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IMPERFECT KNOWLEDGE AND BEHAVIOR IN THE FOREIGN EXCHANGE MARKET

by **Michael D. Goldberg**
and
Roman Frydman

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C. V. STARR CENTER FOR APPLIED ECONOMICS

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

Abstract

This paper explores the consequences of imperfect knowledge for exchange rate dynamics within the monetary class of models. The framework we develop, which we call the theories consistent expectations (TCE) framework, provides a particular formalization of a world in which agents use theories in order to look forward, but in which these theories provide only qualitative knowledge rather than quantitative knowledge about the economy. In doing so we abandon the RE assumption that agents act as if they are capable of generating quantitatively correct forecasts. The main characteristics of the TCE framework are: 1) it recognizes the existence of a pluralism of theories describing exchange rate dynamics and allows agents to base their forecasting functions on one or more of the existing theories; 2) it does not assume that the precise magnitudes of the parameters of economic models are known to agents, i.e., the stock of extant theories provides qualitative rather than quantitative knowledge about the economy; and 3) it replaces the assumption of perfect foresight with the assumption that agents are able to correctly predict the direction of change of the exchange rate, which we call qualitative rationality. We find that as long as agents possess at least some degree of imperfect knowledge, the monetary models of the exchange rate generate movements that are consistent with observed behavior, but which are anomalous in the context of the monetary models with RE.

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Imperfect Knowledge and Behavior in the Foreign Exchange Market*

Michael D. Goldberg

The Whittemore School of Business and Economics
University of New Hampshire
Durham, New Hampshire 03824
(603) 862-3385

and

Roman Frydman

Department of Economics
New York University
New York, NY 10003
(212) 998-8967

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It has been apparent for some time now that traditional asset-market models of the exchange rate provide poor explanations of the modern floating rate period. Perhaps most troubling for exchange rate theorists are the recurring episodes of large and persistent "misalignments", although other notable anomalies include poor in-sample fit, poor out-of-sample fit and a lack of cointegrating relationships.[1] In reviewing the evidence, two of the leading researchers in the field have concluded 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)."

Aside from the problems associated with statistical inference, there are only two possible explanations for the observed inadequacy of traditional exchange rate models. The problem is due either to the assumptions concerning the underlying structure of the economy (i.e., those embodied in the semi-reduced form) or to the assumptions used in modeling exchange rate expectations. The more modern choice-theoretic approaches to open-economy macroeconomics can be seen as an attempt at uncovering the problems inherent in the semi-reduced-form specifications of traditional theory.[2]

In this paper we consider the other possibility and explore the consequences of imperfect knowledge for exchange rate dynamics within the monetary class of models. The framework we develop, which we call the theories consistent expectations (TCE) framework, provides a particular formalization of a world in which agents use theories in order to look forward (as with the rational expectations (RE) framework), but in which these theories provide only qualitative knowledge rather than quantitative knowledge about the economy.[3] In doing so we abandon the RE assumption that agents are capable (or act as if they are capable) of generating

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[1]For a review of the empirical record see Dornbusch and Frankel [1987], MacDonald and Taylor [1993] and Taylor [1995].

[2]For an excellent treatment of the more modern approaches see Frenkel and Razin [1992]. It should be pointed out that this drive for models with well-specified microfoundations remains nascent, implying that the macroeconomist must "take guesses and rely on a battery of models that cannot be derived from first principles....we see no alternative to using shortcuts, at least for the time being and probably forever (Blanchard and Fischer [1989], ch.1)."

[3]Earlier work on developing the TCE framework can be found in Frydman and Phelps [1990], Goldberg [1991] and Goldberg and Frydman [1993]. Soros [1987,1985] has also emphasized the crucial importance of imperfect knowledge for understanding the dynamics in financial markets.

quantitatively correct forecasts. We find that exchange rate movements are characterized by persistent movements either towards or away from purchasing power parity (PPP) as long as agents possess imperfect knowledge concerning the relationship between fundamentals and the exchange rate, as formalized by the TCE framework. Furthermore, if the movement is initially towards PPP, then there is no tendency to stop when this benchmark level is reached and shooting through occurs. Remarkably, the degree to which agents lack perfect knowledge is unimportant for these results. We find that as long as agents possess some degree of imperfect knowledge, the monetary models of the exchange rate generate dynamics that are consistent with the anomalous behavior observed in the literature. Our results suggest that the implications of imperfect knowledge should be explored further before abandoning the monetary and other traditional exchange rate models.

This line of research is further motivated by the now a sizeable body of evidence indicating the inadequacy of RE for explaining behavior in financial markets (e.g., Frankel and Froot [1987b] and Ito [1990] for the foreign exchange market and Schiller [1985,1988] for the stock market, among others). In terms of the foreign exchange market, Dornbusch states that, "there is now overwhelming evidence that the hypothesis of informed, rational speculation must be rejected (Dornbusch [1989], p. 249)." The problem, of course, is that "rejection is not enough since it has to be rejection in favor of an alternative paradigm and the fact is we do not have a better one (Dornbusch [1989], p. 249)."

In order to model forward-looking behavior, it is necessary to endow agents with some conception(s) of the world, i.e., theory is a prerequisite for connecting the present with the future, and, therefore, connecting expectations with fundamentals. The rational expectations hypothesis formalizes forward-looking expectations in a particular way by endowing the economic analyst and economic agents with knowledge of the true quantitative model. An alternative, and arguably more plausible, assumption is that economic agents, as well as the economic analyst, have only imperfect knowledge of the relationships between the exchange rate and fundamentals. The TCE framework provides one particular formalization of such a world. With TCE, there exists a number of theories available to agents for forecasting, which we call the set of leading theories. In addition, the TCE framework assumes that the precise magnitudes of the parameters of the leading theories are not known to agents. Instead, the stock of leading theories informs agents only in a qualitative sense, in that they impart knowledge as to which fundamental variables may be important for exchange rate movements and as to the algebraic signs of the weights that should be attached to these fundamental variables. Expectations functions are said to be theories consistent if they include either all or a subset of the variables of one or more of the leading theories and if the weights attached to these variables are consistent in sign with at least one of the leading theories.

Allowing for forward-looking behavior is problematic, irrespective of whether agents are endowed with the true quantitative model or with imperfect knowledge. The former case raises epistemological questions concerning how agents have come to know the true model. The literature on learning and convergence to the rational expectations equilibrium has shown that, even in highly stylized models, convergence occurs only under very special conditions. For example, most of the convergence results assume that agents adhere *collectively* to a non-rational learning rule[4] Thus, the theoretical foundations of the RE approach are weak at best.

As for the case of imperfect knowledge, the problem is that endowing agents with anything other than the true quantitative model leads to non-white-noise forecasting errors. Such errors are usually thought to be "systematic and exploitable," and thus the use of non-RE forecasting functions has been considered tantamount to "irrationality" in the sense that agents are not using all available information. However, in a world of imperfect knowledge, information contained in past forecasting errors is, in general, difficult to exploit in the formulation of *ex ante* forecasts. This follows from one of the important results in this paper that a world characterized by imperfect knowledge is also characterized by structural shifts, in terms of switches in

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[4]See Frydman [1982] and Frydman and Phelps [1983] for early analyses of this issue. For further development of these arguments and a number of new results see Spear [1989].

expectations functions and in the policy environment.[5] Such shifts, in turn, generally imply that distribution functions of forecasting errors vary over time, thereby frustrating attempts to exploit *ex ante* past information on forecasting errors.

The question arises, however, as to what is meant by the term "rational" in a world where agents have imperfect knowledge. We propose to replace the assumption of perfect foresight with the assumption of qualitative rationality (QR). Agents are said to be qualitatively rational if they are able to correctly predict the *direction* of change of the exchange rate. With qualitative rationality, it is rational for agents to use TCE forecasting rules as long as they are capable of predicting the right side of the market. Such non-RE rules are shown to always exist. Of course, agents would like to have a forecasting strategy that predicts correctly not only the direction of change, but also the magnitude of this change (as with perfect foresight), but in a world of imperfect knowledge this is beyond their capacity. We assume that the best agents can hope for is to get the direction of change right. It should be emphasized that although the assumption of qualitative rationality is weaker than the assumption of perfect foresight, assuming that agents know enough to predict the right side of the market is still a strong assumption. We do not contend that this assumption is necessarily realistic, but rather is a stylized way to model the expectations formation process. The assumption of QR is the weakest strong assumption one can impose that makes it rational to use a wrong model.

There are other examples in the exchange rate literature of models with imperfect knowledge that also generate non-standard dynamics, namely the noise-trader models of Frankel and Froot [1987a] and Kirman [1990]. There are two key differences between these models and the one developed here. First, the rationale for the non-standard dynamics in the noise-trader models stems from switching between a fundamental model and a model based on chartism. With TCE, we assume that agents always use fundamentals in forecasting.

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[5]The finding of structural change is ubiquitous in macroeconomics, especially in connection with financial markets. For the foreign exchange market see Meese [1986], Boughton [1987] and Goldberg and Frydman [1996b]. Meese remarks that "the most menacing empirical regularity that confronts exchange rate modelers is the failure of the current generation of empirical exchange rate models to provide stable results across subperiods of the modern floating rate period (Meese [1986], p.365)." For analysis of the implications of structural change and non-stationary forecast errors for RE modeling see Frydman and Rappoport [1987] and references therein.

The non-standard dynamics emerges not because agents move away from using fundamentals, *but because agents do not know how to perfectly interpret the movements in fundamentals*. Our analysis makes clear that noise trading is not required for obtaining dynamics that are consistent with the empirical record. Instead, such dynamics are the result of a more general phenomenon, namely the existence of imperfect knowledge concerning the relationship between fundamentals and the exchange rate. Second, with TCE, it is rational for agents to use their TCE forecasting equations, because they are able to predict the right side of the market. In contrast, with the noise-trader models, agents' forecasting strategies continuously mispredict not only the magnitude of the change in the exchange rate but also its direction. Since such strategies are not even qualitatively rational, it is not clear why they would be used by "rational" agents.

The paper is structured as follows. Section 2 formalizes the TCE hypothesis (TCEH) and specifies the set of leading theories. In section 3 we solve the composite model using the TCE framework and report on the general implications of the approach, while in section 4 we examine how well these general implications match up with the empirical record. In section 5 we offer concluding remarks.

2.0 A Formal Representation of the TCEH

In this section we formalize the way agents form expectations. With TCE, neither the economic analyst nor the economic agents are assumed to know (or act as if they know) the true quantitative model, i.e., the world is assumed to be characterized by imperfect knowledge. The TCE framework also assumes that in general, the theories used for forecasting differ across agents (i.e., expectations are heterogeneous) and that the specific mix of theories used collectively is unknown to the economic analyst. Despite this looseness, we can still solve the model and obtain well-defined and testable implications. We find that, except for some special cases, all of the key results of the analysis do not depend on the particular mix of theories used by agents. Instead, they depend solely on the existence of some gap in the knowledge agents possess and knowledge of the true quantitative model.

It is useful to begin by specifying the set of leading theories. In this paper we assume that this set is comprised of the monetary class of exchange rate models. The reason for choosing the monetary class of models is completely analogous to the choosing of only one model with RE, namely we are interested in uncovering the implications of the semi-reduced-form assumptions of the monetary models together with the expectational assumptions of TCE. It should be pointed out that it would be possible to include a wider set of economic theories, as well as to include models based on chartism.[6]

The most commonly used monetary models of the exchange rate include the following three: 1) the flexible-price model of Frenkel [1976] and Bilson [1978] (the FB model); 2) the sticky-price model of Dornbusch [1976] and Frankel [1979] (the DF model); and 3) the sticky-price model of Hooper and Morton [1982] (the HM model).[7] We assume that the set of leading theories is comprised by these three models. The basic (semi-reduced-form) structure of these models can be expressed as special cases of the following composite model:

$$m = \gamma p + \phi y - \lambda i , \tag{1}$$

$$\dot{p} = \delta\left[\nu(s - p - q_n) - \alpha(i - i_n)\right] + \dot{\bar{p}} , \tag{2}$$

$$E(\dot{s}) = i , \tag{3}$$

$$q_n = q_{n_0} - \eta k , \tag{4}$$

where m, p, and y denote the log levels of domestic minus foreign money supply, price and income respectively, I denotes the level of the domestic minus foreign short-term interest rates, k is the de-trended

[6]It should be pointed out that if noise-trader models are included in the set of leading theories, then agents may not be using fundamental models all of the time. In not including noise-traders into the analysis, we show that such behavior is not required to generate dynamics that are consistent with the empirical record. Instead, our analysis shows that such dynamics are the result of the more general phenomenon of imperfect knowledge.

[7]This classification scheme is due to Meese and Rogoff [1983].

level of domestic minus foreign cumulative trade balances, s is the log level of the exchange rate (defined as the domestic currency price of foreign currency), i_n and q_n are the natural levels (a term made precise below) of I and the log level of the real exchange rate, q_{n_0} is an initial condition on q_n, the symbols "$\bar{}$" and "$\dot{}$" denote steady-state value and time derivative respectively and $E(\dot{s})$ denotes the conditional forecast of $\dot{s}$.

Equation (1) describes equilibrium in the money markets, where we use the standard symmetry assumption that domestic and foreign money demand parameters are equal.[8] Equation (2) shows how relative prices adjust to the long-run when they are assumed to be sticky in the short-run (the DF and HM cases). Price adjustment is a function of excess demand, which depends on the deviation of the real exchange rate and the nominal interest rate from their natural levels.[9] The natural levels of relative interest rates (i_n) and the real exchange rate (q_n) are defined as those long-run levels that would be obtained with RE. As such, q_n implies PPP and i_n is equal to $E(\dot{\bar{p}})$. This last result follows from the fact that with RE, the long-run levels of domestic and foreign real interest rates are constant and equal. Equation (3) is uncovered interest rate parity (UIP) and is the equilibrium condition for the foreign exchange market. Finally, equation (4) makes use of the work in Hooper and Morton [1982] and assumes that if the real exchange rate changes over time, then its movements are related to movements in cumulative trade balances from trend. We assume that all such movements from trend are unexpected.

The models encompassed in equations (1) through (4) comprise the set of leading theories. These equations do not, however, imply any specific forecasting functions for the exchange rate. As Keynes [1936] has already noted, the key importance of the market's expectation (the average opinion) for the dynamics of the exchange rate gives rise to an infinite regress problem.[10] It is important to emphasize that the forecasting

[8] These money demand restrictions are standard in the literature and we make use of them for convenience only. They in no way alter the main conclusions of our analysis.

[9] Goldberg [1995] shows that when the price-adjustment rule does not include interest rates (e.g., as in Frankel [1979]), money is not neutral *in the long-run* in this class of models with RE.

[10] For an analysis of the infinite regress problem in macroeconomic models see Phelps [1983].

equations implied by equations (1)-(4) are indeterminate in both a quantitative and a qualitative sense, i.e., these equations do not imply any specific relationship between fundamentals and the exchange rate. They do not even imply that a specific set of variables should be included in the forecasting functions.[11] Thus, although we postulate in this paper that individual forecasting functions are based on a set of leading theories in a qualitative sense, we still have to circumvent the infinite regress problem. The following expectational hypothesis overcomes this problem by making use of the qualitative structure of the RE reduced-form solutions of the set of leading theories:

> **The Theories Consistent Expectations Hypothesis** (TCEH): 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 extant models are defined to be those obtained when using the RE solution technique.

The TCEH allows a formal specification of the *qualitative structure* of agents' forecasting functions. It assumes that agents possess knowledge of the qualitative structure of the RE reduced forms and that this qualitative structure informs agents only as to the potentially relevant fundamental variables underlying exchange rate movements and as to the algebraic signs of the weights that should be attached to these fundamental variables.[12] In a world with imperfect knowledge, reduced forms obtained with the RE solution method do not inform agents as to the true quantitative weights that should be attached to fundamentals. Thus, although the TCEH assumes agents to have knowledge of the qualitative structure of RE forecasting functions, the assumption of imperfect knowledge, as formalized by the TCEH, implies that rational expectations are beyond the capacity of agents. It should be pointed out that the TCEH assumes that agents may choose to use only a subset of the variables of a particular RE reduced form in their forecasting equations (although with

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[11]For a rigorous analysis of the indeterminacy of forecast functions in models with expectations see Frydman [1982]. Frydman also shows that this indeterminacy leads to serious learning and convergence problems in RE models, which provides the ultimate rationale for the assumption of imperfect knowledge employed in this paper.

[12]It would be possible for the TCEH to assume that this qualitative structure also includes knowledge about the qualitative relationships between the parameters appearing in the RE reduced forms, which would be analogous to the cross-equation restrictions found with RE, but we do not explore this assumption in this paper.

parameters that are consistent in sign) or use variables from more than one model. This is a consequence of the fact that agents do not know the true model.

The rationale for using reduced forms obtained with the RE solution method as a way to circumvent the infinite regress problem is the same as the rationale that underlies the REH, namely, we assume that agents use all available information. In a world of imperfect knowledge, however, the question arises as to what agents know. The RE solution method is, without question, the predominant way of closing models in the literature, implying that the qualitative structure of the RE reduced forms is what agents have available when contemplating the future. The TCEH assumes, therefore, that this qualitative structure is part of agents' information sets.

In order to implement the TCEH, therefore, it is necessary to derive first reduced-form forecasting equations for each of the models encompassed in equations (1) through (4) using the RE solution method. As for the DF and HM models, we have the following:

$$E(\dot{s}) = \theta(\bar{s} - s) + \frac{1}{\gamma}\pi , \tag{5}$$

$$\bar{s} = \frac{1}{\gamma}(m - \phi y) + \frac{\lambda}{\gamma^2}\pi + q_{n_0} - \eta k , \tag{6}$$

where $\pi = \dot{m} - \phi\dot{y}$ and the parameter θ is the stable root of the system, which has been redefined to be positive.[13] The reduced-form forecasting equation for the sticky-price DF model obtains when $\eta = 0$, whereas the reduced form for the sticky-price HM model obtains when η is allowed to be non-zero. As for the flexible-price FB model, when prices are assumed to be flexible we have $s = \bar{s}$. This implies the following forecasting equation:

[13] In deriving equations (5) and (6) we make the standard assumptions of stability and constant growth rates of money and income. See Boyer and Hodrick [1981] for a discussion of these assumptions. Note, the term "reduced-form" is used in describing the foresting equations because they are derived directly from the reduced forms of the encompassed models.

$$E(\dot{s}) = i , \tag{7}$$

since $I = \frac{\pi}{\gamma}$.

Agents are assumed to know and use the reduced forms in equations (5) through (7). Again, these reduced forms inform agents as to the important fundamental variables and as to the algebraic signs of the weights that should be attached to these fundamental variables. In general, agents' estimates of these weights will differ and will not be quantitatively correct. In the aggregate, if all agents use the reduced forms in (5) through (7), then the aggregate forecasting equation will be based on these three reduced forms. This aggregate TCE forecasting equation can be expressed as follows:

$$E(\dot{s}) = (1 - \sigma)\left[\tilde{\theta}(\tilde{\bar{s}} - s) + \frac{1}{a_1}\tilde{\pi} \right] + \sigma i , \tag{8}$$

$$\tilde{\bar{s}} = \frac{1}{a_1}(m - a_2 y) + \frac{a_3}{a_1^2}\tilde{\pi} + \tilde{q}_n , \tag{9}$$

$$\tilde{\pi} = \dot{m} - a_2\dot{y} = a_1\tilde{\bar{\dot{p}}} = a_1\tilde{\bar{\dot{s}}} , \tag{10}$$

$$\tilde{q}_n = (1 - \omega)\tilde{q}_n^{Df} + \omega(\tilde{q}_{n_0}^{HM} - a_4 k) , \tag{11}$$

where σ is the share of agents subscribing to the FB model, the symbol "~" denotes an estimate arrived at by agents, ω is the proportion of agents believing in sticky prices who subscribe to the HM model, the superscript DF (HM) denotes a variable estimate by the section of the market subscribing to the DF (HM) model and all of the parameters and variables with a "~" are weighted averages of the parameter and variable estimates from the two groups believing in sticky-prices, i.e., $\tilde{\theta} = (1-\omega)\tilde{\theta}_{DF} + \omega\tilde{\theta}_{HM}$, $a_1 = (1-\omega)a_1^{DF} + \omega a_1^{HM}$, etc.. This implies that $\tilde{\bar{s}} = (1-\omega)\tilde{\bar{s}}_{DF} + \omega\tilde{\bar{s}}_{HM}$, $\tilde{q} = (1-\omega)\tilde{q}_{DF} + \omega\tilde{q}_{HM}$ and $\tilde{\pi} = (1-\omega)\tilde{\pi}_{DF} + \omega\tilde{\pi}_{HM}$.

There are two simplifying assumptions implicit in equation (8) which reduce the extent to which agents' knowledge falls short of that assumed in the RE case. First, we assume agents know that the domestic and foreign money demand parameters are equal. Second, we assume that agents observe $\dot{m}$ and $\dot{y}$. Both of these assumptions do not alter the main conclusions of the analysis. This is because our main conclusions do not depend on the size of the gap in knowledge relative to the RE case, but rather they depend on there being at least some gap. Both assumptions still allow for a considerable degree of uncertainty concerning the true underlying model.

It should be pointed out that although equation (8) contains the fundamental variables from all of the extant theories, the TCEH allows for aggregate forecasting equations that relate $E(\dot{s})$ to only a subset of the variables (with parameter signs that are theories consistent) appearing explicitly or implicitly on the right-hand side of (8). As such, the TCEH allows for agents to focus on only a subset of the potentially relevant fundamental variables for determining exchange rate movements. This kind of behavior is consistent with the work of Froot, Scharfstein and Stein [1991] which suggests that a world characterized by short forecasting horizons , agents may focus on only a subset of the relevant fundamental variables in forming expectations. Our study can be viewed as examining the macroeconomic implications of such non-RE behavior.

Before moving on to solving the composite model, it is important to discuss the rationality of the TCE assumptions implied in equation (8). Since agents' TCE forecasting equations are not RE, they generate non-white-noise forecasting errors. If these non-white-noise forecasting errors involve a systematic component, then agents who continue to use the non-RE rules behind (8) would be acting "irrationally" in the sense of throwing away relevant information. This is the conundrum that arises in moving away from RE. Anything other than RE seems to imply an inconsistency with the intuitively appealing idea that agents try to do the best they can. There are two ways to proceed. One way is to assume that agents continuously update their beliefs in an attempt to learn the true model. However, this does not solve the problem because convergence to the

RE equilibrium occurs only under special conditions and generally requires that agents adhere to a non-rational forecasting rule collectively. But, if convergence does not occur, then what justification exists for agents to use the imputed learning strategy? Presumably, in such a situation agents would be continuously updating the way they learn (i.e., learning how to learn), but this just gives rise to an infinite regress problem.

The Frankel and Froot [1987a] model provides an example of this learning approach. In this model, agents continuously shift the weights they attach to two conceptions of the world (one fundamental model and one chartist model), in an unsuccessful attempt to learn the true model. Persistent movements of the exchange rate away from the fundamental equilibrium occur precisely because agents shift away from the fundamental model and to the chartist model over time. The system experiences a countermovement when agents begin moving back to the fundamental model. The problem, however, is that as the exchange rate moves away from the fundamental equilibrium in one direction, agents are continuously predicting the exchange rate to move in the exact opposite direction, i.e., every divergent phase generated in the Frankel and Froot model is associated with agents being on the wrong side of the market *continuously*. Why should agents continue to use a learning strategy that is not only incapable of delivering the true model, but also causes them to incorrectly predict the direction of change of the exchange rate?

Since the use of specific learning algorithms by rational agents is difficult to justify and the implications of models including such algorithms are problematic, we suggest in this paper alternative assumptions that can justify the use of non-RE forecasting equations by rational agents. One of the important results in this paper is that a world characterized by imperfect knowledge implies structural shifts in terms of switches in expectations functions and in the policy environment. In general, such structural shifts imply non-stationary distribution functions, which frustrate agents' attempts to exploit *ex ante* past information on forecasting errors in order to learn the true model. The question arises, however, as to the meaning of "rationality" in a world in which quantitatively correct forecasts are beyond the reach of agents. We propose that the assumption of quantitative (or perfect foresight) rationality be replaced by the assumption of qualitative rationality (QR).

Agents' forecast functions are said to be qualitatively rational as long as they correctly predict the *direction of change* of the exchange rate. Under QR, all agents are assumed to know enough about the world to be capable of choosing particular TCE forecasting equations that can predict the direction of change of the exchange rate at every point in time. We assume that agents will continue to use their particular TCE forecasting rules predict the right side of the market because the most they can hope for is to be qualitatively rational.

It should be emphasized that QR is not better than perfect foresight. Agents would prefer a forecasting rule that predicted both the direction of change and the magnitude of this change, but learning such a rule is assumed to be beyond their capacity. It should also be emphasized that although QR is a weaker assumption than RE, it is still a strong assumption. We do not contend that this assumption is necessarily realistic, but rather is a stylized way to model exchange rate expectations.

In addition to serving as a rationality criterion, the assumption of QR provides a basis for the switching of expectations functions. In the next section the monetary models with TCE are shown to generate persistent movements in the exchange rate away from the long-run RE level of PPP. It is the combination of such divergent behavior and qualitative rationality that gives rise the switching nature of expectations functions. We discuss these dynamics in the next two sections.

3.0 Closing the Model with TCE

A. Mathematical Stability and Economic Instability

With TCE, neither the economic analyst nor the economic agents are assumed to know the true quantitative model, implying that neither know how to link up expectations with fundamentals perfectly. The TCE framework models such a world by assuming that agents make use of a number of theories in forecasting and that these theories endow them with only qualitative knowledge. As for the economic analyst, the particular mix of theories used by agents is assumed to be unknown. In addition, the analyst is unsure as to which semi-reduced form best describes the underlying structure of the economy. Despite this looseness, however, we are able to solve the model and derive testable implications that are independent of the particular mix of theories used by agents and independent of the particular semi-reduced form utilized by the analyst. The purpose of this section is to explicate these general implications[14]

We begin by closing the composite model in equations (1) through (4) with the TCE aggregate forecasting equation in (8). In doing so, we make the usual assumptions of a fixed policy environment and aggregate forecasting equation, i.e., we assume constant growth rates for money and income and (given qualitative rationality) we treat the parameters of equation (8) as being stable indefinitely (see footnote 12). The reduced-form time paths for the nominal exchange rate and relative goods prices, which are derived in section A of the appendix, are as follows:

$$p(t) = (p_0 - \bar{p}_0)e^{\theta t} + \bar{p} , \tag{12}$$

$$s(t) = (s_0 - \bar{s}_0)e^{\theta t} + \bar{s} , \tag{13}$$

$$\bar{p} = \bar{p}^* + \frac{v\tilde{\theta}\lambda}{d}(\tilde{\bar{s}} - \bar{s}^*) + \frac{(v + \tilde{\theta}\alpha)\lambda}{d{a_1}^2\gamma^2}(a_1\gamma^2\tilde{\pi} - \gamma {a_1}^2\pi) , \tag{14}$$

$$\bar{s} = \bar{s}^* + \frac{\tilde{\theta}(\alpha\gamma + v\lambda)}{d}(\tilde{\bar{s}} - \bar{s}^*) + \frac{v\lambda}{da_1\gamma}(\gamma\tilde{\pi} - a_1\pi) , \tag{15}$$

where $\theta = \dfrac{-\delta[\tilde{\theta}(v\lambda + \alpha\gamma) + \gamma v]}{\tilde{\theta}\lambda} < 0$, e^x denotes the exponential function raised to the power of x, $d = (v + \tilde{\theta}\alpha)\gamma + v\tilde{\theta}\lambda$, $\tilde{\bar{s}}$ is given in equation (9) and $\bar{s}^*$ and $\bar{p}^*$ are the long-run levels of the nominal exchange

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[14]The TCE framework is rich enough so that questions concerning particular mixes can be explored, e.g., what are the implications of agents believing in sticky prices in a world where prices are flexible? This and some other special cases are examined in a working paper version of this study, Goldberg and Frydman [1994].

rate and relative prices that would be obtained in any one period under the stable RE case, i.e.,

$\bar{p}^* = \frac{1}{\gamma}(m - \phi y) + \frac{\lambda}{\gamma^2}\pi$ and $\bar{s}^* = \bar{p}^* + q_n$.

Equations (12) and (13) show that the reduced-form time paths for p and s are standard in form, in that they each depend on a short-run adjustment term and a steady-state solution. Since $\theta < 0$, the system is mathematically stable, in that in any given time period the level of relative goods prices and the nominal exchange rate both adjust toward their long-run levels at a rate of θ. If goods prices are flexible, so that $\delta = \infty$, then $\theta = \infty$, implying that these adjustments are instantaneous. The mathematical stability of the process reflects the fact that all of the sticky-price theories available to agents imply regressive expectations, i.e., with TCE, $\theta > 0$. But, it is important to point out that these regressive expectations are in terms of what agents believe to be the true long-run values, which in general are not correct. It is this discrepancy between the true long-run values of the system and what agents believe to be these long-run values that gives rise to the non-standard dynamics of the model.

This is borne out in equations (14) and (15). With TCE, the steady-state solutions for p and s are not only functions of the true parameters of the economy, but they are also functions of agents' estimates of these parameters. These solutions reveal that the long-run levels of s and p depend on the relative movements of what agents believe to be the long-run level of the nominal exchange rate ($\tilde{\bar{s}}$) and the long-run level that would be obtained if agents possessed RE ($\bar{s}^*$). Only when agents are assumed to know the true parameters of the economy, so that $a_1 = \gamma$, $a_2 = \phi$, $a_3 = \lambda$, $a_4 = \eta$ and $\tilde{q}_{n_0} = q_{n_0}$ (implying that $\tilde{\bar{s}} = \bar{s}^*$, $\tilde{\pi} = \pi$ and $\tilde{q}_n = q_n$), will the long-run TCE solutions collapse to the standard RE levels involving PPP, i.e., although the TCE case encompasses the stable RE case, in general, PPP will not hold in the long-run with TCE. Furthermore, the growth rates of $\bar{p}$ and $\bar{s}$ differ in general, and this implies (as long as expectations and the policy environment remain stable) that the long-run values of s and p involve unbounded and persistent movements away from PPP levels. This is because $\bar{p}$ and $\bar{s}$ are different functions of the quantity $\tilde{\bar{s}} - \bar{s}^*$ and because the growth rates of $\tilde{\bar{s}}$

and $\bar{s}^*$, which are constant, differ in general.[15] Hence, on the one hand, the model is mathematically stable, in that the system converges monotonically to its steady-state levels. But, on the other hand, the long-run levels the system converges to imply unbounded and persistent movements away from PPP, i.e., from an economic perspective, the model is unstable.

It is important to emphasize that these results do not depend on any specific assumptions concerning either the mix of theories used by agents or the underlying structure of the economy, rather these results depend on the existence of imperfect knowledge as formalized by the TCEH. Note, that as long as $\tilde{\bar{s}}$ and its growth rate differ from $\bar{s}^*$ and its growth rate, the long-run values of s and p will diverge from PPP values. But, this will be the case no matter what mix of theories agents use for forecasting. All that is required for this result is that agents do not know the true parameters of the model. This discrepancy between the levels and growth rates of $\tilde{\bar{s}}$ and $\bar{s}^*$ is also independent of whether q_n is exogenous or a function of k or whether prices are sticky or flexible. If goods prices are sticky and some exogenous disturbance occurs, then the system adjusts monotonically to its non-PPP steady-state, whereas if goods prices are flexible, then this adjustment is instantaneous. In both cases, the steady-state involves an ever increasing movement away from PPP.

The fact that the steady-state levels of s and p involve such unbounded movements, implies that the steady-state level of the real exchange is nonconstant and also diverges from its natural PPP level. This, in turn, implies (given equation (2)) a corresponding movement in the steady-state level of nominal interest rates. The solutions for $\bar{q}$ and $\bar{i}$ are as follows:

$$\bar{q} = q_n + \frac{\tilde{\theta}\alpha\gamma}{d}(\tilde{\bar{s}} - \bar{s}^*) + \frac{\tilde{\theta}\alpha\lambda}{d a_1^2 \gamma^2}(a_1 \gamma^2 \tilde{\pi} - \gamma a_1^2 \pi) , \tag{16}$$

[15] Note, $\dot{\tilde{\bar{s}}} = \frac{1}{a_1}(\dot{m} - a_2\dot{y})$ and $\dot{\bar{s}}^* = \frac{1}{\gamma}(\dot{m} - \phi\dot{y})$. We assume for simplicity that agents observe $\dot{m}$ and $\dot{y}$. Assuming otherwise would still lead to a discrepancy between $\tilde{\bar{s}}$ and $\bar{s}^*$ while needlessly complicating the model.

$$\bar{i} = i_n + \frac{v\tilde{\theta}\gamma}{d}(\tilde{\bar{s}} - \bar{s}^*) + \frac{(v+\tilde{\theta}\alpha)\gamma}{da_1{}^2\gamma^2}(a_1\gamma^2\tilde{\pi} - \gamma a_1{}^2\pi) \, . \tag{17}$$

It follows also that the steady-state levels of relative real money balances ($\bar{m}$-$\bar{p}$) and relative real interest rates ($\bar{r}=\bar{i}-\frac{1}{a_1}\tilde{\pi}$) are also a function of the quantity $\tilde{\bar{s}}$ -$\bar{s}^*$. They are, therefore, non-constant and involve divergent movements away from natural RE levels. It is useful to summarize these findings in the following general implication:

> **Implication 1** - As long as agents possess imperfect knowledge, as formalized by the TCEH, and expectations functions and the policy environment remain stable, then all of the real variables of the system diverge from their natural RE levels in the long-run. Such behavior involves unbounded and persistent movements away from PPP.

The intuition behind this general result can be seen in equations (A3) and (A5) in the appendix. The guesses of agents as to the true parameters of the economy in any one period translate into estimates of the long-run nominal exchange rate and its rate of growth. Movements in $\tilde{\bar{s}}$ cause the long-run nominal exchange rate to move, as incipient capital flows work to maintain UIP (equation (A5)). But, these movements in $\bar{s}$ necessarily involve greater departures away from PPP, since $\dot{\tilde{\bar{s}}}$ and $\dot{\bar{s}}^*$ are not equal. As these departures grow in the long-run, they must be matched by a growing discrepancy between the long-run relative nominal interest rate and its natural level according to equation (A3). This requisite movement in long-run nominal interest rates (and, therefore, in long-run real interest rates) is matched by a corresponding movement in the long-run level of relative goods prices, so as to maintain equilibrium in the money markets.

B. A One-Time Change in the Money Growth Rate

This kind of long-run behavior is of course transmitted to the short-run. In order to see the implications of this, consider a one-time fall in the (relative) money growth rate, $\dot{m}$. Figure 1 captures the dynamics of a particular time period, i.e., a period of time within which expectations functions and government policy remain fixed.[16] The solid lines plot the various long-run values of the model with respect to time, including the actual and perceived long-run values and those that would be obtained with RE. The actual long-run values serve as the center of gravity and are the levels the system will be adjusting to in the short-run. As for the nominal exchange rate, it can be shown that it necessarily overshoots what agents believe to be its long-run value on impact, $\tilde{\bar{s}}$, and the actual long-run nominal exchange rate, $\bar{s}$ (see our working paper, Goldberg and Frydman [1994]). This is shown in figure 1a, where the nominal exchange rate jumps from point A to point B on impact.

This overshooting of the nominal exchange rate, together with the one-for-one fall in i_n, leads to a state of disequilibrium in the goods markets, involving an excess supply for domestic goods and an excess demand for foreign goods.[17] It is this excess supply and excess demand that underlies the short-run adjustment of the system from the point of impact. The short-run adjustment paths are illustrated by the dotted lines in the figures. Both the nominal and real exchange rate rise from the point of impact, whereas the time paths for relative goods prices and relative interest rates may be rising or falling. With quickly adjusting goods prices both I and p will be falling initially (time path 2 in the figures 1b and 1d); whereas, with slowly adjusting goods prices, p and possibly I will be rising (time path 1 in the figures). This is an interesting result because it implies that a domestic currency depreciation over time may be associated initially with a rising or falling interest rate differential.

Figure 1 reveals the general character of a world of imperfect knowledge. Although the gaps between actual levels and long-run levels shrink as the system adjusts, the nominal and real variables of the system all

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[16]The specific assumptions behind figure 1 are outlined in the appendix.

[17]Note, $di_n = d\bar{\pi} = \frac{1}{a_1} d\dot{m}$.

eventually move in a persistent fashion away from their natural RE values. Figure 1 also reveals another general implication of the model with TCE:

> **Implication 2** - Persistent movements of the real variables of the system may be toward natural RE levels initially. However, once these levels are reached, there is no tendency to stop and shooting through these benchmark levels occurs.

The reason for this is that although the exchange rate may have returned to its PPP level, the driving variables of the system continue to move. It is the combination of these movements and the (theories consistent) weights agents use in interpreting these movements that leads them to bid the exchange rate away from PPP; and, the assumption that they are capable of predicting the right side of the market as the exchange rate diverges makes it rational for them to do so. (In the appendix, we show that there always exists a class of TCE forecasting equations that are capable of predicting the right side of the market.)

C. Shifts in Expectations Functions and the Policy Environment

The kind of divergent behavior implied by implications 1 and 2 can also be generated in models with RE, if it is assumed that agents get locked into a bandwagon or bubble movement. The difference is that with RE bubbles, the divergent behavior occurs because expectations become detached from fundamentals; whereas with TCE, expectations are always grounded on fundamentals. Furthermore, with RE bubbles, there is no explanation for why the system might find itself on one of the divergent paths. In such a world, agents inexplicably cause the system to diverge, even though they have perfect knowledge. With TCE, however, the divergent behavior occurs because of imperfect knowledge. Agents are unsure as to the precise fundamentals to use in forecasting and as to the quantitative weights that should be attached to these fundamentals and this causes the system to move away from PPP levels.

The question arises as to whether economic agents and policy officials remain passive as the system diverges. In a world of imperfect knowledge, if expectations functions and the policy environment remain stable, then the divergent movements of the real variables of the system are unbounded. Thus, the only way to obtain reasonable long-run conclusions (i.e., to obtain finite real values in the long-run) is to assume that expectations functions and the policy environment shift periodically. This reasoning leads to a third general implication of the TCE framework:

> **Implication 3** - The fact that the real variables of the model with TCE all diverge if expectations functions and the policy environment remain stable, implies that expectations functions and the policy environment eventually shift. Such shifts may involve changes in the set of fundamentals agents use in forecasting.

One way to view these shifts is to assume that there exits some threshold beyond which if the exchange rate continues to diverge, then either policy officials and/or economic agents respond by changing the policy environment and expectations functions respectively. In Goldberg and Frydman [1994], we adopt an approach that is standard in the RE literature and treat this threshold as exogenous.[18] We find that the divergent nature of the system with TCE provides some justification for the existence of such a threshold. The rationale for policy officials rests on two intuitively appealing assumptions. First, large departures from PPP are assumed to lead to large trade imbalances and calls for protection; and second, we assume officials want to avoid both of these occurrences. As for economic agents, they are unconcerned with deviations from PPP, in that as the exchange rate diverges they are able to predict the right side of the market. However, if policy officials react by changing the way the driving variables move, then agents might subsequently find that their TCE forecasting equations begin to predict the wrong side of the market. Our assumption of QR implies that if this occurs, then agents will switch their forecasting equations to rules that are capable of predicting the right side of the market. In addition to this possibility of reacting to policy changes, agents may also anticipate policy

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[18]The model of Blanchard and Watson [1984], for example, posits some exogenous probability of a change in expectations functions and a bursting of the bubble without explaining what factors might bring such a change about. The implicit assumption here is that the periodic structural shifts in expectations functions and the policy regime are ultimately unforecastable. In Goldberg and Frydman [1994] we subscribe to this view and assume that there exits some exogenous and potentially time-varying threshold based on gaps from PPP, beyond which expectations functions and/or the policy environment shift. We examine the conditions under which such shifts lead to a subsequent countermovement in the nominal exchange rate.

moves by switching expectations functions prior to any changes in policy. The rationale here is that agents are aware of the motivations of policy officials and so attempt to avoid being caught on the wrong side of the market when changes in policy do occur.[19]

It should be pointed out that shifts in expectations functions with TCE due to unanticipated and anticipated changes in policy is completely analogous to the change that occurs in the stable RE case ala the Lucas critique.[20] There are, however, two major differences. First, with TCE, agents do not know which specific set of fundamentals is correct, implying that a shift in expectations functions may be accompanied by a change in the set of fundamentals used for forecasting. Second, the only way to obtain reasonable long-run conclusions is to assume that expectations functions and the policy environment shift periodically.

4.0 Examining the Empirical Record and Testing the TCEH

In this section we examine whether the three general implications of the monetary models with TCE are consistent with the empirical record. We also present empirical evidence lending support for one of the basic assumptions of the TCEH, that exchange rate expectations are related to fundamentals. In testing the TCEH, we make use of survey data on exchange rate expectations collected by Money Market Services International (MMSI). These and other similar data have been examined in previous studies (e.g., Frankel and Froot [1987] and Ito [1990]), mainly in an attempt to discern the univariate properties of exchange rate expectations. In this study we use these data to examine whether there exists a multivariate relationship between expectations and the fundamentals of the monetary models.

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[19]In a companion paper (Goldberg and Frydman [1996a]) we explicitly incorporate into individual expectations functions this idea that agents are concerned about large deviations of the exchange rate from PPP. This allows us to develop a macroeconomic framework in which the distinction between the short-run and long-run and the peso problem are both important factors for exchange rate expectations. In this model, PPP serves as a long-run anchor for the system. However, this anchor has a negligible influence on the short-run movements of the exchange rate when the system is close to PPP. Only when the gaps from PPP become "large" does this PPP anchor play a significant role. For early discussions of this role of PPP for exchange rate dynamics see Schulmeister [1983,1988] and Soros [1987,1995]. See also the study by Leijonhufvud [1981], which argues the importance of the distinction between being far away as opposed to being close to equilibrium for understanding macroeconomic phenomena.

[20]See Goldberg and Frydman [1994] for such an exercise.

Figure 2 plots the actual monthly DM/$ exchange rate and the monthly PPP exchange rate over the period from March 1973 to June 1994. This figure shows that exchange rate movements mimic well the basic character of the monetary models with TCE, as given by the first two general implications of the preceding section. First, the figure reveals that the exchange rate has a strong proclivity to trend over long periods of time, where these trends often involve long and persistent movements away from PPP; and, second, if the trend is initially towards PPP, then there does not appear to be any tendency for the exchange rate to stay at this benchmark level once it is reached. Instead, the exchange rate often shoots through this benchmark level and continues to trend in the same direction, away from PPP. Such behavior has been characterized as "long swings" in the literature and is well documented (e.g., see Frankel [1985], Dornbusch and Frankel [1989], Engel and Hamilton [1990] and Obstfeld [1995], among many others).

Several hypotheses have been advanced in order to explain such long swings in the exchange rate and, popular among these are speculative bubbles (e.g., Meese [1986] and Evans [1986]) and the presence of noise traders (e.g., Frankel and Froot [1987a]). Both of these hypotheses explain long swings in the exchange rate as the result of movements away from fundamentals. In contrast, with TCE, expectations are always grounded in fundamentals. The long swings occur because in trying to interpret movements in fundamentals, agents do not get it quite right, i.e., they occur because agents possess imperfect knowledge. Perhaps the most fundamental question in the exchange rate literature is about which view is correct.

The exchange rate literature seems to have settled on the former view, that much of the behavior in the foreign exchange market is unrelated to fundamentals. This is mainly because most of the empirical studies on exchange rates find little connection between fundamentals and exchange rate movements.[21] However, the monetary models with TCE suggest a possible explanation for this failure, because they imply that the reduced forms of the monetary models are unstable due to periodic structural shifts in expectations functions and the

[21]The study most often cited as illustrating this failure is Meese and Rogoff [1983]. Other studies include Backus [1982], Frankel [1983,1984], Meese and Rogoff [1988] and Meese and Rose [1991].

policy environment.

In Goldberg and Frydman [1996b] we find not only that the monetary models experience parameter instability on more occasions than previously documented, but that once this instability is taken into account, a clear relationship between fundamentals and the exchange rate emerges. We find that the exchange rate and the fundamentals of the monetary models are cointegrated, but only within the implied subperiods of relative parameter constancy. When we attempted to fit one exchange rate model to the entire period of floating rates the absence of cointegration and a long-run structural relationship found in other studies reappeared. We also found within the implied subperiods of stability that parameter estimates were mostly significant, with theories consistent signs, and that all of the structural models examined outperformed the random walk model in out-of-sample forecasting by considerable margins.[22] Again, if we attempted to fit one structural model over the entire period of floating rates the dismal in-sample and out-of-sample performance found in other studies reappeared. Hence, previous studies failed to find a connection between fundamentals and exchange rate movements because they did not take into account the kind of structural change implied by the TCEH.

In this paper, the use of the MMSI survey data allows us to test directly the view that exchange rate expectations are grounded in fundamentals and that exchange rate expectations functions experience periodic structural instability.[23] The fact that previous studies examining the survey data mainly employ univariate analyses is perhaps reflective of the widespread belief that fundamentals play no role for exchange rate movements. Our empirical analysis, to be discussed next, indicates that this view is inconsistent with the data.

Figure 3 reports the results of recursive structural change tests carried out on equation (8), using the

[22]For example, at the 6, 9 and 12 month forecasting horizons the structural models outperformed the random walk model by margins of 70 percent in root mean square error and predicted the right side of the market 100 percent of the time during the 1970s. These results indicate 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.

[23]In Goldberg and Frydman [1996b] we presented indirect evidence that the observed instability in reduced forms was due to shifts in expectations functions and the policy environment. First, we found that different sets of fundamentals mattered for exchange rate movements during different time periods and second, we found that many of the break points matched up well with time periods involving major changes in policy.

MMSI one-month forecasts of the DM/$ exchange.[24] The sample period for the analysis runs from January 1985 (the beginning of the MMSI survey) to March 1994. The figure plots the actual and PPP exchange rate, where the solid vertical lines indicate points of structural breaks. The figure reveals that expectations functions for the rate of change of the exchange rate experienced structural breaks on four occasions over the sample period, thereby providing direct evidence for the third general implication of the monetary models with TCE. These results also lend support to the view that the structural instability reported in our earlier study is partly due to instability in expectations functions.

In order to test the TCEH view that exchange rate expectations are related to fundamentals, it is necessary to check first whether the variables of equation (8) possess unit roots. Using conventional Dickey and Fuller ADF and Phillips and Perron Z tests, we find that the unit root (I(1)) hypothesis cannot be rejected for all of the fundamental variables, the *expected level* of the exchange rate and the level of the exchange rate (these results are not reported). These results are consistent with most other studies. However, the unit root hypothesis can be rejected for the expected change in the exchange rate ($E(\Delta s)$), i.e., the expected level of the exchange rate ($E(s)$) and s are cointegrated (see table 1). The question that we are interested in is whether $E(\Delta s)$ is related to fundamentals. Although $E(\Delta s)$ is I(0) and the right-hand-side variables of equation (8) are all I(1), estimating (8) using OLS can still shed light on this question. This is because OLS still allows us to test for cointegration and goodness of fit.[25]

Table 1 reports on the cointegration tests. The table reveals that when equation (8) is estimated for the

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[24]See the appendix for a description of the data. The structural change procedures used are the cusum test and Quandt ratio technique. See Brown, Durbin and Evans [1975] for a treatment of both procedures. The methodology used is the same as in Goldberg and Frydman [1996b]. Equation (8) was estimated without imposing the symmetry restrictions. Note, that when we used the expected level of the exchange rate as the endogenous variable instead of the expected change of the exchange rate, we found the same break points.

[25]The reason being that if the OLS residuals of this regression are I(0), then the fundamentals and the level of the exchange rate must themselves be cointegrated. Furthermore, if this is the case, then the fitted values of this regression ($\hat{y}$) are I(0), implying that $E(\Delta s)$ can be regressed on $\hat{y}$ and standard inference applies. If the parameter estimate on $\hat{y}$ is non-zero, then fundamentals matter for exchange rate expectations. This follows because the parameter estimates on the fundamental variables in $\hat{y}$ cannot all be zero if $\hat{y}$ is I(0).

two sufficiently long exchange rate regimes in figure 2 (i.e., the time periods from January 1985 to September 1987 and from May 1991 to June 1994), the unit root hypothesis can be rejected for the OLS residuals at the 1 percent level, i.e., the set of fundamentals and the exchange rate are cointegrated within the implied subperiods of parameter constancy. It is interesting to note that despite the small number of observations (which has been used as an explanation for not finding cointegration in many studies, but which does not affect the validity of our conclusions), we can reject the unit root hypothesis at very high significance levels. This implies, in turn, that the fitted values from these regressions ($\hat{y}_1$ and $\hat{y}_2$) are both I(0).

In table 2 we report on regressing $E(\Delta s)$ on these fitted values. The table reveals that the fitted values $\hat{y}_1$ and $\hat{y}_2$ are highly significant, implying that the fundamentals of the monetary models are important for explaining exchange rate expectations. The R^2 statistics reveal that the set of fundamentals and the exchange rate can account for more than 70 percent of the variance in $E(\Delta s)$ in exchange rate regime 1 and almost 70 percent in exchange rate regime 2.

5.0 Concluding Remarks

The results of this paper can be summarized briefly as follows. Our empirical results provide strong support for the TCEH view that exchange rate expectations are grounded in fundamentals and experience periodic structural shifts. The unforecastability of these shifts, in turn, implies that it is difficult to have or acquire perfect knowledge. Furthermore, our theoretical analysis shows that the absence of perfect knowledge gives rise to long swings in the exchange rate, a feature of floating rates that has been well documented. Therefore, in contrast to other approaches in the literature, our theoretical and empirical analyses suggest that the key to explaining exchange rate movements may lie in recognizing that the exchange rate *does* depend on fundamentals, but that the relationship between the exchange rate and fundamentals *cannot be perfectly known*.

Appendix

In order to derive the reduced-from time path for the nominal exchange rate, it is useful to begin with the equation for $\dot{p}$, which can be simplified in the following way:

$$\dot{p} = \frac{-\delta[\tilde{\theta}(\alpha\gamma + \nu\lambda) + \nu\gamma]}{\lambda\tilde{\theta}}(p - \bar{p}) + \dot{\bar{p}}. \tag{A1}$$

In deriving equation (12) we used the following long-run relationships:

$$\bar{p} = \frac{1}{\gamma}(m - \phi y) + \frac{\lambda}{\gamma}\bar{i}, \tag{A2}$$

$$\bar{s} = \bar{p} + q_n + \frac{\alpha}{\nu}(\bar{i} - i_n), \tag{A3}$$

$$s = \bar{s} - \frac{\gamma}{\lambda\tilde{\theta}}(p - \bar{p}). \tag{A4}$$

These long-run relationships are defined for a given TCE aggregate forecasting equation and policy environment. Equations (A2) and (A3) follow directly from equations (1) and (2). Equation (A4), which follows from equations (1), (3) and (8), relates the discrepancy between the equilibrium exchange rate and its long-run value to the discrepancy between the current and long-run levels of relative goods prices. This relationship is reflective of the fact that with the aggregate forecasting equation specified, the dynamics of the system are a direct product of the movement in relative goods prices. This being the case, we can solve for the reduced-form time paths of p and s by solving the single first-order differential equation in (A1). This gives rise to equations (12) and (13) in the text.

In order to solve for the long-run levels of p and I in any one time period (and, therefore, for s and q), we make use of the following long-run relationship:

$$\bar{i} = \tilde{\theta}(\tilde{\bar{s}} - \bar{s}) + \frac{1}{a_1}\tilde{\pi} . \qquad \textbf{(A5)}$$

which follows directly from UIP and equation (8). Equation (A5), together with equations (A2) and (A3) give rise to the long-run solutions for I and p in equations (14) and (15) respectively. These long-run solutions, in turn, imply the long-run solutions for s and q in equations (16) and (17) respectively (given equation (A3) and the fact that $\bar{q} = \bar{s} - \bar{p}$).

In order to construct the time plots in figure 1 it is necessary to make assumptions about the true parameters of the economy, the beliefs of agents and the relationship between these true parameters and beliefs of agents. The specific assumptions behind figure 1 are: 1) prices are sticky (i.e., $\delta < \infty$); 2) some agents believe in sticky prices (i.e., $\sigma < 1$); 3) the growth rates in relative income and money, $\dot{y}$ and $\dot{m}$, are both positive; 4) the money demand parameters are such that $a_1 > \gamma$ and $a_3 < \lambda$; and 5) both a_2 and ϕ are small enough so that π and $\tilde{\pi}$ are both positive and a_2 is small relative to ϕ so that $\frac{1}{\gamma}\pi < \frac{1}{a_1}\tilde{\pi}$. It is important to emphasize that the general implications of the model with TCE in no way depend on these specific assumptions.[26] Instead, they allow us to determine the relative magnitudes and algebraic signs of π and $\tilde{\pi}$, the signs of the growth rates of the long-run values of the system and the relationship between the impact effects on the endogenous variables of the model. Note, figures 1a through 1d assume that the fall in $\dot{m}$ is small enough so that π and $\tilde{\pi}$ both remain positive and $\pi < \tilde{\pi}$. This gives rise to the upward sloping curves in the graphs.

In order to see that there always exists a class of TCE forecasting equations that are capable of predicting the right side of the market, consider first the time path for the nominal exchange rate in figure 1.

[26] In Goldberg and Frydman [1994] we work through a number of cases with varying assumptions about the true parameters of the economy and the beliefs of agents.

From the point of impact at B, the rate of change of s is positive, as it converges monotonically to its long-run value. Thus, in order for agents to be on the right side of the market, $E(\dot{s})$ must be positive along the time path from point B. Given the TCE forecasting equation in (8), there are potentially three terms that contribute to the sign of $E(\dot{s})$. The first term, which depends on the sign of $\tilde{\bar{s}}$-s, is positive in the figure. As for the other two terms, they are also positive given the assumption that $\tilde{\pi} > 0$. Thus, in figure 1, agents are able to predict the right side of the market as the exchange persistently moves towards PPP levels initially as well as during the phase involving persistent movements away from PPP. If, instead, $\tilde{\pi} < 0$, then the magnitude of $\tilde{\bar{s}}$-s would have to be large enough to outweigh the effects of the other two terms. It should be clear from this example that it is always possible to find a set of theories consistent weights such that the resulting $\tilde{\bar{s}}$ delivers the correct sign on $E(\dot{s})$. Our assumption of qualitative rationality assumes that agents know enough to obtain such sets of theories consistent weights.

Data Description

All data are monthly. The data set begins in January 1985 and ends in June 1994. The trade balance data are from the O.E.C.D. (M.E.I.) data bank. All other time series for the fundamentals are from the IFS data bank. The survey data are from Money Market Services International (MMSI). The data supplied by MMSI are the median of repondents forecasts of the four-week ahead DM/$ exchange rate. Forecasts are collected each week on Friday. Monthly data for these forecasts was constructed by taking the forecast that was closest to the end of each month.

s	end of month, DM/$
E(s)	four week forecast, DM/$
I	end of month 3-month treasury bill rate
I^*	end of month 3-month interbank deposit rate
π and π^*	proxied by using a moving average of current inflation (based on the CPI) and inflation over the preceding 11 months.
y and y^*	an index of industrial production, seasonally adjusted
m and m^*	M_1; end of month, in billions of local currency
k and k^*	in billions of local currency, cumulative sum started in Jan. 1980

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Figure 1: A One–Time Fall in $\dot{m}$

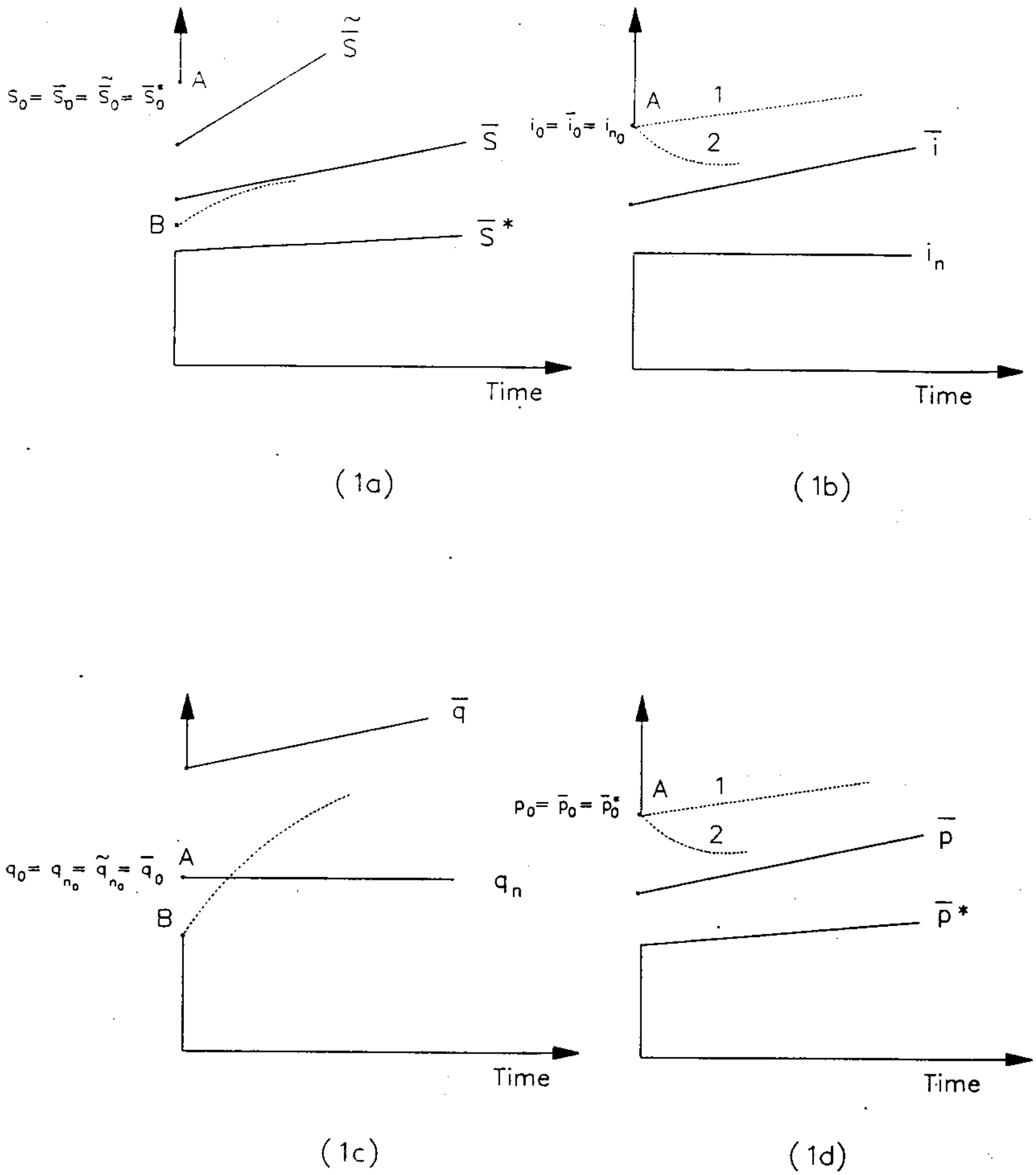

Figure 2

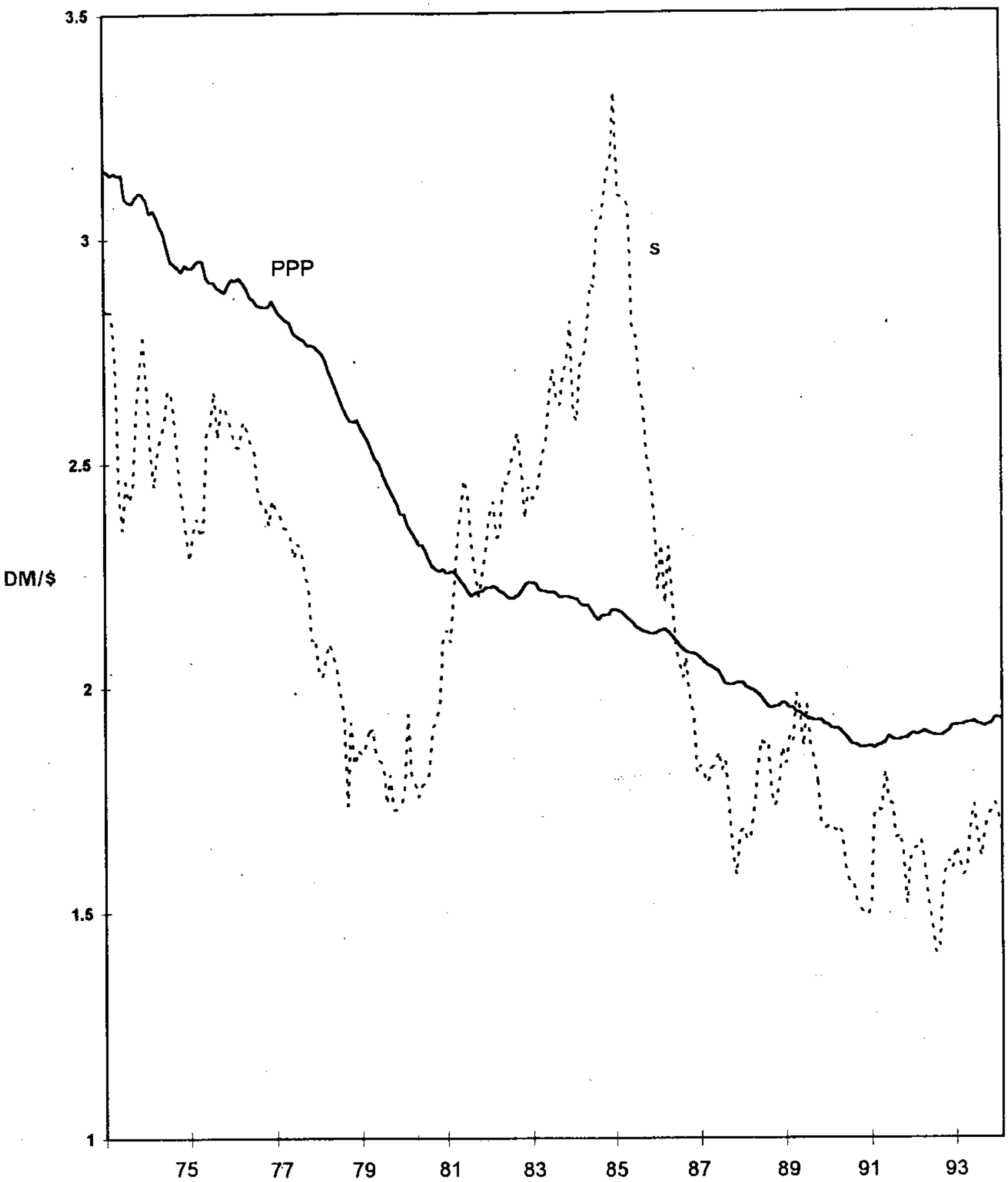

Figure 3

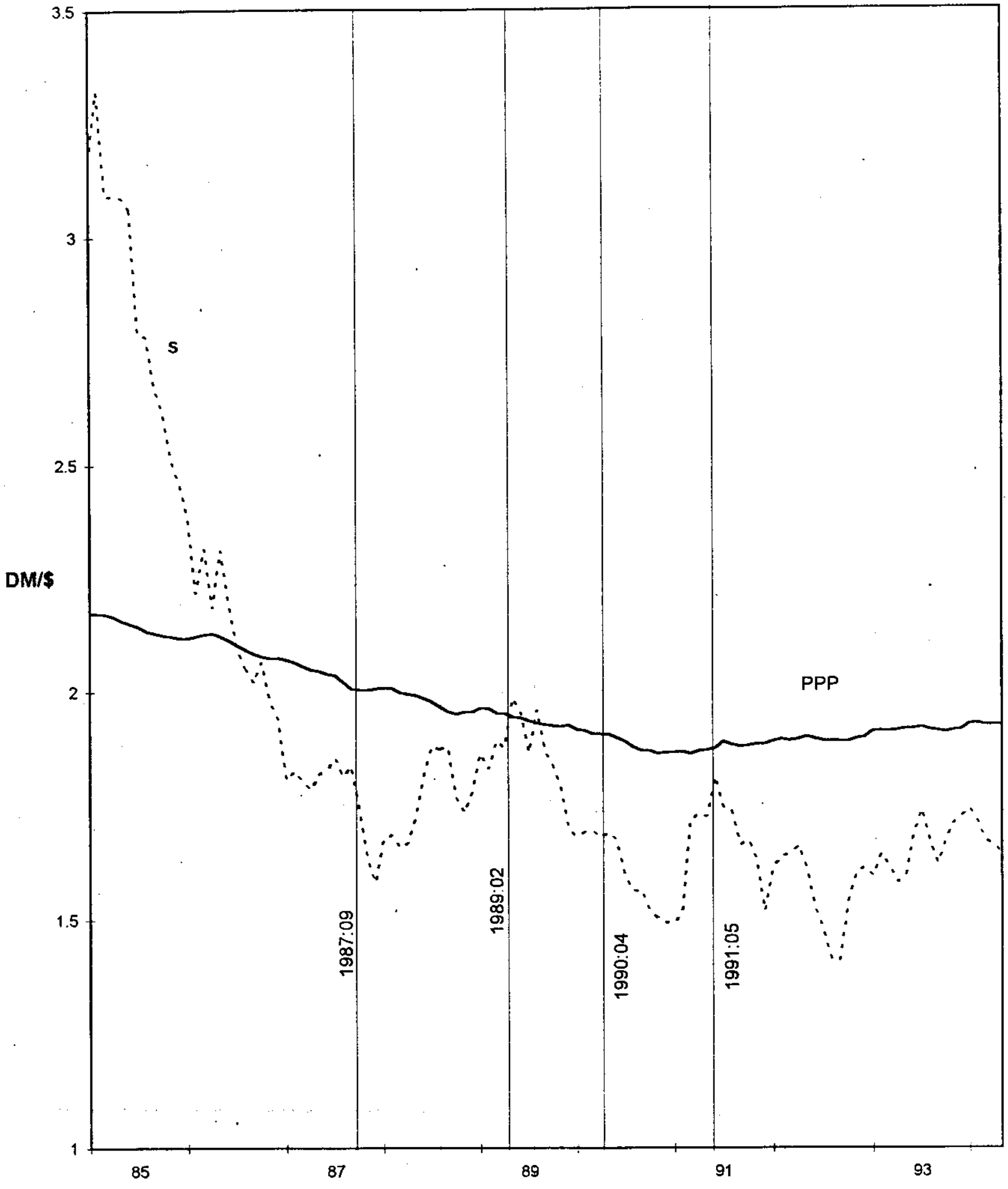

TABLE 1

Residual-Based Tests of Cointegration ADF and Z Tests[a]

	Without Intercept		With Intercept	
	t_α	$Z(t_\alpha)$	t_α	$Z(t_\alpha)$
E(ΔS)	3.08**	6.80*	3.30*	6.92*
Model 1	3.38	8.98***	3.29	8.82***
Model 2	4.67*	8.34***	4.60*	8.16***

[a]The test statistics t_α and $Z(t_\alpha)$ are the augmented Dickey and Fuller (ADF) and Phillips and Perron (Z) t-statistics. The autocorrelation Lag used for the ADF tests was 3. Critical values are obtained from Charemza and Deadman [1992]. Models 1 and 2 are equation (8) without imposing the symmetry restrictions for exchange rate regimes 1 (1985M1:1987M9) and 2 (1991M5:1994M6) respectively. Critical values are obtained from Charemza and Deadman [1992] (CD). In order to obtain critical values for models 1 and 2, which involve estimating 11 parameters (N=11), we extrapolate the case of N=8 in CD. The symbols *, ** and *** denote statistical significance at the 10, 5 and 1 percent levels.

TABLE 2

Testing for Significance of Fundamentals for Exchange Rate Expectations[a]

	$\hat{\alpha}$	$t_{\hat{\alpha}}$	R^2	DW
$\hat{y}_1$	1.00	10.25***	.778	2.86
$\hat{y}_2$	1.00	9.05***	.689	2.25

[a]Statistics are for OLS regressions of E(ΔS) on $\hat{y}_1$ and $\hat{y}_2$ for exchange rate regimes 1 (1985M1:1987M9) and 2 (1991M5:1994M6) respectively. $\hat{y}_1$ and $\hat{y}_2$ are the fitted values from the OLS estimation of equation (8) for the two exchange rate regimes. $t_{\hat{\alpha}}$ is the t-statistic on the parameter estimates for $\hat{y}_1$ and $\hat{y}_2$ and the symbol *** denotes statistical significance at the 1 percent level.