. In section 3 the methods and results of the structural change analysis are reported, while section 4 discusses the methods and results of the in-sample regression analysis. Section 5 reports on the results of the out-of-sample forecasting experiments. In section 6 the broader macroeconomic issues are discussed, while in section 7 we offer concluding remarks.

2.0 The Composite Model: The RE and TCE Cases

In this section a composite monetary model of the exchange rate is developed that encompasses three of the more frequently used models in both the theoretical and empirical literature: 1) The Frenkel [1976] and Bilson [1978,1979] (FB) flexible-price model; 2) The Dornbusch [1976] and Frankel [1979] (DF) sticky-price model; and 3) The Hooper and Morton [1982] (HM) sticky-price model. The purpose of this section is not only to obtain a composite model that can be used to carry out the empirical analysis, but also to show that with the TCEH, different sets of fundamental variables may matter during different time periods in a way that still places testable restrictions on the data. The reader is referred to Goldberg and Frydman [1991a,b] for the a more complete

Engel [1982] et. al.. They find some improvement in out-of-sample forecasting.

discussion on the TCEH and the macroeconomic implications of closing the monetary models with this alternative expectational hypothesis.

One of the novelties of this study is that it develops a composite model which allows for imperfect capital mobility and distinct parameters across both the domestic and foreign money demand equations (i.e., the parameters of the foreign money demand equation are not proscribed to be equal in absolute terms to their foreign counterparts, a restriction hereafter called the difference restriction). These two extensions to the standard two-country sticky-price models are provided in Goldberg [1991a], where it is shown that both extensions are required in the standard RE framework to obtain a reduced form in which all parameters are distinct, i.e. a reduced form in which the difference restriction is not imposed. This is important because it is found in both Haynes and Stone [1981] and Goldberg [1991a] that the common practice in the literature of imposing this difference restriction is inconsistent with the data. Furthermore, the work of Gandolfo et. al. [1990a,b,1991] and Papell [1985] provide evidence suggesting that the assumption of imperfect capital mobility may be more appropriate for modeling exchange rates.³ Finally, Goldberg [1991a] shows that the two extensions of imperfect capital mobility and distinct money demand parameters give rise to a new test for the uncovered interest rate parity (UIP) condition that does not depend on the absence of a risk premium. This new test for UIP is discussed more fully below.

2.1 The RE Case

The basic (semi-reduced form) structure of the FB, DF and HM monetary models can be expressed as special cases of the following composite model:

³For a general discussion on the appropriateness of imperfect capital mobility for modeling exchange rates see Goldberg [1991b].

$$m = a_1 p + a_2 y - a_3 i \quad (1)$$

$$m^* = b_1 p^* + b_2 y^* - b_3 i^* \quad (2)$$

$$\dot{p} = c_1(e + p^* - p - \bar{q}) + \dot{p}^* \quad (3)$$

$$\dot{p}^* = d_1(\bar{q} - e - p^* + p) + \dot{p}^* \quad (4)$$

$$\delta(e + p^* - p - \bar{q}) + \beta(i - i^* - E(\dot{e})) = 0 \quad (5)$$

$$\dot{\bar{q}} = \bar{q}_0 - g_1 k + g_2 k^* \quad (6)$$

where m , p , and y denote the log levels of domestic money supply, price and income respectively, i denotes the level of the domestic short-term interest rate, k is the de-trended level of domestic cumulative trade balances, e is the log level of the exchange rate (defined as the domestic currency price of foreign currency), q is the log level of the real exchange rate, \bar{q}_0 is an initial condition on \bar{q} , the symbols "-", "*" and "." denote steady-state value, foreign country variable and time derivative respectively and $E(\dot{e})$ denotes the conditional forecast of \dot{e} .

Equations (1) and (2) describe equilibrium in the domestic and foreign money markets. Equations (3) and (4) show how prices adjust to the long-run when they are assumed to be sticky in the short-run (the DF and HM cases). Equation (5) makes use of the work in Frenkel and Rodriguez [1982] and is an equilibrium flow relationship for the balance of payments, where the first term is the balance on the trade account and the second term is net capital inflow. The parameter β represents the speed of adjustment in the asset markets. In the limit, when asset markets clear

instantaneously, such that $\beta = \infty$ (i.e., $\delta/\beta=0$), equation (5) reduces to the standard UIP condition. Finally, equation (6) makes use of the work in Hooper and Morton [1982] and assumes that if \bar{q} changes over time, then its movements are related to movements in cumulative trade balances from trend. Note, that when prices are flexible (the FB case) we have $\dot{p} = \dot{p}^*$ and $\dot{p}^* = \dot{p}^*$, so that equations (3) and (4) reduce to the purchasing power parity condition, $e = p - p^* + \bar{q}$.

In order to close any variant of the composite model given in equations (1) through (6) it is necessary to specify the forecasting equation $E(\dot{e})$. The usual approach, which is followed in the FB, DF and HM cases, is to make use of the RE solution technique. The resulting forecasting equations for the three monetary models are captured in the following two equations:

$$E(\dot{e}) = \theta(\bar{e} - e) + \frac{1}{a_1} \pi - \frac{1}{b_1} \pi^* \quad (7)$$

$$\bar{e} = \frac{(b_1 a_3 - a_1 b_3) \left[\frac{c_1}{d_1} \left[p_0^* - \frac{1}{b_1} (m_0^* - b_2 y_0^*) \right] + \left[p_0 - \frac{1}{a_1} (m_0 - a_2 y_0) \right] \right]}{\frac{c_1}{d_1} a_1 b_3 + b_1 a_3} \quad (8)$$

$$+ \frac{1}{a_1} (m - a_2 y) - \frac{1}{b_1} (m^* - b_2 y^*) + \frac{(c_1 + d_1) a_3 b_3}{d_1 \left[\frac{c_1}{d_1} a_1 b_3 + b_1 a_3 \right]} \left(\frac{1}{a_1} \pi - \frac{1}{b_1} \pi^* \right)$$

$$+ \bar{q}$$

where θ (which is redefined to be positive) is the stable nonzero root of the system, π (π^*) denotes the rate of growth of m (m^*) in excess of the growth of relative money demand due to movements in y (y^*), i.e., $\pi = (\dot{m} - a_2 \dot{y})$ and $\pi^* = (\dot{m}^* - b_2 \dot{y}^*)$, and p_0 and p_0^* are initial conditions on p and p^* respectively. (Note, that $\dot{p} = \frac{1}{a_1} \pi$ and $\dot{p}^* = \frac{1}{b_1} \pi^*$.) The expectations function in equation (7) is standard in form, but because of the extension of distinct money demand parameters

the solution for \bar{e} in equation (8) is not. In fact, with distinct money demand parameters the solutions for \bar{p} , \bar{p}^* , \bar{i} , \bar{i}^* , $\frac{\bar{m}}{p}$ and $\frac{\bar{m}^*}{p^*}$, in addition to \bar{e} , are all functions of initial conditions and speed of adjustment parameters. It is easily verified that in the standard case where $a_1=b_1=1$, $a_2=b_2$ and $a_3=b_3$, the standard solution for \bar{e} obtains, i.e., $\bar{e}=(m-m^*)-a_2(y-y^*)+a_3(\pi-\pi^*)+\bar{q}$.⁴

In order to derive the reduced forms of the three monetary models, equations (1), (2), (6), (7) and (8) are substituted into the equilibrium condition for the foreign exchange market in equation (5), yielding the following:

$$\begin{aligned}
e = & \frac{\beta(b_1a_3 - a_1b_3)}{(\beta\theta + \delta)(\frac{c_1}{d_1}a_1b_3 + b_1a_3)} \left[\frac{c_1}{d_1} \left[p_0^* - \frac{1}{b_1}(m_0^* - b_2y_0^*) \right] + \left[p_0 - \frac{1}{a_1}(m_0 - a_2y_0) \right] \right] \\
& + \frac{1}{a_1}(m - a_2y) - \frac{1}{b_1}(m^* - b_2y^*) + \frac{(\delta a_3 - \beta a_1)}{(\beta\theta + \delta)a_1} i - \frac{(\delta b_3 - \beta b_1)}{(\beta\theta + \delta)b_1} i^* \quad (9) \\
& + \frac{c_1b_3(a_1 + a_3\theta) + d_1a_3(b_1 + b_3\theta)}{d_1(\beta\theta + \delta)(\frac{c_1}{d_1}a_1b_3 + b_1a_3)} \left[\frac{1}{a_1}\pi - \frac{1}{b_1}\pi^* \right] + q_0 - g_1k + g_2k^*
\end{aligned}$$

Table 1 summarizes the predictions inherent in equation (9), where we call this composite model the

⁴The reason for the nonstandard steady-state solutions stems from the fact that with distinct money demand parameters the dynamical representation of the model possesses a zero root. For a discussion on this point see Goldberg [1991b]. One of the interesting consequences of the presence of a zero root is that movements in the driving variables of the model, including money and the money growth rate, have real effects in the long-run in terms of real interest rates and real money balances. In fact, it is shown in Goldberg [1991b] that in the standard case *with* the difference restriction imposed on the parameters of all domestic and foreign money demand determinants, neither the nonstandard steady-state solutions for \bar{p} , \bar{p}^* , \bar{i} , \bar{i}^* , $\frac{\bar{m}}{p}$ and $\frac{\bar{m}^*}{p^*}$ individually nor the real effects in terms of \bar{i} , \bar{i}^* , $\frac{\bar{m}}{p}$ and $\frac{\bar{m}^*}{p^*}$ individually disappear, although they do disappear in the relative quantities $(\bar{p}-\bar{p}^*)$, $(\bar{i}-\bar{i}^*)$ and $\frac{(\bar{m}-\bar{m}^*)}{(\bar{p}-\bar{p}^*)}$.

Dornbusch et. al. (D+) model. The HM and DF models are obtained by setting $a_1=b_1=1$, $a_2=b_2$,

Table 1
The Predictions of the Asset Market Models^a

Models^b

| Variables ^c | FB | DF | HM | D+ |
|------------------------|-----|-----|-----|-----|
| m | | | | + |
| m* | | | | - |
| m - m* | + | + | + | |
| y | | | | - |
| y* | | | | + |
| y - y* | - | - | - | |
| i | | | | +/- |
| i* | | | | +/- |
| i - i* | + | - | - | |
| π | | | | + |
| π^* | | | | - |
| $\pi - \pi^*$ | | + | + | |
| k | | | - | - |
| k* | | | + | + |
| constant | +/- | +/- | +/- | +/- |

Notes: a. Symbols indicate parameter sign predictions of the structural models listed. The symbol "+" denotes the prediction of a positive parameter value and the symbol "-" denotes the prediction of a negative value. Entries that include both symbols indicate that the model's prediction is ambiguous for that parameter value.

b. Model definitions: FB denotes the Frenkel-Bilson model, HM denotes the Hooper-Morton model and D+ denotes the Dornbusch et al. model. All models are for the German mark - U.S. dollar exchange rate (e).

c. Variable Definitions: m and m* denote log levels of German and U.S. money supply (M_t); y and y* are log levels of German and U.S. real income (proxied by an index of industrial production); i is the German 3 month interbank deposit rate and i* is the U.S. 3 month treasury bill rate; π and π^* are expected German and U.S. long run inflation rates (proxied by an average of inflation rates over the preceding twelve months using the CPI); k and k* are German and U.S. cumulative trade balances; and e is the deutsche mark price of one U.S. dollar. All data are monthly.

$a_3=b_3$ and $\beta=\infty$, where in the DF case $g_1=g_2=0$. The FB model is obtained by setting

$c_1=d_1=\infty$ and imposing all of the restrictions of the DF case. The predictions of the FB, DF and HM models are also summarized in table 1.

There are two aspects of the D+ model in equation (9) that are noteworthy.⁵ First, the parameter values on the domestic and foreign interest rate variables may be positive or negative in the case of sticky prices. The algebraic signs in this case depend on the degree of capital mobility. This shows that the common practice in the literature of interpreting a positive parameter value on the relative interest rate variable as indicating flexible prices is not necessarily valid. Second, the distinct parameters on the interest rate variables in equation (9) stem solely from the fact that β is finite. It is easily verified that in the case of perfect capital mobility, where $\beta = \infty$, the difference restriction on the domestic and foreign interest rate variables reappears. This then provides a way to test the UIP condition, where a rejection of the difference restriction on the interest rate variables implies imperfect capital mobility and the absence of UIP. Note, this result is not altered if a standard risk premium is added to equation (5).

2.2 The TCE Case

The standard implementation of the REH assumes that agents use (or behave as if they use) a forecasting equation that is identical to the reduced form of the analyst's model. This solution technique makes the analysis determinate and seemingly precise at the cost of extreme assumptions concerning the information and knowledge that agents possess.⁶ In this subsection we use the TCEH instead to close the monetary models of the exchange rate.

⁵For a fuller discussion of these aspects see Goldberg [1991b].

⁶ See Frydman and Phelps (1983) for a discussion of these issues.

Although the TCEH relaxes some of the strong assumptions of the RE approach, it preserves the spirit of RE in that agents are assumed to use the set of existing theories in forming their forecasts. The object here is to show that with the TCEH, different sets of fundamental variables may matter during different time periods in a way that still places testable restrictions on the data. This is accomplished in two steps. First, it is shown how the arguments of the aggregate forecasting equation ($E(\hat{e})$) may change with TCE. It is then shown how such shifting of expectations functions leads to different sets of fundamental variables in the reduced form for e .

In attempting to formulate a less informationally demanding hypothesis in the spirit of the REH, the basic difficulty is immediately encountered. It is not enough to say that the forecasting equations of agents are based on the extant economic models, since these models themselves contain forecasts of the endogenous variables, i.e., we are faced with the infinite regress problem that dates back to Keynes [1936].⁷ The following hypothesis attempts to overcome this problem:

The Theories Consistent Expectations Hypothesis: Agents are said to hold theories consistent expectations if their forecasting functions contain variables appearing with the same algebraic signs as in the reduced form of at least one of the extant models. The reduced forms of the models are defined to be the reduced forms obtained when using the RE solution technique.

In the spirit of the REH, the TCEH supposes that agents base their forecasts on the *RE* reduced form from one of the extant economic models. However, the TCEH does not attribute to agents the quantitative knowledge of the parameters of the existing models. Instead, agents are assumed to have a qualitative (intuitive) understanding of the economy.

⁷ This infinite regress problem is analyzed in the context of the RE approach in Phelps [1983].

This is formalized by assuming that they use their own estimates (guesses) of the parameters in place of the true values. The assumption embodied in the TCEH is that these parameter estimates will have the same algebraic signs as those of at least one of the RE reduced forms. Furthermore, the TCEH does not suppose that only one model (the analyst's) is known and used by agents. Instead, it allows for the possibility that different models or only some of the variables of a model (although with parameter signs that are consistent with one of the models) are utilized by agents at different points in time.

As such, the TCEH closes the composite model in equations (1) through (6) by giving rise to an aggregate forecasting equation ($E(\dot{e})$) that is based on the three RE forecasting functions given in equations (7) and (8). (Note, that in the case of flexible prices the RE forecasting equation is given by $E(\dot{e}) = i - i^*$, since with flexible prices $i - i^* = \frac{1}{a_1} \pi - \frac{1}{b_1} \pi^*$.)

This assumption that market agents subscribe to one or more or a subset of the three monetary models, together with the fact that the reduced-form forecasting equations for the FB, DF and HM models are all linear, ensures that the forecasting equation in the aggregate will be a linear function of the variables of the three monetary models, where the weights attached to each of the variables will be consistent in algebraic sign with at least one of the three models. Thus, the TCEH gives rise to an aggregate forecasting function of the following form:

$$E(\dot{e}) = h_0 + h_1 m - h_2 m^* - h_3 y + h_4 y^* + h_5 (i - i^*) + h_6 \pi - h_7 \pi^* - h_8 k + h_9 k^* - h_{10} e \quad (10)$$

There are several noteworthy aspects of equation (10). First, all of the parameters of the equation are determinate in sign. This is because the three monetary models do not provide conflicting predictions as to the *rate of change of e*. For example, all of the theories predict

an increase in \dot{e} given an increase in domestic money. (Note, the predictions of the sticky-price models concerning the *level* of e possibly conflict with those of the flexible price model in terms of the interest rate variables — see table 1.) Second, the interest rate variables enter the aggregate forecasting equation with the difference restriction. This is because the interest rate variables do not enter the forecasting equations of the sticky-price models (see equations (7) and (8)) and because the forecasting equation of the flexible-price model is just $E(\dot{e}) = i - i^*$. (In fact, f_5 is equal to the proportion of agents in the market that subscribe to the flexible-price model.) Third, any of the parameters f_0 through f_{10} may be zero. There are four cases to consider: 1) All agents believe in flexible prices, implying that $f_5=1$ and all of the other parameters are equal to zero; 2) All agents believe in sticky prices, implying that $f_5=0$; 3) All agents believe that the long-run real exchange rate (\bar{q}) is constant, implying that $f_8=f_9=0$; and 4) Agents do not interpret the set of extant theories literally and use only a subset of the variables contained in any one theory, implying that any of the parameters f_0 through f_{10} may be zero. (In this case, the interest rate variables may not enter the aggregate forecasting equation with the difference restriction.) The final aspect noteworthy of the aggregate forecasting equation in (10) is that the set of variables with nonzero parameters may change over time since agents may be switching between cases 1 through 4.

In terms of different fundamental variables entering the reduced form for e during different time periods, the situation depends on whether the underlying structure of the economy is characterized by flexible prices or sticky prices. If prices are flexible, then the exchange rate is completely determined by the PPP condition. In such a world, exchange

rate expectations do not explicitly influence exchange rate movements.⁸ As a consequence, there is no room for switching expectations functions to impact on the reduced form for e .

If, however, the underlying structure of the economy is characterized by sticky prices, then the phenomenon of switching expectations functions does influence the reduced form for e . With sticky prices, the reduced form for e is obtained by substituting the aggregate forecasting equation in (10) into either the UIP condition (if capital is perfectly mobile) or the balance of payments flow relationship in equation (5) (if capital is imperfectly mobile). In the case of perfect capital mobility, all of the fundamental variables present in the reduced form, except the interest rate variables, enter solely through the expectations channel. As a consequence, all of these variables are candidates for coming in and out of the reduced form for e (through $E(\dot{e})$) over time. In the case of imperfect capital mobility and a constant \bar{q} , the only fundamental variables entering solely through the expectations channel are the cumulative trade balance variables, k and k^* . As such, these are the only variables that can potentially come in and out over time. Finally, in the case of imperfect capital mobility and a nonconstant \bar{q} , all of the variables enter the reduced form for e independently of the expectations channel. As a consequence, there is no possibility for the set of fundamentals entering the reduced form for e to change over time under this scenario. Table 2 catalogues the various alternatives.

It is interesting to note that the restrictions generated with the TCEH are sufficient in some cases not only to identify the underlying structure of the economy, but also to say something about the expectations formation process, provided that the underlying (semi-reduced-form) structure of the economy is assumed to be stable. For example, if the set of

⁸This is the criticism of the flexible-price monetary model made in Mussa [1984].

significant variables changes over time, then this suggests the underlying structure of the economy involves sticky prices. If the trade balance variables come in and out, then this

Table 2
A Catalogue of the Fundamental Variables that Can Come In and Out Under Various Assumptions Concerning the Underlying Structure of the Economy^a

| Variables | Assumptions | | | |
|---------------|-----------------|--------------------------|---|--|
| | Flexible Prices | Perfect Capital Mobility | Imperfect Capital Mobility and Constant \bar{q} | Imperfect Capital Mobility and Nonconstant \bar{q} |
| money | | ✓ | | |
| income | | ✓ | | |
| interest rate | | | | |
| inflation | | ✓ | | |
| trade balance | | ✓ | ✓ | |

Note: a. A ✓ indicates that the variable can come in and out over time, whereas a blank indicates the contrary.

implies that the long-run real exchange rate (\bar{q}) is constant, but agents view \bar{q} as being constant during some periods and a function of the cumulative trade balance variables during others. Finally, if the set of fundamental variables that come in and out over time involves more than just the cumulative trade balance variables, then this suggests the underlying structure of the economy involves perfect capital mobility.

3.0 The Finding of Structural Change

The purpose of this and the next two sections is to investigate the view that the poor

performance of the standard monetary models of the exchange rate is at least partly due to the problem of structural change. To this end, the analysis searches for subperiods of the modern floating rate period during which reduced-form parameters are relatively constant and then examines within each subperiod the performance of the monetary models on the basis of in-sample and out-of-sample fit and whether cointegrating relationships exist. There are three issues that need to be addressed in order to carry out such an analysis. First, the exercise of locating subperiods of parameter constancy must be based on objective criteria in order to avoid the problem of data mining. As such, the analysis uses structural change tests that search the data recursively for the possibility of one or more break points, rather than relying on tests that require the choosing of break points a priori. In contrast, most empirical studies that test for structural instability test for only one break point in a sample covering the 1970s and 1980s and impose the location of this break point a priori.⁹

Second, the exchange rate and all of the fundamental variables of the monetary models are generally recognized to be integrated of order one ($I(1)$), i.e., all of these variables are nonstationary due to a unit root in their autoregressive representations (e.g., see Meese [1986] and Meese and Rogoff [1988]).¹⁰ The problem with working with such nonstationary variables is that although standard regression techniques with $I(1)$ variables

⁹See footnote 1 for references. Two exceptions here are Engel and Hamilton [1990] and Boughton [1987]. The former study finds that the *univariate* process underlying exchange rate movements shifts periodically, giving rise to episodes of a generally rising or falling exchange rate. The switches in regime are modeled as the outcome of a first order Markov process. The latter study uses the same recursive techniques employed in this study. However, the author allows for only one break point in a sample that runs from May 1973 through December 1984 and, despite finding structural instability in the late 1970s, estimates his models using the entire sample.

¹⁰In Goldberg [1991a] the variables of the monetary models are subjected to a large battery of unit root tests including the ADF tests of Fuller [1976] and Dickey and Fuller [1981] and the Z tests of Phillips [1987] and Perron [1988]. In every case the null of a unit root could not be rejected.

produce super consistent estimates (Stock [1987]), they also generate spurious results in terms of R^2 and conventional inference tests (see Granger and Newbold [1974] and Phillips [1986]). This problem of spurious regressions is particularly troubling because as the sample size is increased the R^2 measure tends to one, the Durbin Watson statistic tends to zero (in the case of no cointegration) and the standard t- and f-statistics increase in value even though the variables of the model may be genuinely unrelated. In order to circumvent this problem of spurious regressions, so that the in-sample fit of the monetary models can be assessed, we utilize the systems approach of Phillips [1988]. This systems approach to estimating models with I(1) variables specifies the unit roots explicitly and, in doing so, provides for standard inference with regressions specified in levels.

The final difficulty in conducting the empirical analysis is that the problem of multicollinearity frequently arises when working with I(1) regressors, in that the presence of insignificant I(1) regressors may bias the results of the structural change and regression analyses as well as the out-of-sample forecasting experiments.¹¹ In order to address this problem, we proceed in a sequential manner. When testing for stability, in-sample and out-of-sample fit and cointegration we begin with the composite model. At each stage, the composite model is reduced by deleting those variables that are found to be insignificant. These reduced models are then tested as well for stability, in-sample and out-of-sample fit and cointegration.

3.1 The Structural Change Procedures

The structural change procedures used are the cusum test and the Quandt ratio (QR)

¹¹See Hendry [1986] for a discussion on this issue.

technique.¹² The cusum test is based on the cumulative sum of standardized recursive residuals, D_r (where $r=k+1, \dots, T$ and k and T denote the number of regressors and sample size respectively). Brown, Durbin and Evans [1975] show that under the null hypothesis of no structural break and independent errors the D_r 's have an expected value of zero with independent steps, i.e., this cusum follows a random walk under the null. This test procedure, which uses OLS to estimate the recursive residuals, is valid even in the case of $I(1)$ variables. This is because OLS estimation generates residuals that are super-consistent. In contrast, valid inference using standard estimation techniques, such as the OLS based Chow test, is not possible with $I(1)$ variables (e.g., see Stock [1987] and Phillips [1988]).

One of the problems with the cusum test is that it only reveals when the sample path of D_r has deviated too far from its expected value of zero (indicating that a break has already occurred) and not when the break first appears. Use of the QR technique provides a partial remedy to this problem, in that if a structural break is maintained to occur somewhere in the sample (based on the cusum test), then the QR technique attempts to locate its most likely point. This is accomplished by computing the standard likelihood ratio statistic (the Quandt ratio) for deciding between the null hypothesis of a break at r against and the alternative of no break. The estimate of the point at which the structural break occurs is then the value of r at which the Quandt ratio reaches a minimum.¹³

The procedure for locating points of structural instability is as follows. We start at the beginning of the sample and test the $D+$ model for stability using the cusum test and QR

¹²A treatment of both tests is provided in Brown, Durbin and Evans [1975].

¹³This procedure of first using the cusum test to determine that a break has occurred and then the QR technique to determine its approximate location is suggested in Frydman [1983].

technique. Once a break point is found, we estimate a reduced model for the implied region of stability (if possible) and then test the reduced model for stability. Once the break point associated with the reduced model has been verified to match that of the composite model, which we find in every case except one (see footnote 17), we check the residuals of the reduced model for serial correlation. The problem with serially correlated residuals is that they can distort the size of the cusum test, since the confidence bounds are constructed with the assumption that the time path of D_t involves independent steps under the null hypothesis. In order to reduce the influence of this problem when detected, we add the following regressors to the regression equation: 1) First differences of each of the explanatory variables; 2) Two lags of each of these first difference terms; and 3) Two lags of the exchange rate first differenced. We find that the inclusion of these $I(0)$ variables, which does not disturb the consistency of the parameter estimates on the $I(1)$ variables and hence the consistency of the residuals (see Granger [1986]), is able to account for most of the serial correlation present. We then re-test for stability using this augmented model.¹⁴ Once the first break point is established, we re-run the cusum test and QR technique using the $D+$ model, but with a subsample that begins after the location of the first break point.¹⁵ Additional break points are found in a similar way.

¹⁴Since the variables of the reduced models are found to be cointegrated, the addition of the first difference terms can be viewed as capturing the short run dynamics of the system. It is true that structural breaks found with the augmented reduced models may be due in part to shifts in the parameters of the first difference terms. However, as the next section makes clear, there is no doubt that the parameters of the static long run relationship are also shifting.

¹⁵It is necessary to restart the structural change procedures once a break has been detected because after this point the cusum no longer has an expected value of zero, whether or not the true model returns to the original relationship.

3.2 The Structural Change Results

The results of the cusum and QR tests are summarized in figure 1.¹⁶ The break points in the figure are indicated by the dotted vertical lines, so that a total of five break points are found.¹⁷ The unshaded regions numbered 1 through 3 in the figure, therefore, are the regimes of relative structural stability. The first exchange rate regime begins in July 1974 and runs through September 1978, the second begins in November 1979 and runs through August 1984 and the last exchange rate regime of stability begins in September 1985 and runs until the end of the sample in March 1988.

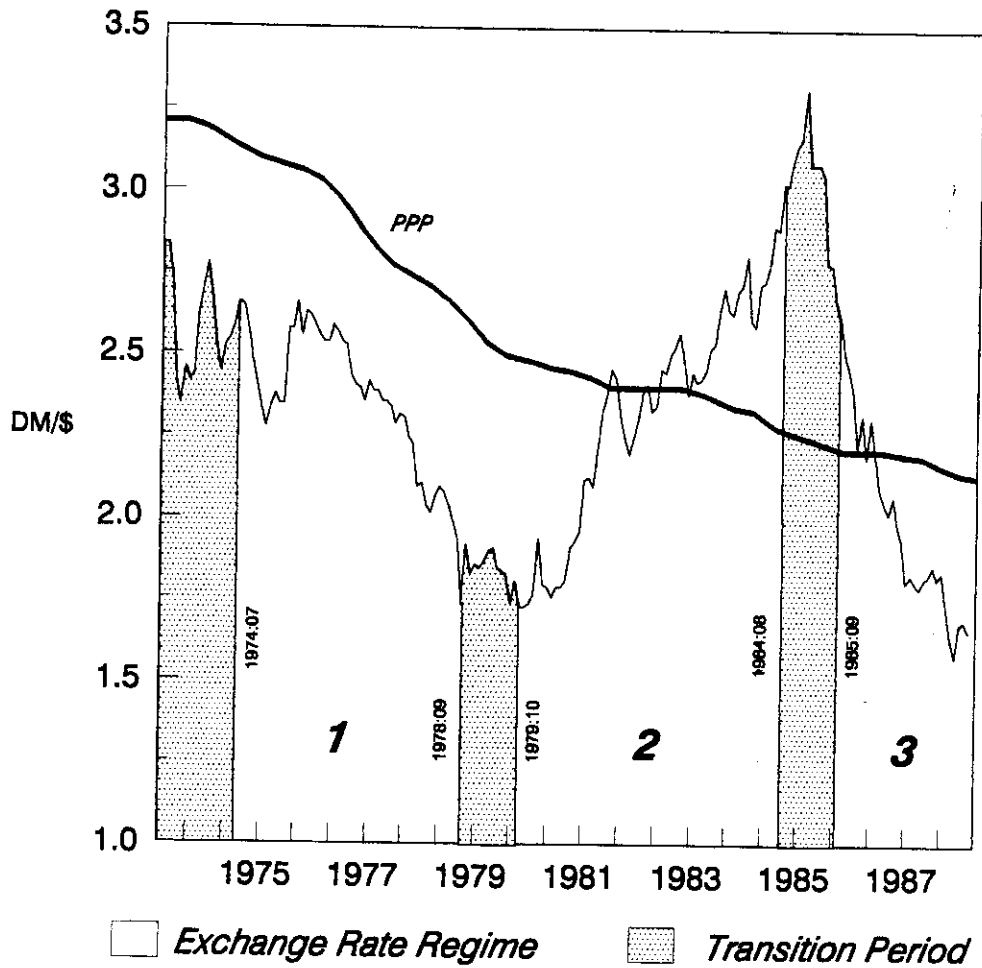
There are several noteworthy aspects about the results in figure 1. First, after the first two exchange rate regimes and after the collapse of the Bretton Woods era of fixed rates there are periods of transition, i.e., periods of time which are relatively transient and which are distinct from the regime they immediately follow (these are the shaded regions in figure 1). The reasons for why they arise may include uncertainty on the part of market agents as

¹⁶The trade balance data used in the analysis are from the O.E.C.D. (M.E.I.) data bank. All other time series are from the IFS data bank. The 3 month treasury bill rate and the 3 month interbank deposit rate are used for U.S. and German interest rates respectively. Long run inflationary expectations are proxied by using the average inflation rate (based on the CPI) over the preceding 12 months. An index of industrial production is used as a proxy for real output since data on real output are reported only quarterly. Finally, M_1 is used as the definition of money.

¹⁷Reduced models are estimated for the first two exchange rate regimes. The other periods of stability are too small to use the systems approach of Phillips [1988], which require the estimation of 30 parameters when testing the full composite model. When the residuals of the reduced model for the first exchange rate regime are tested for serial correlation (by regressing them on ten lags) some degree of correlation is found, but no lag is significant at the 10 percent level when based on either the t-test or F-test. (This result stands in contrast to the results of other studies, which generally find serially correlated residuals in similar regressions. This finding is discussed more fully in section 5 on out-of-sample forecasting.) In contrast, the residuals of the reduced model for the second exchange rate regime are found to be serially correlated. We find, however, that inclusion of the first difference terms as outlined in the preceding subsection does not alter the location of the original break point.

Figure 1
Exchange Rate Regimes and Transition Periods

Sample Period 1973:03 - 1988:03



to which model is currently relevant, the choosing of a model not encompassed by the D+ model, the occurrence of a (rational or irrational) stochastic bandwagon movement (see Evans [1986] and Meese [1986]), or a movement away from relying on a model based on fundamentals to one based on chartism (see Frankel and Froot [1987b] and Kirman [1990]).¹⁸

The transition period following the Bretton Woods era is of particular interest because it provides justification for the common practice in the literature of deleting some arbitrary period of time at the beginning of the floating rate period prior to analysis (e.g., see Frankel [1979,1983,1984]).¹⁹ This practice is usually based on the belief that the market required some time to acquaint itself with the new regime of floating rates. The period following this interval of learning is dubbed the period of mature floating. Our structural change results show that not only is the multivariate process governing exchange rate movements different in this first subperiod of floating (thus validating the story of immature floating), but they also eliminate the arbitrariness in determining its duration.

¹⁸The break point in November 1979, which gives rise to the transition period following the first exchange rate regime, is not based on the cusum and QR tests, but rather is based on a Chow test using the systems approach of Phillips [1988] (the systems approach allows valid inference to be drawn from an F-statistic). Ideally, the structural change tests should be able to locate such transition periods if they exist. However, these periods may be too transient for the cusum test to detect. In light of this problem and the fact that transition periods are found after the Bretton Woods era of fixed rates and after the second exchange rate regime, we check for a structural break in November 1979. November 1979 is chosen because it is the period in which the value of dollar finally turns around. The systems based Chow test indicates a break at the 2.5 percent significance level.

¹⁹The model used in locating the break point in July 1974 is the D+ model without a constant. When a constant is added to the regression, the cusum and QR tests indicate that a break does not occur until October 1978. However, when a reduced model is fitted to this first (possible) region of stability (i.e., from March 1973 through September 1978) the constant term is found to be insignificant.

Another interesting aspect of the results in figure 1 is that the collapse of the first two exchange rate regimes (along with the subsequent transition periods) are proximate to the two major turning points in the value of the dollar during the modern flexible rate period. This accords well with the approach with TCE, which suggests that when agents switch the set of fundamentals used in forecasting or policy officials react due to large deviations from natural values, the structural instability generated will be associated with major turning points in the exchange rate. This suggests then, that the structural change findings are due in part to the expectations channel. It should be noted that this finding is also suggestive of the market behavior implied in Schulmeister [1983,1987] and Soros [1987].

Finally, each of the break points after the break in July 1974 (which ushers in the period of mature floating) is explainable by a major shift in policy, which also suggests that the instability is arising through the expectations channel. The break in October 1978 (break point A in figure 1) was preceded by a protracted period of dollar depreciation and accelerating U.S. inflation. This in turn led to very low real interest rates in the U.S. and continued capital outflow. In order to stem the troubling tide the U.S. implemented a package of measures in November 1978 (which was perhaps anticipated in October 1978), which included the Carter bond program of active intervention (the level of intervention for the month of November in support of the dollar was \$6.86 billion, a record at that time) and measures to tighten monetary policy. In addition, the German Bundesbank was also intervening at very high levels (see Frankel [1982]). These measures were initially successful as the dollar firmed in the last quarter of 1978. However, in the second quarter of 1979 the dollar began its slide once again. Volker was appointed in August 1979 and, in October of that year (break point B in figure 1), the Fed announced that it was de-emphasizing the

federal funds rate as an operating target. Instead, the primary operating target became nonborrowed reserves. This shift in monetary policy, with its associated rise in U.S. interest rates, was enough to finally turn around the trend in the dollar.

In terms of the 1980s, the dollar and U.S. trade deficit had climbed so high by the first quarter of 1984 that the stated Reagan (and Regan) policy of laissez faire was changed to one of actively trying to talk the dollar down. Intervention picked up after a long absence and with the 1984 presidential election over, there was a major change in policy (perhaps again anticipated in September 1984, which is break point C in figure 1). James Baker took over as Treasury Secretary in January 1985 with the stated goal of getting the dollar down and improving the trade picture. He engineered an international agreement that involved reducing the U.S. budget deficit and relaxing U.S. monetary policy (Volcker agreed to cooperate) in return for fiscal stimulus and high interest rates abroad. Although this policy was discussed at the Bonn economic summit in May 1985, this policy of international coordination was not formally announced by the G-7 until September 1985 (break point D in figure 1) at the Plaza hotel in New York.

Hence, the structural change findings reported in figure 1 indicate that the problem of structural change is more prevalent than previously documented. The findings give rise to three periods of relative parameter constancy along with three transition periods. In addition, the structural change findings provide evidence that the instability is due in part to unstable expectations functions, since the structural breaks are proximate not only to periods involving major changes in policy, but also to periods involving major turning points in the value of the dollar. In the next two sections the importance of allowing for structural instability in testing for in-sample and out-of-sample fit and cointegration is explored.

4.0 Estimating Reduced Models and The Finding of Cointegration

The purpose of this section is twofold. First, reduced models are estimated for the first and second exchange rate regimes and second, the variables of each reduced model are tested for cointegration. The major finding is that the variables of both reduced models are found to be cointegrated, suggesting that there are longer-run relationships between exchange rates and macroeconomic fundamentals operating in the foreign exchange market. In addition, many of the fundamental variables are found to be significant and to enter with parameter signs that are consistent with at least one of the asset market models subsumed in the composite model. Finally, the two reduced models are found to differ in both non-zero parameters and variables. The discussion of the macroeconomic implications of these findings is postponed until section 6.

Much of the evidence on the asset market models from in-sample regression studies is based on estimating reduced forms that are expressed in levels, i.e., on estimations of static long-run relationships. But, such an approach is problematic due to the presence of $I(1)$ variables. It may be the case, however, that although a group of variables are individually nonstationary, there may exist market forces that work over time causing these variables to move together, i.e., there may exist some linear combination of the $I(1)$ variables that is stationary. In such a case the variables are said to be cointegrated.²⁰ The finding of cointegration is important because it is a statistical precondition for the existence of a stable long-run relationship among $I(1)$ variables, the very claim made by standard exchange rate theory.

²⁰The early articles developing the theory of cointegration include Granger [1983] and Engel and Granger [1987]. See also Hendry [1986] and the other articles contained in the special issue.

There are a number of studies that test whether the macro variables of standard exchange rate theory are cointegrated (see Meese [1986], Meese and Rogoff [1988] and Meese and Rose [1989]). All of these studies, which use a sample period that includes the 1970s and 1980s, are unable to reject the null hypothesis of no cointegration. In response to this finding of no cointegration and the problem of spurious regressions, much of the empirical work since the mid-1980s has been based on exchange rate equations that are specified in first differences (e.g., see Meese [1986], Meese and Rogoff [1988] and Papell [1988], among many others). But, it should be emphasized that such an approach is unsatisfactory for testing the validity of the standard asset market models, if it is maintained a priori that there is no relationship in levels. This is because standard exchange rate theory does not provide for a relationship between the exchange rate and fundamental variables in first differences that is independent of a relationship in levels. Acknowledging that no long-run relationship exists is sufficient to invalidate standard exchange rate theory, whether or not there exists a relationship in first differences. If it is found that a relationship between the exchange rate and macroeconomic fundamentals exists in first differences, but not in levels, then a new theory of exchange rate dynamics is required.

4.1 The Method of Reduction

In order to estimate reduced models for the first two exchange rate regimes the approach of Phillips [1988] is followed. This approach, which extends the work of Johansen [1988], applies maximum likelihood (ML) estimation on a system that specifies the unit roots explicitly. This system can be expressed as follows:

$$\begin{bmatrix} y_t \\ \Delta x_t \end{bmatrix} = \begin{bmatrix} 0 & b' \\ 0 & 0 \end{bmatrix} \begin{bmatrix} y_t \\ x_t \end{bmatrix} + \begin{bmatrix} u_t \\ v_t \end{bmatrix} \quad (11)$$

where y_t denotes an I(1) dependent variable, x_t is a vector of I(1) explanatory variables, b is the cointegrating vector and u_t and v_t are generated by a stationary vector ARMA model. It is shown in Phillips [1988] that when y_t and x_t are cointegrated, the ML estimator of b is consistent, unbiased and has a standard asymptotic distribution.²¹

In order to make this systems approach operational, the ARMA process underlying u_t and v_t must be specified. This raises some difficulty, however, because the D+ model involves 10 explanatory variables, implying that the system of equations in (11) involves 11 equations. In light of this and because the longest regime of stability consists of 58 observations, the analysis is limited to considering AR errors only. An AR specification is arrived at in a sequential manner using the system of equations in (1). For each exchange rate regime, we begin by estimating (11) with an AR(2). Then, all the AR terms that are found to be insignificant are deleted and the system in (11) is re-estimated. If the residuals of any of the 11 equations are found to be autocorrelated (by regressing these residuals on 10 lags), then additional AR terms are added until independent residuals are obtained. In all 11 cases, tests of the residuals produced by this procedure for autocorrelation could not reject the null hypothesis of no autocorrelation. As such, AR errors are found to fit the data

²¹An estimator of the cointegrating vector with standard asymptotic properties can also be obtained using the procedure developed in Phillips and Hansen [1988], which adjusts the OLS parameter estimates and standard errors of the cointegrating regression nonparametrically. The authors call this procedure fully modified least squares (FMLS). This procedure was initially employed in estimating the composite model, but the results were found to be overly sensitive to the value of the lag truncation parameter used in estimating the long-run covariance terms. This approach was therefore found to be unusable. However, Nicoletti [1990] uses FMLS with much success.

reasonably well.

As mentioned earlier, one of the problems in working with $I(1)$ regressors is that they may appear correlated even though there is no genuine relationship between them. This can lead to the problem of multicollinearity, where a variable whose parameter is insignificant when estimating the composite model may become significant (or even change sign) when one or more of the other explanatory variables are deleted. As such, there is no unambiguous rule by which to delete variables. The procedure followed here is to begin by deleting one explanatory variable at a time, beginning with the variable whose t -value is the lowest. Once those variables with insignificant parameters have been deleted, they are added back in different combinations. This provides an additional check that these variables are not deleted because of a spurious relationship among the regressors. It should be noted that although the analysis attempts to overcome the problem of multicollinearity, this problem does give rise to ambiguity and it therefore raises the question of what can be inferred from the data. However, it should be emphasized that although the reduction results need to be interpreted with care, the problem of multicollinearity in no way detracts from the results of the out-of-sample forecasting analysis or the findings of cointegration.

4.2 The Reduction and Cointegration Results

Tables 3 and 4 present the results of the reduction analysis for the first two exchange rate regimes. Several aspects are noteworthy. First, the problem of multicollinearity is evident during both exchange rate regimes. For example, there are a number of instances where parameter estimates are initially either insignificant or significant and of the wrong sign and then, when insignificant variables are dropped from the regression, these parameter

Table 3
Reduction Results: First Exchange Rate Regime (1974:7 - 1978:9)
Full Information Maximum Likelihood Estimation^f

| Regressions | | | | | | | |
|------------------------------------|----------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Explanatory variables ^b | Lagged ^c Values | (1) | (2) | (3) | (4) | (5) | (6) |
| π^* | 1 | 0.781 (0.19) | | | | | |
| π | 1 | -1.599 (-0.20) | -0.757 (-0.09) | | | | |
| m^* | 1,2,6 | -0.023 (-0.14) | 0.026 (0.16) | 0.017 (0.11) | | | |
| m | 2,6 | -0.045 (-0.52) | -0.066 (-0.75) | -0.067 (-0.81) | -0.104 (-1.45) | | |
| Constant | | 0.667 (0.78) | 0.484 (0.57) | 0.465 (0.55) | 0.695 (1.12) | 0.104 (0.26) | |
| i^* | 3,8 | 2.685 ^d (5.81) | 2.600 ^d (5.50) | 2.641 ^d (5.55) | 2.663 ^d (5.59) | 2.254 ^d (5.31) | 2.390 ^d (5.62) |
| i | 1 | -1.169 ^d (-2.51) | -1.135 ^d (-2.54) | -1.179 ^d (-3.31) | -1.260 ^d (-3.76) | -1.258 ^d (-3.72) | -1.472 ^d (-5.76) |
| y^* | 1,3 | 1.115 ^d (7.92) | 1.137 ^d (8.12) | 1.138 ^d (9.59) | 1.140 ^d (9.69) | 1.150 ^d (9.69) | 1.150 ^d (10.48) |
| y | 1 | -0.970 ^d (-7.47) | -0.986 ^d (-7.46) | -0.971 ^d (-8.14) | -0.965 ^d (-8.19) | -0.935 ^d (-8.01) | -0.916 ^d (-9.18) |
| k^* | 1.5 | 6.700 ^d (11.86) | 0.660 ^d (13.67) | 0.663 ^d (14.16) | 0.660 ^d (14.20) | 0.622 ^d (14.74) | 0.618 ^d (16.99) |
| k | 2,6 | -0.019 (-0.30) | -0.026 (-0.40) | -0.022 (-0.46) | -0.014 (-0.30) | -0.061 ^f (-1.73) | -0.067 ^d (-2.79) |

Notes: a. Estimation is based on the systems approach as outlined in Phillips [1988]. The dependent variable is the German mark-U.S. dollar exchange rate. No lagged values of u_t are added to the cointegrating equation in regressions (1) through (6) because u_t is found to be i.i.d. One lagged value of u_t is added to the cointegrating equation in regression (7) in order to explain u_t up to an i.i.d. error process.

b. See Table 1 for variable definitions. All data are monthly.

c. Figures indicate the lagged values of Δx_t required in order to explain v_t up to an i.i.d. error (see equation system (1)).

d. Significant at the 95 percent level and of a correct sign.

e. Significant at the 95 percent level and of an incorrect sign.

f. Significant at the 90 percent level and of a correct sign.

g. Significant at the 90 percent level and of an incorrect sign.

Table 4
Reduction Results: Second Exchange Rate Regime (1979:10 - 1984:8)
Full Information Maximum Likelihood Estimation^a

| Regressions | | | | | | | | | |
|------------------------------------|----------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|---------------------------------|---------------------------------|--------------------------------|
| Explanatory Variables ^b | Lagged Values ^c | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| π | 1 | 0.002 (.023) | | | | | | | |
| m | 1 | -0.117 (-1.04) | -.117 (-1.05) | | | | | | -.407 (-3.36) |
| m* | 2,4 | 0.283 (1.50) | .278 (1.50) | .179 (1.04) | | | | | .912 (6.29) |
| k* | 3,5 | -0.069 ^a (-1.82) | -0.063 (-1.68) | -0.078 ^a (-2.12) | -0.085 ^a (-2.37) | | | | |
| k | 3,5 | 0.143 ^e (2.01) | 0.157 ^e (2.23) | 0.139 ^a (1.97) | 0.150 ^e (2.11) | 0.293 ^e (8.64) | | | |
| Constant | | 2.183 ^f (1.92) | 2.22 ^d (2.00) | 2.209 ^f (1.98) | 3.18 ^d (5.44) | 3.087 ^e (4.82) | 0.926 (1.29) | | |
| π^* | 1 | -0.179 ^d (-3.20) | -0.173 ^d (-3.29) | -0.187 ^d (-3.55) | -0.211 ^d (-4.80) | -0.161 ^d (-3.75) | -0.503 ^e (-23.09) | -0.521 ^e (-28.74) | -0.285 ^e (-6.73) |
| i* | 2,4,6 | 1.312 ^d (6.44) | 1.293 ^d (6.55) | 1.373 ^d (7.07) | 1.430 ^d (7.36) | 1.539 ^d (7.00) | 0.927 ^e (3.88) | 0.927 ^e (3.89) | .701 (3.08) |
| i | 1,2,3 | 2.566 ^d (6.66) | 2.607 ^d (8.29) | 2.586 ^d (8.47) | 2.553 ^d (8.34) | 2.904 ^d (10.78) | 1.672 ^e (5.76) | 1.720 ^e (6.07) | 1.803 (6.78) |
| y* | 1 | -0.415 ^e (-2.54) | -0.441 ^e (-2.76) | -0.452 ^e (-3.19) | -0.412 ^e (-3.25) | -0.217 (-1.57) | 0.765 ^e (9.03) | 0.751 ^e (8.81) | 0.310 ^e (2.64) |
| y | 1 | -0.319 ^d (-2.19) | -0.332 ^d (-2.31) | -0.290 ^d (-2.04) | -0.313 ^d (-2.30) | -0.584 ^d (-3.99) | -0.776 ^e (-4.48) | -0.558 ^e (-6.46) | -0.873 ^e (-8.29) |

Notes: a. Estimation is based on the systems approach as outlined in Phillips [1988]. The dependent variable is the German mark - U.S. dollar exchange rate. One lagged value of u_t is added to the cointegrating equation in all regressions, which explains u_t up to an i.i.d. error process.

b. See Table 1 for variable definitions. All data are monthly.

c. Figures indicate the lagged values of Δx_t required in order to explain v_t up to an i.i.d. error process (see equation system (16)).

d. Significant at the 95 percent level and of a correct sign.

e. Significant at the 95 percent level and of an incorrect sign.

f. Significant at the 90 percent level and of a correct sign.

g. Significant at the 90 percent level and of an incorrect sign.

estimates become significant and of the correct sign (e.g., German trade balances and U.S. income during the first and second exchange rate regimes respectively). Furthermore, once the insignificant variables are dropped and then added them back in different combinations during the second exchange rate regime, U.S. and German money supply levels are found to be significant, although with parameter signs that are inconsistent with the standard approaches.²² Hence, it is important to proceed in a step-wise fashion and to check many combinations of variables when working with I(1) variables. This ensures against excluding a variable which is initially insignificant, but subsequently becomes significant when another (insignificant) variable is deleted. Thus, the number of variable combinations that we estimate is much larger than the number reported in tables 3 and 4. The results of these other estimations are found to confirm the results shown in the tables.

The results in tables 3 and 4 indicate that regression (6) in table 3 and regression (8) in table 4 are the empirical reduced models for the first and second exchange rate regimes respectively, showing that the set of significant variables changes over time. It is important to note that this finding confirms the view that the structural change results reported in the preceding section are due in large measure to the shifting nature of the long-run relationship (as opposed to shifts in the short-run dynamics).²³ The decision to drop U.S. and German cumulative trade balances during the second exchange rate regime (regressions (5) and (6)) rests on the argument that the observed correlation is most likely the result of the causation running from the regressant to the two regressors. As discussed more fully in section 6, the seemingly anomalous parameter signs for the money supply variables during the second exchange rate regime are sensible if increases in money

²²None of the deleted variables during the first exchange rate regime are found to be significant when added back.

²³See footnotes 14 and 17.

lead to higher interest rates.

The issue of cointegration is important, not only because such a finding would support the claim that economic fundamentals do provide a long-run anchor for exchange rate movements, but also because the systems approach of Phillips [1988] applies only to cointegrated variables. In table 5 the results of unit root tests for the FIML residuals generated by the two reduced models are reported. (RS1 and RS2 denote the residuals from the reduced models for the first and second exchange rate regimes respectively.) The results show that the unit root hypothesis is rejected at the 1 percent level for the residuals of the first exchange rate regime and at the 5 percent level for the residuals of the second exchange rate regime.²⁴ Hence, the variables of both reduced models are found to be cointegrated, thereby supporting the claim that there are longer-run relationships between exchange rate dynamics and macroeconomic fundamentals operating in the foreign exchange market. It should be emphasized that when either of the reduced models or the D+ model is estimated over the entire sample period the null of no cointegration cannot be rejected. This provides strong evidence against the common practice of using just one linear model to explain the entire period of floating rates.

5.0 Out-of-Sample FIT

In this section it is shown that the dismal results reported in Meese and Rogoff [1983] are, in large measure, the result of allowing the forecasting experiment to run past the end of one exchange rate regime and into the next. We find that if, instead, the forecasting experiment takes into account

²⁴The critical values for these residual based unit root tests depend on the number of regressors (n) in the cointegrating relationship and, as such, the standard Dickey and Fuller tabulations do not apply in this case (see Engle and Yoo [1986] and Phillips and Ouliaris [1988]). Critical values for the test statistics t_{α} , $Z(t_{\alpha})$ and $Z(\bar{\alpha})$ for the cases of $n \leq 5$ are found in Phillips and Ouliaris [1988]. Critical values for cases of $n > 5$ are obtained through extrapolation.

Table 5
Residual Based Tests of Cointegration
ADF and Z Tests^a
 Size of Root and Test Statistics

| FIML Residuals ^b | p ^c | n ^d | (1+ $\hat{\alpha}$) | t _α | z(t _α) | z($\hat{\alpha}$) |
|-----------------------------|----------------|----------------|----------------------|----------------|--------------------|---------------------|
| RS1 | 7 | 6 | 0.15 | -2.08 | -6.00 ^e | -41.97 ^f |
| RS2 | 3 | 7 | 0.38 | -3.73 | -5.52 ^e | -39.58 |

Notes: a. The test statistics t_α and Z(t_α) are the augmented Dickey and Fuller (ADF) and Phillips and Perron Z t-statistics for the size of the root respectively, whereas the test statistic Z($\hat{\alpha}$) is the Phillips and Perron Z α -statistic for the size of the root (see Fuller [1976] and Dickey and Fuller [1981] and Perron [1987]). Critical values depend on the number of regressors (n) in the cointegrating relationship. Critical values are obtained from Phillips and Ouliaris [1988] for the cases where n is less than or equal to 5. For cases where n is greater than 5 critical values are obtained through extrapolation.

b. Definitions: RS1 denotes the residuals from the reduced model for the first exchange rate regime (regression (6) in table 2); RS2 denotes the residuals from the reduced model for the second exchange rate regime (regression (7) in table 2).

c. Figures indicate the number of lagged first difference terms ($\Delta y_{i,t}$, $i = 1, p$) that were found to be significant in regressions (a) through (c) for the ADF statistics.

d. Figures indicate the number of regressors in the cointegrating relationship.

e. Significant at the 95 percent confidence level.

f. Significant at the 90 percent confidence level.

the structural breaks, then the structural models outperform the random walk model by considerable margins. The dismal results of Meese and Rogoff [1983] are replicated in the first half of table 6. The analysis focuses on the forecasting performance of three models — the HM model in table 1 (which is one of the three structural models examined in Meese and Rogoff [1983]), the reduced model for the first exchange rate regime (RM1), and the random walk (RW) model. The analysis also relies on two criteria for measuring forecasting performance — root mean square forecast errors (RMSE) and the number of times (in percent) that the various models correctly predict the direction

Table 6
Out-of-Sample Fit: First Exchange Rate Regime
Root Mean Square Forecast Errors (RMSE) and Direction of Change Statistics (DCS)*

| Forecasting Horizon (in months) | End of Forecasting Period: June 1981 ^b | | | | | | End of Forecasting Period: Sept. 1978 ^c | | | | | |
|---------------------------------|---|-------|-------|-----|-----|------------------|--|------|------|------|------|-----|
| | RMSE | | | DCS | | | RMSE | | | DCS | | |
| | RW | HM | RM1 | HM | RM1 | Nob ^d | RW | HM | RM1 | HM | RM1 | Nob |
| 1 | 3.63 | 7.32 | 10.83 | 51 | 47 | 55 | 2.15 | 2.64 | 2.54 | 64 | 59 | 22 |
| | | | | | | | | 3.08 | 2.28 | 59 | 59 | |
| 3 | 5.83 | 9.65 | 13.30 | 58 | 58 | 53 | 4.32 | 3.24 | 3.20 | 80* | 80* | 20 |
| | | | | | | | | 3.68 | 2.87 | 75* | 80* | |
| 6 | 8.93 | 12.69 | 16.36 | 68 | 68 | 50 | 6.77 | 3.46 | 3.27 | 100* | 100* | 17 |
| | | | | | | | | 3.65 | 2.47 | 100* | 100* | |
| 9 | 11.08 | 15.48 | 19.48 | 70 | 70 | 47 | 10.14 | 4.37 | 3.95 | 100* | 100* | 14 |
| | | | | | | | | 4.03 | 3.56 | 100* | 100* | |
| 12 | 13.08 | 18.63 | 23.59 | 72 | 72 | 44 | 13.59 | 4.92 | 5.36 | 100* | 100* | 11 |
| | | | | | | | | 6.82 | 4.67 | 100* | 100* | |

Notes: a. RMSE figures are roughly in percentage terms. DCS figures denote the percentage of correct predictions. The two structural models - the original Hooper and Morton Model (HM) and the reduced model for the first exchange rate regime (RM1) - are estimated using OLS. RW denotes the random walk model.

b. Figures are based on an initialization period that begins in March 1973 and runs through November 1976. Forecasting begins in December 1976.

c. The figures on the top of each row are based on an initialization period that begins in March 1973 and runs through November 1976, whereas the figures on the bottom are based on an initialization period that begins in July 1974 and runs through November 1976. In both cases forecasting begins in December 1976 and ends in September 1978.

d. Number of forecasting observations.

e. Significant at the 5 percent level when based on the binomial distribution.

of change of the exchange rate (DCS).²⁵ As in Meese and Rogoff [1983], the initialization period runs from March 1973 through November 1976 with forecasting beginning in December 1976 and ending in June 1981, i.e., forecasting is allowed to run past the end of the first exchange rate regime

²⁵Mean forecast errors and mean absolute forecasts errors are also calculated. These results are found to mirror the results based on RMSE and as such they are not reported. The D+ model is also tested and found to perform slightly better than the reduced model for the first exchange rate regime and slightly worse during the second exchange rate regime.

and into the second exchange rate regime. At each forecasting horizon the structural models are provided with the realized future values of the explanatory variables. Repeated forecasts are generated using rolling regressions. The figures in the first half of the table reveal that when compared to the out-of-sample fit of the random walk model the structural models perform poorly. They are inferior by considerable margins when based on either RMSE or DCS at every forecasting horizon.²⁶

A different story emerges, however, when the structural change findings are taken into account. These results are presented in the second half of table 6. The figures on the top of each row are based on the same initialization period as that used in the first half of the table (the Meese and Rogoff [1983] case); whereas the bottom figures reflect an initialization period that begins in July 1974 and ends in November 1976. In both cases forecasting begins in December 1976 and ends in September 1978 (as such RMSE and DCS for the random walk are the same in both cases). Note, that the bottom figures are based on a sample period that exactly corresponds to the time period of the first exchange rate regime. The figures in this second half of the table reveal that both the HM and RM1 models outperform the random walk by substantial margins when based on both RMSE and DCS at every forecasting horizon save the 1 month horizon. In addition, the structural models perform best at the longer forecasting horizons, suggesting that fundamentals play a greater role over

²⁶The results in the first half of table 7 are more extreme than the results reported in Meese and Rogoff [1983], which show the HM model to perform slightly better than the RW model at the 1 month horizon and slightly worse at the 3, 6 and 12 month horizons. This is because unlike the Meese and Rogoff [1983] study, the residuals of the structural models in table 7 are not corrected for first-order serial correlation (in effect adding the lagged value of the exchange rate as an additional regressor). (The DW statistic for the original HM model over the period from March 1973 through June 1981 is .15.) The structural change and reduction results show, however, that such serially correlated residuals stem from a specification error and not from autoregressive errors in the true data generating process. As such, it is inappropriate to correct for serial correlation using either Cochrane-Orcutt or Fair's instrumental variables technique (both of which are employed in Meese and Rogoff [1983]).

the longer-run. For example, both the HM and the RM1 models are able to correctly predict the direction of change of the exchange rate 100 percent of the time at the 6, 9 and 12 month forecasting horizons. At the twelve month horizon, the RMSE of the RM1 model (4.67 percent) is almost one third that of the random walk model (13.59 percent).²⁷ In order to place this result in some perspective, it is not uncommon for the exchange rate to move 4 or 5 percent in one week! Hence, the large forecasting errors reported in Meese and Rogoff [1983] are largely the result of forecasting errors amassed after the break-point of September 1978.

The results for the second exchange rate regime, which are based on an initialization period that runs from October 1979 through June 1982 are presented in table 7. Although not quite as impressive as the results for the first exchange rate regime, these results lead to a similar conclusion. When the structural change results are not taken into account, so that the forecasting period is allowed to run until the end of the sample in March 1988, the performance of the structural models is everywhere inferior to that of the random walk. These results are presented in the first half of table 7. But, when the break in September 1984 is incorporated into the analysis, the performance of the structural models improves considerably, especially at the longer forecasting horizons. These results are presented in the second half of table 7. The figures on the bottom of each row are based on estimating an equation that includes among its regressors first differences of the dependent variable and each explanatory variable. The addition of such $I(0)$ variables explains the autocorrelated residuals produced by the structural models during the second exchange rate regime and thus reflects the short run dynamics of the system (see footnotes 14 and 17).

As a whole then, the out-of-sample forecasting results in this section, together with the regression and cointegration results of the previous section, show that from a statistical standpoint

²⁷Note, that this reduced model does not need to be adjusted for autocorrelated residuals.

Table 7
Out-of-Sample Fit: Second Exchange Rate Regime
Root Mean Square Forecast Errors (RMSE) and Direction of Change Statistics (DCS)^a

| Forecasting Horizon (in months) | End of Forecasting Period: March 1988 | | | | | | End of Forecasting Period: August 1984 ^b | | | | | |
|---------------------------------|---------------------------------------|-------|-------|-----|----|------------------|---|------|-------|-----------------|------------------|------------------|
| | RMSE | | | DCS | | | RMSE | | | DCS | | |
| | RW | RM2 | HM | RM2 | HM | Nob ^c | RW | RM2 | HM | RM2 | HM | Nob ^c |
| 1 | 3.51 | 11.88 | 10.10 | 35 | 42 | 69 | 2.80 | 3.95 | 4.30 | 46 | 54 | 26 |
| | | | | | | | | 3.27 | 4.45 | 65 ^d | 58 | |
| 3 | 6.46 | 13.85 | 12.96 | 51 | 40 | 67 | 4.57 | 4.39 | 5.92 | 79 ^d | 58 | 24 |
| | | | | | | | | 3.60 | 6.18 | 79 ^d | 54 | |
| 6 | 10.62 | 16.60 | 12.96 | 53 | 44 | 64 | 5.69 | 4.54 | 7.44 | 76 ^d | 67 | 21 |
| | | | | | | | | 3.55 | 8.27 | 86 ^d | 71 ^d | |
| 9 | 14.56 | 19.38 | 22.15 | 48 | 51 | 61 | 6.90 | 5.17 | 8.63 | 61 | 94 ^d | 18 |
| | | | | | | | | 4.12 | 10.38 | 67 | 94 ^d | |
| 12 | 18.59 | 22.48 | 27.26 | 52 | 44 | 58 | 8.41 | 5.89 | 11.12 | 87 ^d | 93 ^d | 15 |
| | | | | | | | | 4.98 | 13.98 | 87 ^d | 100 ^d | |

Notes: a. RMSE figures are roughly in percentage terms. DCS figures denote the percentage of correct predictions. All figures are based on an initialization period that begins in November 1979 and runs through June 1982. Forecasting begins in July 1982. The two structural models - the original Hooper and Morton Model (HM) and the reduced model for the second exchange rate regime (RM2) - are estimated using OLS. RW denotes the random walk model.

b. Figures on the top of each row are for the models indicated, whereas the figures on the bottom of each row are based on adding to the indicated model first differences of all the dependent variable and all of the explanatory variables.

c. Number of forecasting observations.

d. Significant at the 5 percent level when based on the binomial distribution.

macroeconomic fundamentals do matter for exchange rate movements, especially over the longer-run. The primary key to detecting these relationships centers on incorporating the problem of structural change into the analysis. In the next section we explore the broader macroeconomic issues

implied by these findings.

6.0 The Macroeconomic Implications of the Empirical Findings

The structural change findings reported in figure 1 and the reduction results in tables 3 and 4, together with the alternatives summarized in table 2, suggest that the underlying structure of the economy is characterized by sticky-prices. This is because there is no room in the flexible-price case via the expectations channel for explaining not only structural instability, but also different sets of significant fundamentals during different time periods. As such, maintaining that prices are flexible requires the argument that all 5 structural breaks reported in figure 1 are due to shifts in the underlying structure of the economy. Additional evidence for sticky prices is found in the parameter estimates for the interest variables, which are all found to be consistent with the predictions of the sticky-price models, except for the parameter estimate on German interest rates in the 1980s (see table 1). Hence, the data point to one of the sticky-price models.

In terms of the sticky-price alternatives, it appears that the only case consistent with the reduction results is the case of perfect capital mobility. This is because the case with perfect capital mobility and sticky prices is the only one that allows for the money, inflation and cumulative trade balance variables to come in and out of the reduced form over time. One inconsistency with this view is that when the difference restriction on the interest rate variables is tested using a systems based likelihood ratio test, it is found to be inconsistent with the data. This suggests that the assumption of imperfect capital mobility is more compatible with the data. (The likelihood ratio here is found to be 3.95 and 48.72 for the first and second exchange rate regimes respectively.) In order to maintain the view of perfect capital mobility, therefore, it is necessary to argue that market agents use the interest rate variables in forecasting and do not impose the difference restriction in doing so (which is implied

by the flexible-price forecasting equation). One possible explanation for this, which is consistent with the case of sticky prices, perfect capital mobility and TCE, is that agents focus on particular subsets of the variables of each theory and they also make use of more than one theory at a time.

Another apparent inconsistency with the case of sticky prices, perfect capital mobility and TCE is that both money supply variables are found to be significant with inconsistent parameter values during the second exchange rate regime. However, this finding is explainable if changes in money lead to changes in interest rates in the same direction. This can occur if money supply changes (which are not fully anticipated) lead market agents to expect subsequent reversals, i.e., market agents view central bank targets as being credible. It can also happen if changes in money cause market agents to revise their forecasts of the expected inflation rate in the same direction, thereby causing them to adjust the inflation premium component of nominal interest rates. There are a number of studies which find that changes in U.S. interest rates during the early 1980s are indeed positively related to changes in U.S. money (see Engel and Frankel [1982,1984], Cornell [1982], Hardouvelis [1984] and Frankel and Hardouvelis [1985]). Since they also find that these changes in U.S. money are also positively related to the value of the dollar, they conclude that the positive relationship between money and interest rates is the result of a credible Fed policy of targeting money rather than the cause of an expected inflation effect. The reduction results in table 4, therefore, provide additional evidence for such a view of the relationship between U.S. money and interest rates during the early 1980s.

In terms of Germany, it appears that movements in German interest rates reflect changes in inflationary expectations, leading to a positive relationship between i^* and e . In order to test this view we replace the German interest rate variable with the German inflation rate variable in the reduced model for the second exchange rate regime. It is found that German inflation is highly

significant with a parameter value of the correct sign.

Hence, the reduction results reported in tables 3 and 4 can be reconciled with the sticky-price monetary model with perfect capital mobility.²⁸ It is interesting to note that the reduction results presented in tables 3 and 4 are generally consistent with the TCEH. During both exchange rate regimes, the variables that are found to be significant enter, for the most part, with parameter signs that are consistent with the predictions of one of the standard asset market models.

7.0 Conclusion

The findings of this paper lead to two major conclusions. First, macroeconomic fundamentals do matter for exchange rate dynamics, although in a nonstandard way. They matter in that different sets of fundamental variables are significant during different time periods. Second, the basic (semi-reduced-form) assumptions of the sticky-price monetary models of the exchange rate with the TCEH are consistent with the data. The key underlying both of these conclusions has been incorporating the problem of structural instability explicitly into the analysis in a way that is objective and that allows for different sets of significant variables during different time periods. It should be emphasized that the piece-wise linear approach followed here represents only a gross approximation to the data. There are many reasons to believe that reduced-form parameters are not entirely stable even within the separate exchange rate regimes isolated in this study.²⁹ But, the findings of this study show that a piece-wise linear specification provides a reasonable approximation.

²⁸An alternative possibility is that U.S. and German money supplies are endogenous and capital is imperfectly mobile (see Goldberg [1991b]).

²⁹For example the J-curve effect (De Grauwe and Vansanten [1990]), the presence of noise traders (Frankel and Froot [1987] and De Grauwe and Vansanten [1990]), anticipated movements in driving variables and the imposition of target zones (Krugman [1988]) will all generate non-linearities that in a linear setup will lead to instability in reduced-form parameters.

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