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EXCHANGE RATE DETERMINATION UNDER RATIONAL EXPECTATIONS: AN EMPIRICAL INVESTIGATION

The Ohio State University

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EXCHANGE RATE DETERMINATION UNDER RATIONAL
EXPECTATIONS: AN EMPIRICAL INVESTIGATION

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

by

Young Yong Kim B.S., M.A.,

* * * * *

The Ohio State University

1985

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Many people have helped in the conception and the completion of this study. Dr. Driskill was instrumental in the selection of this topic. Dr. Anderson provided the stimulation and guidance throughout the implementation stage. I cannot thank him enough for making himself always available, and for his constant encouragements, suggestions and advice in all phases of this study. Dr. McCafferty reviewed thoroughly every draft. His diligent participation has been an invaluable asset throughout. I have mostly benefited from Dr. Driskill for the ideas and comments, and I am grateful.

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My parents' love, prayers, unconditional support and faith have been a source of strength, a driving force that always inspired me to endure and keep moving forward. My wife Byung Hee's love, understanding and patience have been tested beyond imagination. Her commitment,
sacrifices, and generosity have made this entreprise possible. To my son Dong Keun who spent most of his life without his father's care and love, I have to say many thanks for never complaining; I can only hope that there will be a way to make the whole experience worthwhile to him. I hope this would be a present surprise to my new daughter for not to see her father going through the Ph.D again like her brother did.
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Studies in Economic Development

Studies in Econometrics

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CHAPTER I
INTRODUCTION

There has been much theoretical analysis on exchange rate determination since the overall adoption of a floating exchange rate regime among industrialized countries. The key issue is how to explain the observed variability in exchange rates.

Two strands of the literature are important in predicting exchange rate movements. One is the sticky price version of monetary model (Dornbusch 1976) based on the joint assumptions of rational expectations and perfect capital mobility and substitutability. The crucial implication of the Dornbusch model is that the exchange rate initially overshoots in response to an unanticipated monetary disturbance, and converges monotonically to its long-run equilibrium value. An alternative approach, the so-called stock/flow model, is developed by generalizing the Dornbusch model, permitting imperfect capital mobility and substitutability. Emphasizing stock/flow interactions and relative-price trade-balance effects, the stock/flow model allows short-run undershooting. It also predicts cyclical adjustments of exchange rates towards full stock and flow long-run equilibrium. While the two models' predictions about the long-run relationships between exchange rates, the price level and money supply are the same, they differ in their short-run and intermediate-run
Along with this stream of theoretical developments, there are some empirical studies on exchange rate determination. Driskill (1981a) and Frankel (1979) are of importance. Driskill (1981a) compared the Dornbusch model with the stock/flow model. Using the reduced form exchange rate equation, he reports empirical results which support the stock/flow model and price stickiness in which short-run overshooting is confirmed. But, rational expectations were not tested. Frankel (1979) tested various hypotheses based on his real interest rate differential model and provided evidence supporting his model and price stickiness. However, Driskill and Sheffrin (1981) criticized Frankel's estimates as being inconsistent. Moreover, they formally tested the rational expectations assumption by exploiting the overidentifying restrictions. Driskill and Sheffrin rejected the assumption of rational expectations in the Frankel model.

Previous work of Driskill and Sheffrin (1981) successfully incorporated rational expectations in testing the Frankel model. However, no comprehensive test under rational expectations has emerged for the aforementioned monetary and stock/flow model.

This study explicitly incorporates rational expectations in solving the two models, and attempts to differentiate between them. First, using the rational expectations solution method, we derive the exchange rate equation and construct the system of equations used to test for rational expectations in each model. The coefficients of the exchange rate equation are expressed in terms of underlying structural
parameters. By doing so, we obtain restrictions on those coefficients as well as within- and cross-equation overidentifying restrictions specific to each model. Second, we subject our two models to empirical tests. Hypothesized sign and estimated magnitude of some coefficients in the exchange rate equation are expected to differentiate between the two models. We also test the validity of the rational expectations assumption in each model by the likelihood ratio test or Wald test.

Furthermore, the empirical results will allow us to investigate the following issues:

1. Whether there is short-run overshooting.
2. Whether long-run purchasing power parity holds.

The outline of this study is as follows. Chapter II contains the literature review. In Chapter III, rational expectations solutions of the two models are obtained and testable hypotheses are considered. Chapter IV reports the empirical results. Our empirical results support the stock/flow model. The rational expectations assumption is rejected in the monetary model while it seems acceptable in the stock/flow model. Finally, Chapter V states the main conclusions of this study.
Until recently, the Keynesian approach to the economic theory of exchange rates was dominant. Within the partial framework of the foreign trade sector, the exchange rate is viewed as equilibrating the flow demands and supplies for foreign exchange. Keynesian models typically assume low capital mobility with their emphasis on the role of trade flows in determining the exchange rate. Also, such models usually ignore the role of exchange rate expectations.

In the late 1960s, the classical analysis of exchange rate was revived by the monetary approach which was further refined as the asset market models in the 1970s. In contrast to the Keynesian elasticity approach, the asset market approach views the exchange rate as the relative price of two financial assets. Various versions of asset market models assume high capital mobility and substitutability between domestic and foreign assets and emphasize the role of expectations. The exchange rate is assumed to equilibrate markets for stocks of financial assets.

Since the generalized floating among major currencies in March 1973, several versions of asset market models have been developed to account for the observed behavior of exchange rates. The monetary
model, which is a special case of a more general asset market model, assumes perfect capital mobility and substitutability while the latter allows for imperfect capital mobility and substitutability. That is, the monetary models assign exchange rates no role in balancing the flow demands and supplies for foreign exchange, while the more general asset market models consider the stock/flow interactions in exchange rate movements. However, both models emphasize the role of exchange rate expectations. Among the plausible expectational schemes, special attention is placed on rational expectations. If the foreign exchange market is efficient, unanticipated random disturbance in variables may account for large fluctuations in exchange rates.

Two versions of the monetary model have been developed to explain recent variations in exchange rates; the flexible and sticky price versions. Frenkel (1976) and Bilson (1978, 1979), among others, developed a flexible price version of the monetary model. Frenkel (1976) tested his theory against the German hyperinflation of the 1920s. He found that the foreign exchange market is efficient enough to accept rational expectations, and that instantaneous purchasing power parity holds. Bilson (1978) confirmed the validity of the flexible version of the monetary model. He tested the model against the mark/pound rate for the period of April 1970 to May 1977. Rational expectations were strongly accepted. The implication of the flexible price version of the monetary model is that the high variability in exchange rates is due to the large swings in the exogenous money supply. Also, it is argued that the magnification effect arises from the role of expectations. The behavior
of exogenous variables, especially the money supply, influences the expected and hence actual exchange rates. Within the same framework of flexible prices, Calvo and Rodriguez (1977) demonstrated that the instability of the exchange rate is due to a high elasticity of substitution between currencies. If the two currencies are highly substitutable, a small change in the rate of money growth will result in a substantial change in the exchange rate.

Dornbusch (1976) developed a sticky price version of the monetary model which is more persuasive for the explanation of large fluctuations in exchange rates. It is assumed that foreign exchange and asset markets adjust quickly relative to goods market. The dynamic aspects of exchange rates arise from this assumption. In response to an unanticipated monetary shock, the domestic interest rate falls. This generates an incipient capital outflow which causes the currency to depreciate sufficiently so that the rationally expected rate of future appreciation of the spot rate precisely offsets the interest rate differential. Therefore, the impact effect of a monetary disturbance is an immediate depreciation in the spot rate and the depreciation exceeds the long-run equilibrium value. At the point of initial overshooting, there will be an excess demand for goods arising from the fall in domestic interest rates and from the depreciation in exchange rates which lowers the price of domestic goods. A rise in aggregate demand for domestic goods will cause the domestic price level to rise, which in turn causes the domestic interest rate to rise. The rising interest rate brings about an incipient capital inflow which appreciates the
exchange rate. The important aspect of this adjustment process is that rising prices are accompanied by an appreciating exchange rate. That is, the exchange rate and price level approach monotonically their long-run values.

Niehans (1977), Henderson (1979), Driskill (1980, 1981b) and Bhandari, Driskill and Frenkel (1984), among others, emphasized the stock/flow interactions and relative-price trade-balance effects. The Dornbusch model ignored these aspects through the assumption of perfect capital mobility and substitutability. The former models predict more complex, cyclical adjustment paths of exchange rates than that possible in the Dornbusch model.

Niehans (1977) departed from the asset market equilibrium approach by assuming that individuals' adjustment of actual assets to desired assets is not instantaneous. In his world, the interaction between trade and capital flows can create various adjustment paths of exchange rates and the price level. Short-run undershooting may occur, and the adjustments of the exchange rate and price level can be cyclical. Niehans argues that the various patterns of exchange rate movements, which are possible in his model, are highly suggestive of the actually observed large fluctuations in exchange rates during the past few years.

Driskill (1980) incorporated wealth into the money demand function. If the demand for money is a function of wealth, any depreciation in the exchange rate increases money demand via the effect of an increase in the value of foreign assets held by domestic
residents. This wealth effect dampens the fall in the interest rate following a monetary expansion. In his model, relative-price trade-balance effects combined with a wealth effect may produce a short-run undershooting and cyclical adjustment of the exchange rate. The adjustment of the price level may or may not be cyclical depending upon the trade balance sensitivity to relative price changes.

Driskill (1981b) extended the Dornbusch model by permitting imperfect capital mobility and substitutability. He also explicitly incorporated rationality in exchange rate expectations. Driskill confirmed the possibility of the short-run undershooting and more complex nonmonotonic adjustment paths of exchange rates and the price level. It is argued that the more complex adjustment paths make it possible for the exchange rate at some times to be rationally expected to be heading away from, rather than towards, its long-run equilibrium value. But the relative price term from the domestic output demand function is suppressed in order to focus on the issue of exchange rate overshooting.

Bhandari, Driskill and Frenkel (1984) investigated the relation between exchange rate overshooting and the degree of capital mobility within a framework of stock specification of the capital account. They derive the overshooting criterion in terms of the underlying structural parameters and demonstrate that exchange rate overshooting does not necessarily occur. The likelihood of exchange rate overshooting is positively related to the degree of capital mobility and is inversely related to the responsiveness of the trade balance to relative prices.
and to the interest rate semielasticity of the demand for money. These authors also compare the overshooting criterion under a stock formulation with the corresponding criterion derived from the flow specification. There exists no qualitative difference between the two criteria, however the stock formulation modifies the quantitative implications of the model. The exchange overshooting predicted by the flow specification may become undershooting under stock specification for a certain range of the degree of capital mobility. But this does not necessarily mean that the flow formulation always predicts a larger change in the exchange rate than the stock formulation.

Along with this stream of theoretical development, empirical work has been achieved. In particular, testing the rational expectations assumption within the context of exchange rate determination has been increasingly made possible due to a recent development in econometric techniques. We first survey the econometric papers concerning the estimation and test of the rational expectations models, and then turn to a survey of empirical work in exchange rate determination.

Wallis (1980) developed a method for estimation of economic models embodying rational expectations. Based on a general econometric model, he considers identification of structural parameters and the estimation method. Wallis demonstrates that structural parameters are identified when there are no more expectations variables than exogenous variables in the model. Specifically, the parameters are just-identified, overidentified or underidentified, respectively, when the number of expectations variables is equal to, less than or greater than the
number of exogenous variables. However, there may exist testable restrictions even in the case of underidentification. Two methods of estimation are suggested: system and limited information estimation. The system estimation is a standard multivariate least squares technique which includes full information maximum likelihood and seemingly unrelated regression methods. This method will result in consistent and asymptotically efficient estimates. Also, the restrictions implied by rational expectations can be tested. In contrast, the limited information method does not provide a test of rational expectations although it results in consistent estimates. Wallis also shows that purely extrapolative forecasts of endogenous variables are less efficient than those of rational expectations. Concerning Lucas' critique on econometric policy evaluation, he argues that if the structure of the process generating exogenous variables is kept from the economic structure, the traditional view of econometric policy evaluation is reasserted.

Hoffman and Schmidt (1981) also discussed test methods of the models incorporating rational expectations variables. They suggest two alternative ways to test rational expectations restrictions. One is a likelihood ratio test and the other is a Wald-type test. The likelihood ratio test consists of comparing restricted and unrestricted maximum likelihoods. The test statistic will be asymptotically distributed as chi-square under the null hypothesis that rational expectations and model specification are correct. The Wald test measures by how much the unconstrained estimates fail to satisfy the restrictions. The test
statistic is also distributed asymptotically as chi-square. Monte Carlo experiments demonstrate that there is no relative power advantage of one test over the other for samples of size 50-100. In addition to these test method, Hoffman and Schmidt show how to calculate the number of restrictions under various situations. Typically, the restrictions are generated when each unobservable expectation is replaced with lagged exogenous variables when the rational expectations solution is obtained. When we convert unobservable expected values into observable variables, a number of new variables enter the reduced form equation without adding any additional parameters.

Hoffman and Schlagenhauf (1983a) postulated that tests for rationality should become a part of the model-building process. The validity of the restrictions implied by rational expectations in a particular model is closely related to the accuracy of the model's specification. So, a rejection of restrictions by a data set may come from incorrect model specification rather than an incorrect expectational scheme. Hoffman and Schlagenhauf suggest a procedure which may be tried when the restrictions are rejected. The generating processes of exogenous variables should be investigated first since these processes are often arbitrarily specified. For example, the univariate autoregressive processes may be reexamined based on relevant statistical criteria, or longer lag lengths may be tried. Second, the structural stability of autoregressive processes may be examined as well as that of the model if rejections still occur. If the structural stability breaks down, the test of restrictions is largely meaningless.
Finally if the restrictions are persistently rejected even after the above corrections are made, we would be led to a reexamination of the model's specification based on the underlying economic theory. Hoffman and Schlaginhauf applied this procedure to two macroeconomic models. Their results show that the restrictions are consistently rejected in Taylor's model. The rejection of the restrictions cannot be attributed to the use of an inappropriate formulation of the processes generating the model's exogenous variables. So this result implies that either the rational expectations assumption in Taylor's model is inconsistent with the data or the model is misspecified. In Sargent (1976), once the lag structures of the autoregressive processes for population and money supply are modified, the implied rational expectations restrictions pass the test.

Now we turn to a survey of empirical work done so far in the exchange rate determination. Frankel (1979) tested the Frenkel-Bilson and the Dornbusch model based on the real interest rate differential model. The flexible price version of the monetary model predicts a positive relationship between the interest rate differential and the exchange rate while the alternative sticky price version of the monetary model predicts a negative relationship between the two. He reports evidence for the US dollar/mark rate which supports the sticky price assumption and his real interest rate differential model. Also overshooting is present. Driskill and Sheffrin (1981) however, rejected Frankel's results arguing that Frankel's estimates are inconsistent. The rationally expected exchange rate change, which is used as an
explanatory variable, is correlated with the error term in the exchange rate equation. Furthermore, they formally tested rational expectations by imposing the within- and cross-equation overidentifying restrictions emerging from the rational expectations solution of the model. Once these overidentifying restrictions are tested, rational expectations are rejected in the Frankel's model.

Driskill (1981a) compared the Dornbusch model with the stock/flow model based on the reduced form exchange rate equation, using the Swiss franc/US dollar rate for the period 1973-1977. In the exchange rate equation, the estimated coefficients of the lagged exchange rate and the lagged price level are consistent with the prediction of the stock/flow model. The short-run overshooting is verified. The exchange rate is found to overshoot in the quarter in which a monetary change occurs by a factor of about two. The exchange rate adjusts cyclically while the price level adjusts monotonically, and long-run purchasing power parity holds. Furthermore, the 'long-run' is calculated to be 2-3 years. However in Driskill's, rational expectations were not formally tested.

Demery (1983) also attempted to compare the Dornbusch model with the stock/flow model using the same data set as Driskill. In contrast to Driskill, Demery evaluated the two models based on the estimated coefficients of a reduced form exchange rate equation obtained by imposing the restrictions derived from the model specification and rational expectations. Also, he introduced a moving average process in the error term of the exchange rate equation instead of a first order
autoregressive one as in Driskill. Demery shows that the stock/flow model is superior to the Dornbusch model. In particular, estimated coefficients on lagged exchange rate and lagged price level support the stock/flow model. The stock/flow and unrestricted versions do show the undershooting of the exchange rate while long-run purchasing power parity is not rejected in the stock/flow model. However, the precise rational expectations solution is not obtained. Specifically, the regressivity parameter in the expectational scheme is not solved in terms of the model's structural parameters. Thus, the test of the overidentifying restrictions is incomplete.

In a recent paper, Hoffman and Schlagenhauf (1983b) estimated a monetary equilibrium rational expectations (MERE) model using three exchange rates. They obtain the rational expectations solution of the model and generate testable overidentifying restrictions. It is argued this model, in contrast to previous MERE models, does not suffer from any endogeneity problem arising from potential correlation between the exchange rate and the interest rate since the interest rate does not show up on the right hand side as an explanatory variable. The results show that the MERE model is internally consistent with rational expectations.

Meese and Rogoff (1983) compared the out-of-sample forecasting performance of the three asset market models with a random walk model of the exchange rates. The structural models are the flexible price (Frenkel-Bilson), sticky price (Dornbusch-Frankel) monetary models, and a sticky price model incorporating the current account (Hooper and
Morton). Meese and Rogoff show that the random walk model performs no worse than these structural models for dollar/mark, dollar/yen, dollar/pound and trade-weighted dollar exchange rates for one to twelve month forecast horizons. This evidence shows that the key coefficients of the asset market models become unstable outside the sample period. Meese and Rogoff provide some possible explanations for the results including simultaneous equation bias, sampling error, stochastic movements in the true underlying parameters, or misspecification. However no single satisfactory explanation has been offered.

As seen in the above survey, the empirical work is in a developing stage. The results of Meese and Rogoff exhibit that the general consensus has not yet emerged. At this point, we feel more comprehensive tests are required for further development in the theory of exchange rates. Especially, rational expectations should be explicitly incorporated and tested based on the full specification of the model. That is, interest rate, price and exchange rate equations should be estimated simultaneously. Although almost all the literature on flexible exchange rates emphasizes rational expectations, very few test the empirical validity of rational expectations.
CHAPTER III
THE MODEL

In this chapter, we develop the monetary and stock/flow model under rational expectations. We assume goods prices are sticky. Using the rational expectations solution method attributable to Muth (1961) and Lucas (1973), we obtain a reduced form exchange rate equation. We also construct a system of equations with overidentifying restrictions used to test the rational expectations assumption. In addition, other testable hypotheses are considered.

3 A. Monetary model

There are three building blocks in sticky price version of the monetary model (Dornbusch 1976): a money market equilibrium condition, a goods price adjustment equation, and a joint assumption of perfect capital mobility and substitutability and rationality in exchange rate expectations. This model views the exchange rate as the relative price of assets, and predicts the short-run overshooting. Following an unanticipated permanent change in relative money supply, the exchange rate initially overshoots, and converges monotonically to its long-run value. This overshooting behavior arises mainly from the assumption that assets are perfectly mobile and substitutable, and that
asset markets adjust more quickly relative to the goods market. There is no room for trade flow to play a role in exchange rate determination.

Our specification of the monetary model is in essence the same as the Dornbusch model. It differs from Frankel (1979) and Driskill and Sheffrin (1981) in that we incorporate the interest rate differential as an argument into the relative demand function for domestic output. In those two models, which were used in empirical work, there is no channel for a change in the interest rate differential to affect the relative demand for domestic output, hence the relative price level. Theoretically, omission of the interest rate differential from the domestic output demand function will cause a dampening effect of a monetary shock on the change in domestic output demand, the price level and the second round change in the interest rate differential and exchange rate. One advantage of ignoring the interest rate differential in domestic output demand would be to simplify the rational expectations solution of the model. Thus, the model becomes much easier to handle in the empirical implementation, but the empirical results from these models would not be complete. So, we incorporate the interest rate differential in the domestic output demand function to make the model more complete. Then, the empirical results of our model will give us a more comprehensive idea on the movements of exchange rates. Also, our solution of the monetary model differs from those of Driskill (1981a) and Demery (1984) in that we obtain the explicit solution of rational expectations while they did not. Even though
Driskill and Demery put the interest rate differential in the domestic output demand function, their solutions of the model are incomplete. Rationality in exchange rate expectations is still implicitly considered in those two empirical models.

3 A.1 Money Market

Assuming structural homogeneity in both countries, we can specify the relative demand for money as:

\[ m^d_t = p_t + \phi y_t - \lambda r_t + z_t \]  

(3.1)

where \( m^d_t \): log of relative (domestic to foreign) money demand
\( p_t \): log of relative (domestic to foreign) price
\( y_t \): log of relative (domestic to foreign) real income
\( r_t \): interest rate differential between home and foreign countries
\( \phi \): income elasticity of the demand for money
\( \lambda \): interest rate semielasticity of the demand for money
\( z_t \): serially uncorrelated random variable with zero mean and finite variance \( \sigma_z^2 \).

Assuming equilibrium obtains in each period, we can write the money market equilibrium condition as:

\[ m_t = m^d_t = p_t + \phi y_t - \lambda r_t + z_t \]

Thus,

\[ r_t = \frac{\phi}{\lambda} y_t - \frac{1}{\lambda} m_t + \frac{1}{\lambda} p_t + \frac{1}{\lambda} z_t \]  

(3.2)
3 A.2 Goods market

In the goods market, the relative demand for domestic output depends on relative income, relative price and on the interest rate differential.

\[ \log D_t = \omega_t + \gamma (e_t - p_t) - \theta r_t \]  

(3.3)

where \( e \) is the log of the exchange rate and \( D \) is the demand for domestic output. Even though the more sensible interest rate would be the real interest rate \( r_t = E_t p_{t+1} + p_t \), we take the nominal interest rate as an argument in the domestic output demand function. Using the real interest rate as an argument makes the rational expectations solution of the model too complex with very little change in the basic implications of the model. While we can obtain the solutions of the model, these solutions are too messy to apply to estimation. Specifically, some coefficients of equations (3.5), (3.9) and (3.14) are scaled down by some parameter value and some remain the same. However, restrictions on each individual coefficient and the restrictions among those coefficients essentially remain the same.

The rate of relative inflation depends upon the ratio of relative demand to relative supply:

\[ p_{t+1} - p_t = \gamma (\log D_t - \gamma_t) + w_{t+1} \]  

(3.4)

where \( \gamma \) reflects the speed of price adjustment and \( w \) is a nonautocorrelated random variable with zero mean and finite variance \( \sigma_w^2 \).

Combining equations (3.2), (3.3) and (3.4) yields the following relative price equation.
The joint assumption of perfect capital mobility and exchange rate expectations is written as:

\[ V_t = r_t - \epsilon_t \]

where exchange rate expectations are formed in a rational manner. That is, \( E_t e_{t+1} \) is the log of the expected exchange rate at time \( t+1 \) conditional on information available at time \( t \). The exchange rate is expressed as the domestic currency price of foreign exchange.

3 A.4 Exchange Rate Equation

We assume that the log of the relative money supply and of relative real income follow a random walk. That is,

\[ m_t = m_{t-1} + u_t \quad (3.7) \]
\[ y_t = y_{t-1} + v_t \quad (3.8) \]

where \( u_t \) and \( v_t \) are, respectively, serially uncorrelated random variables with zero mean and finite variance \( \sigma_u^2 \) and \( \sigma_v^2 \). Further it is
assumed that economic agents use these stochastic processes for forecasting. The assumption that the relative money supply follows a random walk implies that any change in this variable is unanticipated.

Combining (3.2), (3.5), (3.6) and the random walk assumptions for the exogenous forcing variables \((m_t, y_t)\), we obtain the following observable reduced form exchange rate equation. (See Appendix A)

\[
e_t = \Pi_1 e_{t-1} + \Pi_2 p_{t-1} + \Pi_3 m_t + \Pi_4 m_{t-1} + \Pi_5 y_t + \Pi_6 y_{t-1} + \Pi_7 z_t + \Pi_8 z_{t-1} + \Pi_9 \omega_t
\]

\[
(3.9)
\]

where \(\Pi_1 = \frac{(1 - \gamma \delta - \frac{\lambda^2}{\alpha})}{1 - \Pi_1}\)

\[
\Pi_2 = \frac{(1 - \gamma \delta - \frac{\lambda^2}{\alpha}) (\Pi_2 - \frac{1}{\alpha})}{1 - \Pi_1}
\]

\[
\Pi_3 = \frac{\Pi_3 + \Pi_4 + \frac{1}{\alpha}}{1 - \Pi_1}
\]

\[
\Pi_4 = \frac{\gamma \delta (\Pi_2 - \frac{1}{\alpha})}{1 - \Pi_1}
\]

\[
\Pi_5 = \frac{\Pi_5 + \Pi_6 - \frac{\phi}{\lambda}}{1 - \Pi_1}
\]

\[
\Pi_6 = \frac{\gamma (\alpha - \frac{\phi}{\lambda} - 1) (\Pi_2 - \frac{1}{\alpha})}{1 - \Pi_1}
\]

\[
\Pi_7 = \frac{\Pi_7 - \frac{1}{\alpha}}{1 - \Pi_1}
\]

\[
\Pi_8 = \frac{\gamma \delta (\Pi_2 - \frac{1}{\alpha})}{1 - \Pi_1}
\]

\[
\Pi_9 = \frac{\Pi_2 - \frac{1}{\alpha}}{1 - \Pi_1}
\]
Solving for $\Pi_1$, we obtain the following two roots:

\[
\Pi_{11} = \frac{1}{2} \left( (Y\delta + \frac{Y\delta}{\lambda}) + ((Y\delta + \frac{Y\delta}{\lambda})^2 + 4Y\delta/\lambda)^{1/2} \right) > 0, \text{ and }
\Pi_{12} = \frac{1}{2} \left( (Y\delta + \frac{Y\delta}{\lambda}) - ((Y\delta + \frac{Y\delta}{\lambda})^2 + 4Y\delta/\lambda)^{1/2} \right) < 0.
\]

For the price equation to be stable, $\Pi_1$ should be less than $Y\delta + \frac{Y\delta}{\lambda}$ (See Appendix B). By the stability of the price equation, we mean that the price level converges from one state of equilibrium to another in response to some exogenous shock. The simple stability condition for the price equation is that the coefficient of the lagged price level in the price equation should be less than unity in absolute value. Therefore, we rule $\Pi_{11}$ out and take $\Pi_{12}$ as a potentially stable root.

If the price equation is unstable, the exchange rate equation becomes unstable. As the price level explodes, the exchange rate diverges further and further. So, this model predicts that the estimated sign of the lagged exchange rate is negative, while the stock/flow model predicts a value less than unity. This is one distinction between the two models.

Other constraints on the $\Pi_1$ s are as follows. (See Appendix B for details)

\[
\sum_{i=1}^{4} \Pi_i = 1, \quad \Pi_2 < 0, \quad \Pi_3 > 1, \quad \Pi_4 < 0, \quad \Pi_5 < 0, \quad \Pi_6 < 0.
\]

The constraint that $\Pi_1$, $\Pi_2$, $\Pi_3$ and $\Pi_4$ sum to 1 means that purchasing power parity holds in the long-run. The constraint that $\Pi_3$ is greater than unity implies there must be short-run overshooting. $\Pi_1$ has to be negative since the impact effect (overshooting) of a monetary expansion is followed by a second-round appreciation. $\Pi_2$ is negative because an increase in the price level will put upward pressure on the interest
rate, which in turn causes the domestic currency to appreciate. The higher exchange rate has a negative second-round effect. The negative effect of the income variables occurs since a rise in income has a positive effect on the demand for money, which causes the domestic currency to appreciate.

3 A.5 A Test for Rational Expectations

To test whether exchange rate expectations are formed rationally, we exploit a set of overidentifying restrictions implied jointly by the structure of the model and rational expectations. Since the derivation of the exchange rate equation requires substitution into equation (3.6) of equations (3.2), (3.5), (3.7) and (3.8), structural parameters are overidentified. To derive the observable reduced form exchange rate equation (3.9), we first substitute (3.2) into (3.6). Then we obtain a standard reduced form equation embodying the expectations variable \( E_t \) on the right hand side as an explanatory variable. The overidentifying restrictions are generated when we convert this unobservable expectations variable into observables. This procedure requires substitution of the equations (3.5), (3.7) and (3.8) into the unobservable reduced form exchange rate equation. In other words, going from (3.6) to (3.9), we add a number of new variables without adding any new structural parameters. Therefore, the structural parameters are overidentified.
For the empirical implementation, the system of equations can be written as following.

\[ m_t = A_0 + A_1 m_{t-1} + u_t \]
\[ y_t = B_0 + B_1 y_{t-1} + v_t \]
\[ r_t = C_0 + C_1 y_t + C_2 m_t + C_3 p_t + z_t \]
\[ p_t = D_0 + D_1 p_{t-1} + D_2 e_{t-1} + D_3 m_{t-1} + D_4 y_{t-1} + z_t' \]
\[ e_t = \Pi_0 + \Pi_1 e_{t-1} + \Pi_2 p_{t-1} + \Pi_3 m_{t-1} + \Pi_4 y_{t-1} + \Pi_5 y_{t-1} + z_t'' \]

where \( z_t' \) is a linear combination of \( z_{t-1} \) and \( w_t \), and \( z_t'' \) is a linear combination of \( z_t, z_{t-1} \) and \( w_t \). So the error terms \( z_t, z_t' \) and \( z_t'' \) are correlated.

For the ease of exposition, we restrict the values of \( A_1 \) and \( B_1 \) to equal 1. Using this simplifying assumption, we obtain the following implicit form of the overidentifying restrictions. (See Appendix C for details) It is implicit because each \( \Pi_i \) is not solved for as a function of the underlying structural parameters.

\[ C_2 + C_3 = 0 \]
\[ D_1 + D_2 + D_3 = 1 \]
\[ \Pi_1 (1 - \Pi_1) = D_2 (\Pi_2 - C_3) \]
\[ \Pi_2 (1 - \Pi_1 - D_1) = -C_3 D_1 \]
\[ \Pi_3 = 1 - \Pi_1 - \Pi_2 - \Pi_4 \]
\[ \Pi_4 (1 - \Pi_1) = D_3 (\Pi_2 - C_3) \]
\[ -\Pi_1 \Pi_5 = \Pi_6 - C_1 \]
\[ \Pi_6(1 - \Pi_1) = D_4(\Pi_2 - C_3) \]

To test these restrictions, first we estimate the system of equations imposing the restrictions to obtain constrained maximum likelihood. We then estimate the same system of equations without restrictions and obtain unconstrained maximum likelihood. Twice the absolute value of the difference between the log of the maximum likelihoods will provide a test statistic distributed as \( \chi^2(R) \), where \( R \) is the degrees of freedom which equal the number of restrictions being tested. An alternative test method is the Wald-type test. This test is based on unrestricted estimates and measures by how much the unrestricted estimates fail to satisfy the restrictions. Under the null hypothesis that the restrictions are true, the test statistic is also the \( \chi^2(R) \).

3 B. Stock/flow Model

A generalization of the narrower monetary view of exchange rate determination has developed to explain the recent behavior of flexible exchange rates. The observed positive correlation between current account and exchange rate movements is taken into account in the stock/flow model. Based on the assumption of imperfect capital mobility and substitutability, this model emphasizes stock/flow interactions and relative-price trade-balance effects. Rationality in exchange rate expectations is also assumed as in the monetary model.
Once the assumption of perfect substitutability between domestic and foreign assets is relaxed, there is room for the exchange rate to respond to the cumulated current account. The dynamic adjustment path becomes more complex than that of the monetary model. While long-run purchasing power parity still holds in this model, predictions about the dynamic path are quite different from that of the monetary model. Following an unanticipated step change in the relative money supply, the exchange rate may or may not overshoot, and approaches cyclically its long-run value. By cyclically, we mean the exchange rate appreciates and depreciates along the adjustment path. However, the exchange rate is still viewed as the relative price of assets. The current account via its effects on net asset positions influences the dynamic adjustment path of the exchange rate towards the long-run full stock and flow equilibrium. The specification of the money market and goods market is the same as in the monetary model. The random walk assumption is again made for the relative money supply and relative income.

Our specification of the stock/flow model is similar to Bhandari, Driskill and Frenkel (1984) who used a stock formulation of the capital account. Here we modify the model in discrete time for estimation purposes. And we introduce the relative price term in the relative demand for domestic output function. While Driskill obtained rational expectations solution of the model, the relative price term was suppressed from the domestic output demand function. Ignoring the relative price term will have a dampening effect of a monetary shock on
the change in domestic output demand, which in turn diminishes the
change in the price level. Furthermore, the second round change in the
interest rate will be smaller than when the relative price term is
present in the domestic output demand function. The second round change
in the exchange rate may or may not be smaller depending upon the stock
and flow effects. Although we may suppress a certain argument in a
theoretical model in order to focus on the important issues being
pursued, we should consider all the relevant variables for empirical
purposes.

Our solution of the model is different from that of Driskill
(1981a) and Demery (1984). As explained in the monetary model, rational
expectations were implicitly considered in both models and were
incompletely tested in Demery.

3 B.1 Foreign Exchange Market

To incorporate imperfect capital mobility and substitutability, a
net demand for foreign assets function and a trade balance function are
specified. The net demand for foreign assets, $B_t$, is assumed to be a
linear function of the expected net yield:

$$B_t = n \left( E_t e_{t+1} - e_t - r_t \right)$$  \hfill (3.11)

where $n$ measures the degree of capital mobility. The trade balance is
specified as a linear function of the log of relative prices and the
log of relative real incomes:

$$T_t = \alpha (e_t - p_t) - \beta y_t + x_t$$  \hfill (3.12)
where $x_t$ is a serially uncorrelated random variable with zero mean and finite variance, $\sigma^2_x$. The condition that $\sigma$ be positive simply states that the Marshall-Lerner condition holds. By taking the first difference of $B_t$, we obtain net capital flows, $\Delta B_t$.

$$\Delta B_t = \eta \left( E_{t+1} e_t - E_{t+1} e_{t-1} - r_t + r_{t-1} \right) \quad (3.13)$$

Equating net capital flows with trade flows and using the rational expectations solution method yields the following exchange rate equation. (See Appendix D)

$$e_t = \Pi_0 + \Pi_1 e_{t-1} + \Pi_2 p_{t-1} + \Pi_3 m_t + \Pi_4 m_{t-1} + \Pi_5 y_t + \Pi_6 y_{t-1} + \Pi_7 z_t + \Pi_8 z_{t-1} + \Pi_9 x_t + \Pi_{10} w_t \quad (3.14)$$

where

$$\Pi_1 = \frac{-\left(1 - \Pi_1 + \Pi_2 \gamma - \left(\frac{1}{n} - \alpha \right) \gamma \delta \right)}{\alpha + \eta \left(1 - \Pi_1 \right)}$$

$$\Pi_2 = \frac{\eta \left(\frac{1}{\lambda} \gamma \delta - \left(\frac{1}{\lambda} - \alpha \right) \gamma \delta \right)}{\alpha + \eta \left(1 - \Pi_1 \right)}$$

$$\Pi_3 = \frac{\eta \left(\frac{1}{\lambda} \gamma \delta - \left(\frac{1}{\lambda} + \alpha \right) \gamma \delta \right)}{\alpha + \eta \left(1 - \Pi_1 \right)}$$

$$\Pi_4 = \frac{\eta \left(\frac{1}{\lambda} \gamma \delta - \left(\frac{1}{\lambda} + \alpha \right) \gamma \delta \right)}{\alpha + \eta \left(1 - \Pi_1 \right)}$$

$$\Pi_5 = \frac{\eta \left(\frac{1}{\lambda} \gamma \delta - \left(\frac{1}{\lambda} + \alpha \right) \gamma \delta \right)}{\alpha + \eta \left(1 - \Pi_1 \right)}$$

$$\Pi_6 = \frac{\eta \left(\frac{1}{\lambda} \gamma \delta - \left(\frac{1}{\lambda} + \alpha \right) \gamma \delta \right)}{\alpha + \eta \left(1 - \Pi_1 \right)}$$
In these expressions, the term $\frac{\alpha}{n}$ is the ratio of the terms of trade effect on the trade balance to the parameter measuring the degree of capital mobility. In addition, the term $\frac{\beta}{n}$ measures the ratio of income sensitivity of the trade balance to capital mobility.

Solving for $\Pi_1'$ as a function of structural parameters produces a cubic equation. Since the solution to the cubic equation requires much algebra, we suggest a graphical method of solution as in Bhandari, Driskill and Frenkel (1984). As seen in Fig. 1 of Appendix E, there exist three pairs of $\Pi_1'$ and $\Pi_2'$, denoted by the points A, B and C. Once the stability condition for the exchange rate equation is imposed, the two pairs B and C are excluded because the values of $\Pi_1'$ in these two pairs exceed unity. Imposing the stability condition implies that the exchange rate should converge from one state of equilibrium to another in response to an exogenous shock. So the pair A where $\Pi_1' < 1$ and $\Pi_2' > 1$ is the only potentially stable pair.

The other $\Pi_1'$'s satisfy the following constraints. (See Appendix E)
As in the monetary model, the sum of the first four $\Pi_i$'s is unity, which implies the long-run purchasing power parity holds. The constraint of $\Pi_3$ simply being positive implies it need not be greater than unity. That is, there may be undershooting in the short-run. $\Pi_1$ can be positive because the second-round effects include a trade surplus which should be realized by an accumulation of foreign assets. This may cause the domestic currency to depreciate further. Similar reasoning applies to $\Pi_2$. $\Pi_5$ and $\Pi_6$ may be positive or negative since income affects trade flows as well as the demand for assets. The positive flow effect may dominate over the negative stock effect.

3 B.2 Test for Rational Expectations

The system of equations used to test rationality is the same as in (3.10) except that $z_t''$ is a linear combination of $z_t$, $z_t'$, $x_t$ and $w_t$. The assumption that the values of $A_1$ and $B_1$ equal unity is again made. Then, the following overidentifying restrictions are obtained (See Appendix F). These also represent implicit forms of the restrictions.

\[
\begin{align*}
C_2 + C_3 &= 0 \\
D_1 + D_2 + D_3 &= 1 \\
\Pi_2' &= 1 - \Pi_1' - \Pi_3' - \Pi_4' \\
\Pi_3' \left[ (1 - 2\Pi_1') + D_2 (\Pi_1' + \Pi_2' - C_3) \right] &= (\Pi_1' - D_2) (\Pi_4' + C_3)
\end{align*}
\]
The test method for rationality is, of course, the same as in the monetary model.

Now we will subject the two models to three tests.

First we examine which model is supported by the estimated coefficients of the lagged exchange rate, the lagged price level and the current money supply in the exchange rate equation. The evaluation will be based on the estimation of the unrestricted system of equations. Since the unrestricted versions of the two models are identical, the estimated coefficients of those variables are important in differentiating between the empirical implications of the two models. Specifically, the lagged exchange rate enters the monetary model with a negative sign \((\Pi_1 < 0)\) while it can be positive in the stock/flow model \((\Pi_1 > 1)\). The lagged price level has a negative sign \((\Pi_2 < 0)\) in the former but it is positive \((\Pi_2 > 0)\) in the latter. Moreover, there must be short-run overshooting \((\Pi_3 > 1)\) in the monetary model while undershooting \((\Pi_3 < 0)\) is allowed in the stock/flow model.

Second, we estimate the system of equations imposing all the within- and cross-equation overidentifying restrictions, and check whether the estimated coefficients have the expected signs and magnitudes in each model. By doing so, we can examine whether the
underlying structural parameters exhibit plausible values. For example, we can examine whether the estimates of income elasticity and interest rate semielasticity of the demand for money are consistent with estimates obtained in other empirical studies. This test will give us additional information in evaluating the two models.

The last test will consist of a formal test of overidentifying restrictions in each model. The likelihood ratio test compares the constrained and unconstrained maximum likelihoods. Twice the absolute value of the difference between the log of the maximum likelihoods will give us the test statistic distributed as \( \chi^2 \) with \( R \) degrees of freedom equal to the number of restrictions being tested. An alternative way to test these restrictions is with the Wald test which is based solely on the result of unrestricted estimation.

Once the empirical results are obtained, we will examine the following questions:

1). Whether there is short-run overshooting.

2). Whether the long-run purchasing power parity is fulfilled
CHAPTER IV

EMPIRICAL IMPLEMENTATION

4 A. Estimation Method

In this section, we discuss the econometric techniques necessary to estimate the model. The unrestricted model to be estimated is a system of equations as shown in (3.10).

\[
\begin{align*}
  m_t &= A_0 + A_1 m_{t-1} + u_t \\
  y_t &= B_0 + B_1 y_{t-1} + v_t \\
  r_t &= C_0 + C_1 y_t + C_2 m_t + C_3 p_t + z_t \\
  p_t &= D_0 + D_1 p_{t-1} + D_2 e_{t-1} + D_3 m_{t-1} + D_4 y_{t-1} + z_t' \\
  e_t &= \Pi_0 + \Pi_1 e_{t-1} + \Pi_2 p_{t-1} + \Pi_3 m_t + \Pi_4 m_{t-1} + \Pi_5 y_t + \Pi_6 y_{t-1} + z_t''
\end{align*}
\]

Our system of equations to be estimated is quite different in several aspects from those of others suggested so far. It differs from Frankel (1979) in that we construct an equation system in which not only asymptotically more efficient estimators can be obtained but the overidentifying restrictions can be imposed in the restricted estimation. Our model differs from Driklill and Sheffrin (1981) in that they did not include the equations of exogenous forcing variables.
(m_t and y_t) in the system. It also differs from Driskill (1981a) and Demery (1983) in the sense that we fully exploit the overidentifying restrictions necessary to test for rational expectations.

In this system of equations, m_t and y_t are assumed to be exogenous. The presence of p_t in the r_t equation causes endogeneity problems because we allow z_t and z_t' to be mutually correlated.

The OLS estimators of m_t, y_t, p_t and e_t equations are unbiased and consistent if the error terms of the equations satisfy the full ideal conditions. However, those of the r_t equation are inconsistent. However, the OLS estimators are less efficient than those of joint estimation. Nevertheless, OLS will be applied to each equation because OLS is a good starting place for empirical work. Our first estimation will be to regress the exogenous forcing variables (m_t and y_t) on their lagged values. By doing so, we can determine whether m_t and y_t follow a random walk. To further examine whether m_t follows a random walk, we employ a test for randomness in a residual vector from the time series. Suppose that we have a fitted ARIMA(p, d, q) time series model, and that we want to check whether the fitted model is appropriate. Using residuals from the fitted equation, we calculate the first K autocorrelations. Under the null hypothesis that the fitted model is appropriate, the test statistic Q will be distributed as $\chi^2$.

That is,

$$Q = (N - d) \sum_{k=1}^{K} \tau_k^2(\hat{d}) - \chi^2(K - p - q)$$

where N is the number of observations in the original time series, and $\tau_k^2(\hat{d})$ (k = 1,.....K) are autocorrelations of the residuals.
Then OLS is applied to the other three equations. By checking the DW statistic for the $r_t$ equation and Durbin's $H$ statistic for the $p_t$ and $e_t$ equations, we test whether the error terms show autocorrelation. If $p_t$ and/or $e_t$ equation exhibit autocorrelation, it must be corrected because these two equations have lagged dependent variables on the right hand side. Otherwise, the estimators will be inconsistent. Though we recognize that the error terms $z_t'$ and $z_t''$ are functions of the underlying structural errors in both the monetary and stock/flow models, we do not take this fact into account because we cannot identify the definite error structure. So we will simply examine whether or not the error terms are serially correlated.

The next step will be a joint estimation of the system. Since $m_t$ and $y_t$ are assumed exogenous, the error terms of these two equations are not assumed to be correlated with those of the other three equations. Also, the error terms of $m_t$ and $y_t$ are assumed to be uncorrelated with each other. Needless to say, it would be preferred to specify a full vector autoregressive process between money and income and to allow the error terms $(u_t, v_t)$ to be mutually correlated. The forecasts from this specification would have better properties than those from the univariate specification. However, the restrictions resulting from this specification are very complicated to handle in the empirical work. So we specify $m_t$ and $y_t$ as univariate autoregressive processes, as in most empirical work. Even in the univariate autoregressive specification of $m_t$ and $y_t$, we may allow the two error terms to be correlated as it is hard to say that money and income do
not have any seemingly causal relation. The result of joint estimation of \( m_t \) and \( y_t \) though did not show any difference from that of separate estimation in the estimated coefficients, standard errors and the maximized likelihood. That is, the error terms \( u_t \) and \( v_t \) do not seem to be correlated. Therefore, the univariate autoregressive specification for \( m_t \) and \( y_t \) seems justified, at least in our empirical context.

However, the error terms of the \( r_t \), \( p_t \) and \( e_t \) equations are allowed to be mutually correlated. This is consistent with the theoretical derivation of Chapter III. Therefore, the joint estimation consists of two procedures. First, the exogenous variables (\( m_t \) and \( y_t \)) are estimated individually by OLS. Second, the \( r_t \), \( p_t \) and \( e_t \) equations are estimated jointly. Then the unrestricted maximized likelihood is the product of the maximized likelihoods from these estimation procedures.

The system of three equations is a simultaneous one because we have an endogenous variable (\( p_t \)) in the \( r_t \) equation. So we first check the identification problem. Since the \( p_t \) and \( e_t \) equations are already reduced forms, there is no identification problem in these equations. Both equations are exactly identified. However, the interest rate equation is overidentified. The rank condition is satisfied while the order condition shows overidentification. Therefore, we will use the full information maximum likelihood method in the joint estimation. This will give us consistent and asymptotically efficient estimators.

Let the system of \( n \) equations be written as

\[
Y_i = X_i B + \epsilon_i \quad i = 1, 2, ..., n
\]

where \( \epsilon_i \) is assumed to be normally distributed with mean
\[ E(\epsilon_{1t}) = 0 \quad t = 1, 2, \ldots, T \]

and variance-covariance matrix given by

\[ E(\epsilon_i \epsilon'_j) = \sigma_{ij} I_T \]

where \( I_T \) is an identity matrix of order \((T \times T)\).

And \( E(\epsilon_i \epsilon'_j) = \sigma_{ij} I_T \)

Then the joint distribution of the elements of \( \epsilon_i \) is

\[
f(\epsilon_i) = f(\epsilon_{1}, \ldots, \epsilon_n) = \frac{1}{(2\pi)^{n/2}} \frac{1}{|\Omega|^{1/2}} e^{-\frac{1}{2}(\epsilon_i \Omega^{-1} \epsilon_i)/2}
\]

where

\[
\Omega = \begin{pmatrix}
\sigma_{11} I_T & \cdots & 0_{1n} I_T \\
0_{n1} I_T & \cdots & 0_{nn} I_T
\end{pmatrix}
\]

The logarithmic likelihood function for the \( T \) observations on \( Y_t \) conditional on the values of \( X_t \) is

\[
\log L = -\frac{nT}{2}\log(2\pi) - \frac{T}{2}\log|\Omega| - \frac{1}{2} \sum_{t=1}^{T} \epsilon_{1t}' \Omega^{-1} \epsilon_{1t}
\]

\[
= -\frac{nT}{2}\log(2\pi) - \frac{T}{2}\log|\Omega| - \frac{1}{2} \sum_{t=1}^{T} (Y_{1t} - X_{1t}B)' \Omega^{-1} (Y_{1t} - X_{1t}B)
\]

The maximum likelihood estimators are obtained by maximizing \( \log L \) with respect to \( B \). The resulting estimators are consistent and more efficient than those of OLS applied to each equation separately. Also we obtain the log of maximized likelihood.

For the test of within- and cross-equation restrictions implied by the model specification and the rational expectations assumption, two test methods will be used. The first one is the likelihood ratio test.
The likelihood ratio test consists of comparing the constrained maximum likelihood with the unconstrained one. In the constrained estimation, the complete system consisting of 5 equations must be estimated jointly because the autoregressive parameters of the exogenous variables appear in the whole system. Under the null hypothesis that the restrictions are true, twice the absolute value of the difference between the log of the maximum likelihoods will be distributed asymptotically as $\chi^2(R)$, where $R$ is the number of the restrictions being tested. A second test is the Wald test. Let $\hat{\theta}$ be the maximum likelihood estimators of $\theta$ without imposing the restrictions. Then the test statistic

$$W = h(\hat{\theta})'(DED')^{-1}h(\hat{\theta})$$

has an asymptotic $\chi^2$ distribution with $R$ degrees of freedom if the null hypothesis is true. In this expression, $h(\hat{\theta})$ is a vector of functions whose dimension is the number of restrictions, $D$ is the matrix of first derivatives of $h(\hat{\theta})$ with respect to the elements of this vector and $E$ is asymptotic covariance matrix of $\hat{\theta}$. The restrictions should be in the form of $h(\theta) = 0$. Thus, the Wald test is based on the unrestricted estimates. It measures by how much the unrestricted estimates fail to satisfy the restrictions. We accept the null hypothesis if $h(\hat{\theta})$ is sufficiently close to zero. These two tests are asymptotically equivalent in the sense that their test statistics have the same asymptotic distribution. Moreover, Monte Carlo evidence of Hoffman and Schmidt (1981) shows that there is no relative power advantage of using the likelihood ratio test statistic over Wald test statistic, and vice versa.
In the monetary model, the coefficients of the exchange rate equation ($\Pi_1$ through $\Pi_6$) will be solved as a function of the structural parameters ($\lambda, \phi, \gamma_6, \gamma_6$ and $\gamma/(\sigma-1)$). By doing so, we convert the implicit form of the restrictions to an explicit form. Then we obtain the restricted system of equations. In this case, the maximum likelihood estimators are obtained by maximizing the likelihood function with respect to the unknown structural parameters. Of course, the log of likelihood function is obtained, we can apply both likelihood ratio test and Wald test to the monetary model.

In the stock/flow model, we encounter a problem in solving the coefficients of the exchange rate equation, $\Pi_1'$ through $\Pi_6'$, as a function of the structural parameters. Since we cannot solve for $\Pi_1'$ algebraically as a function of the structural parameters (as seen in chapter III), we treat $\Pi_1'$ as one parameter. Then we solve for $\Pi_2'$ through $\Pi_6'$ as a function of $\Pi_1'$ and the structural parameters. Under this situation, we lose one restriction. The problem in this case is that we can hardly assess the properties of the estimators. Efficiency of the estimators may be affected. Therefore, a statistical test cannot be done for the missing restriction. One method is suggested to overcome this difficulty. By varying $\Pi_1'$ from minus one to one, we get various sets of estimated structural parameters estimated. Among those, we choose the one whose likelihood function is the highest. This method may give us some evidence regarding the empirical validity of the restrictions. The Wald test cannot be applied to the stock/flow model however, since we do not have explicit form of restrictions.
4 B. Estimation

4 B.1. Data

The model is estimated for the Swiss franc/US dollar rate, using quarterly data from 1973 (2) to 1982 (4), resulting in 39 observations. Quarterly data are used since it is more consistent with the theoretical models developed under the framework of the sticky price assumption and the trade-balance adjustment.

The freely floating exchange rate regime was introduced among major industrialized countries in March 1973. The sample period stops at 1982 (4) because the money supply data in International Financial Statistics (IFS) are revised from 1983 (1), especially the money supply data of Switzerland. The major reason of choosing the Swiss franc/US dollar rate in our estimation is that over the sample period the rate floated relatively cleanly and the two currencies are not involved in the 'snake' arrangement.

The exchange rates used are averages of monthly end of period rates, and the price level is the wholesale price index. Even though the consumer price index is available, we use wholesale price index since the latter would be more relevant in international trade. Actually, the performance of the wholesale price index was better than that of consumer price index. The industrial production index is used as a proxy for real income because quarterly income data are not available for Switzerland. The money stock is $M_3$. It is a well-known empirical finding that US $M_1$ has not been very stable because of the
so-called 'Goldfeld puzzle'. Goldfeld's standard money demand equation seriously overpredicts the demand for $M_1$ money in the mid-1970s and underpredicts it in 1980s. Some explanations are made about this issue of the unstable $M_1$ demand. Among those, the most comprehensive suggestions are made by Gordon (1984). Since our sample falls in this unstable period of $M_1$ demand, we choose $M_3$ as an appropriate monetary aggregate. Finally, US interest rates are averages of three month T-bill rates and Swiss interest rates are also averages of three month short-term deposit rates. Needless to say, it is hard to determine which interest rate is the most appropriate in macroeconomic empirical work. These two interest rates are comparable and are representative short-term rates in both countries.

The US money supply data were provided from the FRB, and Swiss money stock data were taken from the International Financial Statistics of IMF. The US wholesale price index was obtained from IFS and the Swiss wholesale price index was taken from the monthly bulletin of the Swiss National Bank. All other sources of data are found in OECD Main Economic Indicators.

4 B.2 OLS and Unrestricted Estimation

In actual estimation, the income variable was included in the $r_t$ equation. It was dropped from the other equations ($p_t$ and $e_t$) because the estimated coefficients of income were insignificant and income did not affect the estimation results. In this case, the interest rate
equation is still overidentified. Dropping the income variable makes the equation system, particularly the restricted system, highly simplified. All estimation was done using version 3.4B of the TSP package.

First, \( m_t \) was regressed on its lagged values. The representative results are as follows. (Standard errors are in parentheses).

\[
\begin{align*}
\hat{m}_t &= .150 + .930 \hat{m}_{t-1} \\
&\quad (.082) (.039) \\
\hat{R}^2 &= .9386 ~ F = 566.143 \\
\hat{m}_t &= .182 + .874 \hat{m}_{t-1} - .460 \hat{m}_{t-2} + .502 \hat{m}_{t-3} \\
&\quad (.077) (.150) (.197) (.146) \\
\hat{R}^2 &= .9466 ~ F = 207.635
\end{align*}
\]

Though \( t \) values in the AR(3) model are significant, the AR(3) model is rejected at 1% significant level by the \( F \) test. The hypothesis to be tested is whether the coefficients of \( m_{t-2} \) and \( m_{t-3} \) are zero. The calculated \( F \) value is

\[
F = \frac{R^2_{1.2} - R^2_4}{1 - R^2_4}\left(-\frac{39 - 4}{2}\right) = 3.90
\]

And the critical \( F \) value at (2,35) degrees of freedom is approximately 5.18. So we take the AR(1) process as the stochastic process of \( m_t \). The random walk assumption that the coefficient of \( m_{t-1} \) equals one is not rejected at the 5% significance level. Also, the assumption that the constant term equals zero is not rejected at 5% level of significance. To further investigate that \( m_t \) follows a random walk, we
calculated the Q statistic using the first 25 autocorrelations (which is sufficiently large) of residuals of two equations. For the first set of residuals from the equation (4.1), the Q statistic was calculated to be 34.25, which indicates that nonrandomness of the residuals is rejected at 5% significance level. The critical value at the 5% significance level with 24 degrees of freedom is 36.4. The Q statistic obtained from an equation in which the constant term and the coefficient on $m_{t-1}$ were restricted to $(0, 1)$ was 32.10. Nonrandomness of the residuals is rejected at the 10% significance level. So the assumption that the relative money supply follows a random walk seems justified.

Relative income also follows a random walk process.

$$y_t = 0.011 + 0.893 y_{t-1}$$  \hspace{1cm} (4.2)

\begin{align*}
\hat{R}^2 & = 0.8258 \\
F & = 176.374
\end{align*}

The random walk assumption is not rejected at 5% level of significance. The test for nonrandomness of residuals was also applied to $y_t$ series. The Q statistic calculated from the equation (4.2) was 9.21. And the Q statistic obtained from an equation in which the constant term and the coefficient on $y_{t-1}$ are constrained at $(0, 1)$ was 10.75. There is no doubt as to the adequacy of the random walk model.

The interest rate equation shows the following result.

$$r_t = 6.564 - 2.614 m_t + 6.596 p_t + 27.176 y_t$$  \hspace{1cm} (4.84)

\begin{align*}
\hat{R}^2 & = 0.7154 \\
F & = 32.58 \\
DW & = 1.47
\end{align*}
All estimates have the correct signs. However, the estimate of $m_t$ is not significant. The DW statistic shows 'inconclusive' about serial correlation. In such a case, we may or may not respond. The general approach is to incorporate a first order autoregressive process in the error term. Since the presence of AR(1) is not clearly rejected, this approach is more conservative from the statistics viewpoint. Therefore, the interest rate equation was reestimated allowing the AR(1) process in the error term. Using the Cochrane-Orcutt iterative method, we obtained the following result.

$$r_t = .202 + .608 m_t + 5.565 p_t + 25.482 y_t + .270 z_{t-1}$$

$$(15.02) (7.50) (2.12) (5.69) (.16)$$

$${\hat{R}}^2 = .7378 \quad F = 35.70$$

The sign of the estimated coefficient of $m_t$ has changed, but it is still insignificant. The first order correlation coefficient $\rho$, is insignificant at 5% significance level. Thus, we ignore the presence of autocorrelation in the $r_t$ equation. This specification of the interest rate equation will greatly simplify both the restricted and unrestricted equation systems.

The relative price equation was also estimated by OLS.

$$p_t = -.773 + .818 p_{t-1} - .005 e_{t-1} + .405 m_{t-1}$$

$$(.493) (.086) (.113) (.396)$$

$${\hat{R}}^2 = .7700 \quad F = 42.295 \quad Durbin H = -.310$$

The estimated coefficient of $e_{t-1}$ has the wrong sign, and the estimates of $e_{t-1}$ and $m_{t-1}$ are not significant. Durbin's H statistic does not indicate serial correlation in the error term.
Finally, the exchange rate equation was estimated by OLS, including a dummy variable which has a value 1 for every fourth quarter and 0 otherwise. This dummy variable reflects the year-end demand for Swiss franc by Swiss firms for the 'window dressing' of their end-of-year financial statement. So we expect the US dollar to depreciate, hence the expected sign of the dummy variable is positive.

$$e_t = -.064 + .932 e_{t-1} - .017 p_{t-1} + 2.298 m_t - 2.147 m_{t-1} + .048 D$$

$$R^2 = .9466 \quad F = 132.19 \quad Durbin H = 2.636$$

Notice that the estimated coefficient on the dummy variable is significantly positive. Durbin's H statistic clearly shows autocorrelation in the error term. Since there is a lagged dependent variable on the right hand side, the estimates are inconsistent. Therefore, the Cochrane-Orcutt method was applied, which resulted in the following:

$$e_t = -.080 + .676 e_{t-1} + .137 p_{t-1} + 2.196 m_t - 1.582 m_{t-1} + .038 D$$

$$R^2 = .9539 \quad F = 150.10 \quad \rho = .697$$

The first order correlation coefficient, $\rho$, is highly significant. Notice that the sign of the estimated coefficient of $p_{t-1}$ has changed.
As a result, we will incorporate the AR(1) process of the error term in the joint estimation of the system.

The joint estimation of $r_t$, $p_t$ and $e_t$ equations was done using the method of full information maximum likelihood. Using this method, we can obtain consistent and asymptotically efficient estimators, and we can impose within- and cross-equation nonlinear restrictions in the constrained estimation. The method used was GAUSS which is the fastest in terms of convergence. The model is linearized in its variables and then estimated by multivariate regression applied to the reduced form. This method gives exact maximum likelihood estimates, but somewhat incorrect standard errors of the estimates. The convergence criterion is .01.

Although the method of multivariate regression in the TSP package is also useful in the joint estimation of a system, this method is not exactly applied to our system. Since there is an endogenous variable, $p_t$, on the right hand side of the interest rate equation and the error terms of the price and interest rate equations are allowed to be mutually correlated, the estimates obtained by multivariate regression will be inconsistent. Using the instrumental variable method in the multivariate regression will result in consistent and asymptotically efficient estimators.

The result of full information maximum likelihood is the following (The results of $m_t$ and $y_t$ equations are those of OLS).
The log of likelihood function for the joint estimation of the three equations is 53.3649. So the log of the maximized likelihood function for the complete system is 239.4406.

Comparing this result with that of OLS estimation, we notice the magnitudes of the estimated coefficients remain fairly stable, and
almost all signs remain the same. The only exception is that the sign of the estimated coefficient of $m_t$ in the $r_t$ equation has changed, but is insignificant. This could happen if the sample is sensitive to the estimation method or if the error terms are not mutually correlated. If the error terms are uncorrelated while they are assumed to be, the estimates can be contaminated. All estimates in the exchange rate equation except that of $p_{t-1}$ are significant at the 5% level. The estimate on $p_{t-1}$ is insignificant at the 10% level. The critical $t$ value is 1.684 while the $t$ value of the estimated coefficient on $p_{t-1}$ is 1.656.

Dornbusch's short-run overshooting is confirmed and long-run purchasing power parity is not rejected at the 10% level. The sum of the first four estimated coefficients is 1.173 while the standard error is calculated to be 0.634. Also, the hypothesis that the sum of three coefficients in the price equation is unity is not rejected at the 10% significance level. The sum of the three estimated coefficients is 1.301 and the standard error is .280.

In conclusion, the unconstrained estimation result supports the predictions of the stock/flow model. The estimated coefficient of the lagged exchange rate in the exchange rate equation lies between 0 and 1, and that of lagged price has a positive sign. However, the insight of Dornbusch's short-run overshooting is verified as an empirical phenomenon.

4 B.3. Estimation of Restricted System
In the estimation of the restricted system of the monetary model, it was found that convergence is not achieved because of failure to improve the objective function. So \( \Pi_1 \) is also treated as one parameter, as explained in the section 4 A. By varying \( \Pi_1 \) from 0 to \(-1\), we obtain various sets of estimates for the structural parameters. We vary \( \Pi_1 \) from 0 to \(-1\) since the monetary model predicts a negative value of \( \Pi_1 \). Among those sets of estimates, we choose the one whose likelihood function is the highest. Convergence is achieved only for the value of \( \Pi_1 \) equals \(-0.7\). For other values of \( \Pi_1 \), convergence is not achieved because of failure to improve the likelihood function. This result is reported with the restricted system in appendix G. For this given value of \( \Pi_1 \), some parameters are estimated to be huge, which does not make any sense. In particular, \( \phi \), the income elasticity of the demand for money, is estimated to be 2170.51. And \( \lambda \), the interest rate semi-elasticity of the demand for money is 68.16. The estimate for \( \gamma_0 \), which is a product of price adjustment speed and interest rate elasticity of the demand for domestic good, is also large. Finally, the log of the likelihood function is 208.601. Though the test for the restrictions does not make much sense because the likelihood function is not well behaved, the restrictions implied by this model are rejected at the 1% significance level. The calculated \( \chi^2 \) value is 61.7 while the critical value at 5 degrees of freedom is 15.1. The Wald test shows clear rejection of the restrictions. The calculated W value is 265.853, while the critical value at 6 degrees of freedom is 16.8. The degrees of
freedom in the Wald test are 6, but they are 5 in the likelihood test because we lost one restriction in the likelihood ratio test.

In the stock/flow model, convergence is achieved for any given value of \( \Pi_1' \). The log of the likelihood function is the highest when \( \Pi_1' \) is set at 0.5. This result is provided in Appendix G. Almost all the estimated coefficients have the correct signs and reasonable magnitudes. The exceptions are that \( \gamma_0 \) has the wrong sign and \( \phi \) has a somewhat big value (5.716). Also, \( -\frac{\alpha}{\eta} \), the ratio of the terms of trade effect to the degree of capital mobility, has a positive magnitude (0.048), which is consistent with the prediction of the stock/flow model, but the estimate is insignificant. Finally, the restrictions are acceptable. The log of the likelihood function is 233.230 when \( \Pi_1' \) is 0.5. It is not rejected at the 1.0% significance level. The calculated \( \chi^2 \) value is 12.42 while the critical value at 4 degrees of freedom is 13.30.

In short, the overall performance of the stock/flow model is superior to that of the monetary model. That is, the joint hypothesis of the model specification and rational expectations assumption is not rejected in the stock/flow model, but is in the monetary model. This does not necessarily imply that exchange rate expectations are not rational, but that rationality in exchange rate expectations incorporated in the monetary model is not appropriate. The coefficients of the lagged exchange rate and lagged price level are estimated to be positive in the unrestricted version of the model. This tells us the second-round accumulation of foreign assets via a trade surplus will
result in further depreciation of the domestic currency. Even though the stock effect may dominate over the flow effect, the flow of foreign exchange does play a role in the determination of the exchange rate. Furthermore, consideration of the flow effect in the model specification is well matched with rationality in exchange rate expectations.
CHAPTER V
CONCLUDING SUMMARY

This study explicitly incorporated rational expectations in solving the sticky price version of the monetary model and stock/flow model, and subjected the two models to empirical tests. Using the rational expectations solution method, we derived the reduced form exchange rate equation and constructed the system of equations. By doing so, we obtained the restrictions on the coefficients of the exchange rate equation, and the within- and cross-equation overidentifying restrictions for both models. We established testable hypotheses implied by these two models.

Our monetary model departs from Frankel(1979) and Driskill and Sheffrin(1981) in that we incorporate interest rate differential as an argument in the relative domestic output demand function and we construct a system of equations including the equations of exogenous variables. By establishing the system of equations, we made it possible to test internal consistency of the monetary model with rational expectations. It also departs from Driskill(1981a) and Demery(1984) by explicitly incorporating the rational expectations in solving the model and exploiting overidentifying restrictions in testing the model. Thus, our monetary model is more appropriate than any other ones in the
sense that we can test the model on the basis of a more complete picture.

Also, our stock/flow model gives us a more comprehensive idea than those of Driskill (1981a and 1981b) and Demery (1984). It is different from Driskill (1981b) since we put the relative price term in the relative domestic output demand function. While omission of an argument from a model is theoretically plausible depending upon the issues being pursued, all the relevant variables should be taken into account in the empirical context. It departs from Driskill (1981a) and Demery (1984) by incorporating the rational expectations into the model and establishing a system of equations used to test the restrictions implied by model specification and rational expectations. This is important in testing empirical validity of the model.

Our empirical findings for the Swiss franc/US dollar rate show that the overall performance of the stock/flow model is superior to that of the monetary model. The joint hypothesis of the model specification and rationality in exchange rate expectations is empirically verified in the stock/flow model. In the unconstrained estimation, the signs of the estimated coefficients of the lagged exchange rate and lagged price level in the exchange rate equation clearly support the stock/flow model. Also, the long-run purchasing power parity principle holds. However, Dornbusch's insight about the short-run overshooting is verified as an empirical phenomenon. In the constrained estimation, the rational expectations assumption incorporated into the monetary model is clearly rejected by the Wald
test while it seems acceptable in the stock/flow model according to the likelihood ratio test. Though one restriction was not precisely imposed in the constrained estimation of the stock/flow model, the structural parameters obtained plausible signs and magnitudes.

Our results support the idea that the domestic and foreign assets are imperfect substitutes and foreign exchange market is efficient. Thus, exchange rate is determined by the interactions of stock and flow, and rationally expected future exchange rate affects the movements of current spot exchange rate. Though Meese and Rogoff (1983) show that the structural models became unstable in the late 1970s, our results demonstrate that the basic determinants of exchange rates are still stock/flow interactions and exchange rate expectations. Our results also indirectly support the hypothesis that there exists risk premium. The empirical validity of this choice is important to establish since it produces different implications from other ones established under different assumptions. Policy issues, however, were not pursued in this study.

Finally, the limitation of this study is, of course, that we do not have precise, explicit forms for the overidentifying restrictions for the stock/flow model. This problem comes from the fact that the rational expectations solution is almost always too messy and complex. A second limitation would be that we treat the money supply and income as purely exogenous to the exchange rate while these variables may be endogenously determined at the same time.
FOOTNOTES

1. We may include a term capturing the long-run expected inflation differential, as in Frankel (1979), in the specification of the rate of relative inflation. However, it did not improve the prediction of the rate of relative inflation. See Driskill and Sheffrin (1981) on this point.

2. If \( m_t \) and/or \( y_t \) follow other stochastic processes, the solution of the exchange rate equation will differ from the one in the text. For the empirical work, a preliminary investigation of the stochastic processes of exogenous variables (\( m_t \) and \( y_t \)) is required.

3. If \( m_t \) and \( y_t \) show other stochastic processes, the overidentifying restrictions should be modified, which might well be expected in actual empirical work.

4. Since the parameters \( \gamma, \delta, \theta \) and \( \sigma \) are not separable, we treat \( \gamma \delta, \gamma \theta \) and \( \gamma \sigma \) as single parameters, respectively.

5. Since \( u_t \) and \( v_t \) are assumed to be independent of other error terms, and \( z_t, z'_t \) and \( z''_t \) are mutually correlated, it would be preferred to estimate the \( m_t \) \& \( y_t \) equations individually by OLS and estimate jointly \( r_t, \rho_t \) \& e_t equations. The unrestricted maximized likelihood is then the product of the maximized likelihoods from these three estimation procedures.
6. In Fig. 1, the pair B may become stable if the curve XX intersects the curve YY so that the value of $\Pi_1$ becomes less than unity, which causes the multiple solution problem. In this case we assume that the system will make a choice and follow the particular path.

7. See Driskill (1981a) on this point.
Combining the equations (3.2), (3.5) and (3.6), we obtain
\[ e_t = e_{t+1} - \frac{\gamma \delta}{\lambda} e_{t-1} - \frac{1}{\lambda} (1 - \gamma \delta - \frac{\gamma \theta}{\lambda}) p_{t-1} + \frac{1}{\lambda} m_t - \frac{1}{\lambda} \frac{\gamma \theta}{\lambda} m_{t-1} \]
\[ - \frac{\delta}{\lambda} x_t - \frac{1}{\lambda} \gamma (\alpha - \frac{\gamma \theta}{\lambda} - 1) y_{t-1} - \frac{1}{\lambda} z_{t-1} + \frac{1}{\lambda} \frac{\gamma \theta}{\lambda} - \frac{1}{\lambda} w_t \]  
(A.1)

It is useful to know the final solution of \( e_t \) will have the form:
\[ e_t = \Pi_1 e_{t-1} + \Pi_2 p_{t-1} + \Pi_3 m_t + \Pi_4 m_{t-1} + \Pi_5 y_t + \Pi_6 y_{t-1} + \Pi_7 z_t + \Pi_8 z_{t-1} \]
\[ + \Pi_9 w_t \]
Hence,
\[ E_t e_{t+1} = \Pi_1 e_t + \Pi_2 e_{t-1} + (\Pi_3 + \Pi_4) m_t + (\Pi_5 + \Pi_6) y_t + \Pi_8 z_t \]
\[ = \Pi_1 e_t + \Pi_2 \gamma \delta e_{t-1} + \Pi_2 (1 - \gamma \delta - \frac{\gamma \theta}{\lambda}) p_{t-1} + (\Pi_3 + \Pi_4) m_t \]
\[ + \Pi_2 \frac{\gamma \theta}{\lambda} m_{t-1} + (\Pi_5 + \Pi_6) y_t + \Pi_2 \gamma (\alpha - \frac{\gamma \theta}{\lambda} - 1) y_{t-1} \]
\[ + \Pi_8 z_t - \Pi_9 \frac{\gamma \theta}{\lambda} z_{t-1} + \Pi_9 w_t \]  
(A.2)

Substituting (A.2) into (A.1) and rearranging yields the following reduced form exchange rate equation.
\[ e_t = \frac{\gamma \delta (\Pi_2 - 1)}{1 - \Pi_1} e_{t-1} + \frac{(1 - \gamma \delta - \frac{\gamma \theta}{\lambda} - \Pi_2 - 1)}{1 - \Pi_1} p_{t-1} \]
\[ + \frac{\Pi_3 + \Pi_4 + \frac{1}{\lambda}}{1 - \Pi_1} m_t + \frac{\delta (\Pi_2 - 1)}{1 - \Pi_1} m_{t-1} + \frac{\Pi_5 + \Pi_6 - \frac{\delta}{\lambda}}{1 - \Pi_1} y_t \]
\[ + \frac{\gamma (\alpha - \frac{\gamma \theta}{\lambda} - 1)(\Pi - 1)}{1 - \Pi_1} y_{t-1} + \frac{\Pi_8 - \frac{\gamma \theta}{\lambda}}{1 - \Pi_1} z_t \]
For rationality, the equalities given in the text should hold.
Appendix B

In this Appendix, we show the appropriate root of the quadratic equation is $\Pi_{12} < 0$ for the price equation to be stable. To do this, we rewrite the exchange rate equation as following.

$$e_t = \frac{\Pi_2 - \frac{1}{\Pi_1}}{1 - \Pi_1} \left( (1 - \gamma \delta - \frac{\gamma \theta}{\lambda}) p_{t-1} + \gamma \delta e_{t-1} + \frac{\gamma \theta}{\lambda} m_{t-1} \right. $$

$$ + \gamma (\sigma - \frac{\theta \phi}{\lambda} - 1) y_{t-1} - \frac{\gamma \theta}{\lambda} z_{t-1} + w_t \right) + \frac{\Pi_3 + \Pi_4 + \frac{1}{\Pi_1}}{1 - \Pi_1} m_t $$

$$ + \frac{\Pi_5 + \Pi_6 - \frac{\phi}{\lambda}}{1 - \Pi_1} y_t - \frac{\Pi_8 - \frac{1}{\Pi_1}}{1 - \Pi_1} z_t$$

Since the terms in the square bracket simply imply the price equation, the exchange rate equation can be written as:

$$e_t = \frac{\Pi_2 - \frac{1}{\Pi_1}}{1 - \Pi_1} p_t + \frac{\Pi_3 + \Pi_4 + \frac{1}{\Pi_1}}{1 - \Pi_1} m_t + \frac{\Pi_5 + \Pi_6 - \frac{\phi}{\lambda}}{1 - \Pi_1} y_t$$

$$+ \frac{\Pi_8 - \frac{1}{\Pi_1}}{1 - \Pi_1} z_t$$

For the stability of the price equation, the first difference of prices should be stationary under certain parameter restrictions. That is, the coefficient of $p_t$ in the following equation should lie between minus one and one.

$$p_{t+1} = (1 - \gamma \delta - \frac{\gamma \theta}{\lambda}) p_t + \gamma \delta e_t + \frac{\gamma \theta}{\lambda} m_t + \gamma (\sigma - \frac{\theta \phi}{\lambda} - 1) y_t$$

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\[-\frac{\gamma \theta}{\lambda} z_t + w_t \]
\[= ((1 - \gamma \delta - \frac{\gamma \theta}{\lambda}) + \frac{\gamma \delta (\pi_2 - \frac{1}{\lambda})}{1 - \pi_1}) p_t + \ldots \]
\[-1 < 1 - \gamma \delta - \frac{\gamma \theta}{\lambda} + \frac{\gamma \delta (\pi_2 - \frac{1}{\lambda})}{1 - \pi_1} < 1 \]
\[-(1 + (1 - \gamma \delta - \frac{\gamma \theta}{\lambda})) \pi_1 = \frac{\gamma \delta (\pi_2 - \frac{1}{\lambda})}{1 - \pi_1} < \gamma \delta + \frac{\gamma \theta}{\lambda} \]

Therefore, \(\pi_1\) should be less than \(\gamma \delta + \frac{\gamma \theta}{\lambda}\). So we rule \(\pi_{11}\) out and take \(\pi_{12}\) as a potentially stable root.

We will show the constraints on other \(\pi_i\)'s.

1. From the solution to \(\pi_i\)'s, it is obvious \(\prod_{i=1}^{4} \pi_i = 1\). We know that \(\pi_2 - \frac{1}{\lambda} < 0\) from the solution to \(\pi_1\).

2. \(\pi_2\)
   \[\pi_2 = \frac{(1 - \gamma \delta - \frac{\gamma \theta}{\lambda})(\pi_2 - \frac{1}{\lambda})}{1 - \pi_1} < 0\]

3. \(\pi_3\)
   \[\pi_3 = \frac{\pi_2 + \pi_4 + \frac{1}{\lambda}}{1 - \pi_1} = \frac{1 - \pi_1 - \pi_2 + \frac{1}{\lambda}}{1 - \pi_1} = 1 - \frac{\pi_2 - \frac{1}{\lambda}}{1 - \pi_1} > 1\]
   That \(\pi_3 > 1\) implies the short-run overshooting.

4. \(\pi_4\)
   \[\frac{\gamma \theta}{\lambda} (\pi_2 - \frac{1}{\lambda}) \pi_1 = \frac{\gamma \theta - \frac{1}{\lambda}}{1 - \pi_1} < 0\]
5. \( \pi_5 \)

\[
\pi_5 = \frac{\pi_5 \pi_6 - \phi}{1 - \pi_1}
\]

\[
\pi_5 = \frac{\pi_6 - \phi}{\lambda} - \frac{\gamma(\sigma - \frac{\theta \phi}{\lambda} - 1)(\pi_2 - \frac{1}{\lambda}) - \frac{\phi}{\lambda}(1 - \pi_1)}{\pi_1(1 - \pi_1)} < 0
\]

6. \( \pi_6 \)

\[
\pi_6 = \frac{\gamma(\sigma - \frac{\theta \phi}{\lambda} - 1)(\pi_2 - \frac{1}{\lambda})}{1 - \pi_1} < 0
\]
Appendix C

In this Appendix, we derive the overidentifying restrictions for the monetary model. To do this, we rewrite the system of equations as the following with the assumption that the values of $A_1$ and $B_1$ equal to unity.

\begin{align*}
m_t &= A_0 + A_1 m_{t-1} + u_t \\
y_t &= B_0 + B_1 y_{t-1} + v_t \\
r_t &= C_0 + C_1 y_t + C_2 m_t + C_3 p_t + z_t \\
p_t &= D_0 + D_1 p_{t-1} + D_2 e_{t-1} + D_3 m_{t-1} + D_4 y_{t-1} + z_t \\
e_t &= \pi_0 + \pi_1 e_{t-1} + \pi_2 p_{t-1} + \pi_3 m_t + \pi_4 m_{t-1} + \pi_5 y_{t-1} + \pi_6 y_{t-1} + z_t \end{align*}

where

\begin{align*}C_1 &= \frac{\phi}{\lambda} \\
C_2 &= -\frac{1}{\lambda} \\
C_3 &= \frac{1}{\lambda} \\
D_1 &= 1 - \gamma \delta - \frac{\gamma \theta}{\lambda} \\
D_2 &= \gamma \delta \\
D_3 &= \frac{\gamma \theta}{\lambda} \\
D_4 &= \gamma (a - \frac{\theta \phi}{\lambda} - 1) \\
\Pi_1 &= \frac{\pi_2 \gamma \delta - \frac{\gamma \delta}{\lambda}}{1 - \Pi_1} \end{align*}
In these expressions, we have 5 unknown structural parameters, $\lambda$, $\phi$, $\gamma_0$, $\gamma\theta$ and $\gamma(\alpha - 1)$.

Since $\gamma_0$, $\gamma\theta$ and $\gamma(\alpha - 1)$ are not separable, they are treated as single parameters. We have 13 estimated coefficients except for the constant terms. Therefore, we need 8 independent restrictions for the structural parameters to be exactly identified.

Let $\lambda = \frac{1}{c_3}$, $\gamma_0 = d_2$, then $\phi = \frac{c_1}{c_3}$, $\gamma\theta = \frac{d_3}{c_3}$

and $\gamma(\alpha - 1) = d_4 + \frac{c_1 d_2}{c_3}$

Then other equalities provide extra information for these parameters. So we have the following overidentifying restrictions.

\[
\begin{align*}
C_2 + C_3 &= 0 \\
D_1 + D_2 + D_3 &= 1 \\
\Pi_1 (1 - \Pi_1) &= D_2 (\Pi_2 - C_3) \\
\Pi_2 (1 - \Pi_1 - D_1) &= -C_3 D_1
\end{align*}
\]
\[ \Pi_3 = 1 - \Pi_1 - \Pi_2 - \Pi_4 \]
\[ \Pi_4 (1 - \Pi_1) = D_3 (\Pi_2 - C_3) \]
\[ -\Pi_1 \Pi_5 = \Pi_6 - C_1 \]
\[ \Pi_6 (1 - \Pi_1) = D_4 (\Pi_2 - C_3) \]
Appendix D

Equating equation (3.12) with (3.13), we obtain

\[ n \left( E_t e_{t+1} - E_t e_t - e_t + e_{t-1} - r_t + r_{t-1} \right) = \alpha \left( e_t - p_t \right) - \beta y_t + x_t \]  \hfill (D.1)

Substituting (3.2) and (3.5) into (D.1) and rearranging yields:

\[
\begin{align*}
\alpha m & = -\frac{n}{\alpha + n} E_t e_{t+1} - \frac{n}{\alpha + n} E_t e_t + \frac{n}{\alpha + n} e_{t-1} \\
& \quad - \left( \frac{n/\lambda - \alpha}{\alpha + n} \right) \frac{y_t}{\lambda} e_{t-1} - \frac{\left( n/\lambda - \alpha \right) \left( 1 - \gamma_0 - \gamma \right)}{\alpha + n} p_{t-1} \\
& \quad + \left( \frac{n/\lambda}{\alpha + n} \right) p_{t-1} + \left( \frac{n/\lambda}{\alpha + n} \right) m_t - \frac{\left( n/\lambda - \alpha \right) \left( 1 - \gamma_0 - \gamma \right)}{\alpha + n} m_{t-1} \\
& \quad - \frac{n/\lambda}{\alpha + n} m_{t-1} - \frac{n/\lambda}{\alpha + n} y_t + \frac{\beta}{\alpha + n} y_t \\
& \quad - \frac{\left( n/\lambda - \alpha \right)}{\alpha + n} \frac{Y}{\lambda} \left( \frac{\beta}{\alpha + n} - 1 \right) \\
& \quad - \frac{\left( n/\lambda - \alpha \right)}{\alpha + n} \frac{Y}{\lambda} y_{t-1} + \frac{n/\lambda}{\alpha + n} \frac{Y}{\lambda} y_{t-1} \\
& \quad - \frac{n/\lambda}{\alpha + n} z_t + \frac{n/\lambda}{\alpha + n} z_{t-1} + \frac{n/\lambda}{\alpha + n} z_{t-1} \\
& \quad - \frac{1}{\alpha + n} x_t - \left( \frac{n/\lambda - \alpha}{\alpha + n} \right) w_t
\end{align*}
\]  \hfill (D.2)

Again it is helpful to know the final solution to \( e_t \) will have the form:

\[
e_t = \sum_{i=1}^{10} \pi_i e_{t-i} + \pi_2 p_{t-1} + \pi_3 m_t + \pi_4 m_{t-1} + \pi_5 y_t + \pi_6 y_{t-1} + \pi_7 z_t \\
+ \pi_8 z_{t-1} + \pi_9 x_t + \pi_{10} w_t
\]
Thus,

\[ E_{t+1} e_t = \Pi_1 e_t + \Pi_2 p_t + (\Pi_3 + \Pi_4) m_t + (\Pi_5 + \Pi_6) y_t + \Pi_8 z_t \]  
\[ \text{(D.3)} \]

\[ E_{t-1} e_t = \Pi_1 e_{t-1} + \Pi_2 p_{t-1} + (\Pi_3 + \Pi_4) m_{t-1} + (\Pi_5 + \Pi_6) y_{t-1} + \Pi_8 z_{t-1} \]  
\[ \text{(D.4)} \]

Substituting (D.3) and (D.4) into (D.2) and rearranging yields the final solution of \( e_t \) given in the text.
Appendix E

In this appendix, we will provide a graphical method of the solution to \( \Pi_1' \) and show the constraints on the other \( \Pi_1' \)'s. For notational convenience, some substitutions are made.

\[
C_1 = \frac{\phi}{\lambda} \\
C_3 = \frac{1}{\lambda} \\
D_1 = 1 - \gamma\delta - \frac{\gamma\delta}{\lambda} \\
D_2 = \gamma\delta \\
D_3 = \frac{\gamma\delta}{\lambda} \\
D_4 = \gamma(\alpha - \frac{\theta\phi}{\lambda} - 1) \\
D_5 = \frac{\alpha}{\eta} \\
D_6 = \frac{\delta}{\eta}
\]

1. \( \Pi_1' \) and \( \Pi_2' \):

\[
\Pi_1' = \frac{\eta \left( 1 - \Pi_1' + \Pi_2' \gamma\delta - \left( \frac{1}{\lambda} - \frac{\alpha}{\eta} \right) \gamma\delta \right)}{\alpha + \eta \left( 1 - \Pi_1' \right)}
\]
In this expression, 
\[ \Pi_2(0) = C_3 - \left( \frac{1}{D_2} + D_5 \right) > 0, \] and \[ 1 + \frac{D_5}{2} > 1. \]

And, 
\[ \Pi_2' = \frac{D_2 \Pi_2 - \Pi_2 - D_1 (C_3 - D_5) + C_3}{D_5 + 1 - \Pi_1} \]
\[ \Pi_2' (\Pi_1 - 2 + D_1 - D_5) = C_3 (D_1 - 1) - D_1 D_5 < 0 \quad ---- (E.2) \]

From equation (E.2), we obtain the following two asymptotes.
\[ \Pi_2' = 0 \quad \text{and} \quad \Pi_1' = 1 + (D_1 - 1) + D_5 > 1 \]

In the graph, the only stable root is \( \Pi_1' < 1 \), hence \( \Pi_2' > 0 \).

2. \( \Pi_3' \)
\[ \Pi_3' + \Pi_4' = \frac{D_3 \Pi_3 - D_3 D_4 + D_3 D_5}{D_5 + (1 - \Pi_1)} \]
\[ D_3 \Pi_2' = \frac{C_3 D_3 - C_3 D_1 D_3 + D_1 D_3 D_5}{D_5 + (1 - \Pi_1) + (1 - \Pi_1)} \]
\[ \Pi_3' + \Pi_4' = \frac{1}{D_5 + (1 - \Pi_4') \left( D_5 + (1 - \Pi_4') + (1 - D_4) \right)} \]
\[ / \left( C_3 D_3 - C_3 D_1 D_3 + D_1 D_3 D_5 - C_3 D_3 D_5 - C_3 D_5 + C_3 D_1 D_3 \right) \]
\[ -C_3 D_3 \left( 1 - \Pi_4' \right) + D_3^2 D_5^2 + D_3 D_5 - D_1 D_3 D_5 + D_3 D_5 \left( 1 - \Pi_4' \right) \]

Let \( \Delta = \left( D_5 + \left( 1 - \Pi_1' \right) \right) \left( D_5 + \left( 1 - \Pi_1' \right) + \left( 1 - D_1 \right) \right) \)

then,

\[ \Pi_3' + \Pi_4' + C_3 = \frac{1}{\Delta} \left( C_3 \left( 1 - \Pi_1' \right)^2 + \left( D_3 D_5 + 2C_3 D_5 \right) \right. \]

\[ + C_3 D_2 \left( 1 - \Pi_1' \right) + D_3^2 D_5^2 + D_3 D_5 + C_3 D_5^2 + C_3 D_2 D_5 \] > 0

\[ \Pi_3' = \frac{\Pi_3' + \Pi_4' + C_3}{D_5 + \left( 1 - \Pi_1' \right)} > 0 \]

\[ \Pi_3' > 0 \]

3. \( \Pi_4' \)

\[ \Pi_4' = \frac{D_3 \Pi_2' - \left( \Pi_3' + \Pi_4' + C_3 \right) - C_3 D_3 + D_3 D_5}{D_5 + \left( 1 - \Pi_1' \right)} \]

\[ \Pi_4' = \frac{D_3 \Pi_3' + \left( \Pi_3' + C_3 \right) - C_3 D_3 + D_3 D_5}{\left( 1 + D_5 \right) + \left( 1 - \Pi_1' \right)} < 0 \]

\[ \Pi_4' > 0 \]

4. \( \Pi_5' \)

\[ \Pi_5' + \Pi_6' = \frac{D_6 + D_4 \left( \Pi_2' - C_3 + D_5 \right)}{D_5 + \left( 1 - \Pi_1' \right)} \]

\[ \Pi_5' = \frac{D_6 + D_4 \left( \Pi_2' - C_3 + D_5 \right) - \left( C_1 - D_6 \right) \left( D_6 + D_4 \left( \Pi_2' - C_3 + D_5 \right) \right)}{\left( D_5 + \left( 1 - \Pi_1' \right) \right)^2} \]

\[ \Pi_5' > 0 \]

5. \( \Pi_6' \)

\[ \Pi_6' = \frac{\Pi_2 D_4' - \left( \Pi_5' + \Pi_6' \right) - D_4 \left( C_3 - D_5 \right) + C_4}{D_5 + \left( 1 - \Pi_1' \right)} \]
\[
\left( D_4 \left( \pi_2' - c_3 + a_2 \right) + c_1 \right) \left( D_5 + (1 - \pi_1') \right) - \left( D_6 + D_4 (\pi_2' - c_3 + a_2 \right)
\]

\[
\left( D_5 + (1 - \pi_1') \right)^2
\]

\[\pi_6' > 0\]

\[\pi_6 < 0\]
Fig. 1 Graphical Solution of $\Pi_1$
In this Appendix, we derive the overidentifying restrictions for the stock/flow model.

\[ m_t = A_0 + A_1 m_t + u_t \]
\[ y_t = B_0 + B_1 y_t + v_t \]
\[ r_t = C_0 + C_1 y_t + C_2 m_t + C_3 t + z_t \]
\[ p_t = D_0 + D_1 p_{t-1} + D_2 y_{t-1} + D_3 m_{t-1} + D_4 y_{t-1} + z_t \]
\[ e_t = \Pi_0 + \Pi_1 e_{t-1} + \Pi_2 p_{t-1} + \Pi_3 y_{t-1} + \Pi_4 m_{t-1} + \Pi_5 y_{t-1} + \Pi_6 y_{t-1} + z_t \]

where

\[ C_1 = \frac{\phi}{\lambda} \]
\[ C_2 = -\frac{1}{\lambda} \]
\[ C_3 = \frac{1}{\lambda} \]
\[ D_1 = 1 - \gamma \delta - \frac{\gamma \theta}{\lambda} \]
\[ D_2 = \gamma \delta \]
\[ D_3 = -\frac{\gamma \theta}{\lambda} \]
\[ D_4 = \gamma \left( \frac{\alpha - \beta \phi}{\lambda} - 1 \right) \]
\[ \Pi_1 = \frac{(1 - \Pi_1) + \Pi_2 \gamma \delta - \left( \frac{1}{\lambda} - \frac{\alpha}{\eta} \right) \gamma \delta}{\frac{\alpha}{\eta} + (-1 - \Pi_1)} \]
In these expressions, we have 7 structural parameters, $\lambda$, $\phi$, $\gamma_0$, $\gamma_0$, $\gamma(\alpha - 1)$, $\frac{\alpha}{\lambda}$, $\frac{\beta}{\lambda}$ and 13 estimated coefficients (except for constant terms). So, we need 6 independent restrictions.

Let $\lambda = \frac{1}{C_3}$, $\gamma_0 = D_2$ and $\gamma(\alpha - \frac{\theta Y}{\lambda} - 1) = D_4$.

then $\phi = C_1/C_3$, $\gamma_0 = D_3/C_3$ and $\frac{\alpha}{\lambda}$ is calculated from $\Pi'$. That is,

$$\left( \frac{\alpha}{\lambda} + (1 - \Pi') \right) \Pi' = (1 - \Pi' \Pi') + \Pi' Y_0 - (\frac{1}{\lambda} - \frac{\alpha}{\lambda}) Y_0$$

$$\frac{\alpha}{\lambda} = \frac{(1 - \Pi')^2 + \Pi' D_2 - C_2 D_2}{\Pi' - D_2}$$

Other equalities not used for the identification of the structural parameters provide extra information. So we obtain the following overidentifying restrictions.

$$C_2 + C_3 = 0$$
\[ D_1 + D_2 + D_3 = 1 \]
\[ \Pi_2' = 1 - \Pi_1' - \Pi_3' - \Pi_4' \]
\[ \Pi_3'( (1 - 2\Pi_1') + D_2 (\Pi_1' + \Pi_2' - c_3') ) = (\Pi_1' - D_2') (\Pi_4' + c_3') \]
\[ \Pi_4'( 1 + D_2 (\Pi_1' + \Pi_2' - c_3' - 2) ) = \Pi_1'D_3 (\Pi_1' + \Pi_2' - c_3' - 2) + (\Pi_2' + D_3') (D_2' - \Pi_1') + D_3' \]
\[ \Pi_6'( 1 + D_2 (\Pi_1' + \Pi_2' - c_3' - 2) ) = \Pi_1'D_4 (\Pi_1' + \Pi_2' - c - 2) + (\Pi_5' - c_1') (c_2' - \Pi_1') + D_4' \]
1. The constrained monetary model and estimates

\[ m_t = A_0 + A_1 m_{t-1} \]
\[ y_t = B_0 + B_1 y_{t-1} \]
\[ r_t = C_0 - \frac{1}{\lambda} m_t + \frac{1}{\lambda} p_t + \frac{1}{\lambda} y_t \]
\[ p_t = D_0 + (1 - \gamma \delta - \gamma \theta / \lambda) p_{t-1} + \gamma \delta e_{t-1} + \frac{\gamma \theta}{\lambda} m_{t-1} \]
\[ e_1 = \pi_0 + \pi_1 e_{t-1} \]
\[ - \left\{ \frac{((1 - \gamma \delta - \gamma \theta / \lambda) / \lambda) / (-\pi_1 + \gamma \delta + \gamma \theta / \lambda)}{1 - \pi_1 - \pi_1} \right\} p_{t-1} \]
\[ + \left\{ \frac{((1/\lambda)(-\pi_1 + \gamma \delta + (\gamma \theta / \lambda)(1 - A_1)) / (1 - \pi_1 - \pi_1)}{1 - \pi_1 - \pi_1} \right\} m_t \]
\[ - \left\{ \frac{(1/\lambda) (\gamma \theta / \lambda) / (-\pi_1 + \gamma \delta + \gamma \theta / \lambda)}{1 - \pi_1 - \pi_1} \right\} m_{t-1} + T^* D + \rho z_{t-1} \]

\[ \pi_1 (\text{given}) = -0.7 \]
\[ A_0 = 0.214 (0.079) \]
\[ A_1 = 0.899 (0.038) \]
\[ B_0 = 0.012 (0.007) \]
\[ B_1 = 0.880 (0.066) \]
\[ C_0 = 2.351 (0.542) \]
\[ \phi = 2170.51 (31428.9) \]
\[ \lambda = 68.162 (987.043) \]
2. The constrained stock/flow model and estimates

\[ m_t = A_0 + A_1 m_{t-1} \]
\[ y_t = B_0 + B_1 y_{t-1} \]
\[ r_t = C_0 - \frac{1}{\lambda} m_t + \frac{1}{\lambda} \rho_t + \frac{\phi}{\lambda} y_t \]
\[ p_t = D_0 + (1 - \gamma \delta - \gamma \theta / \lambda) p_{t-1} + \gamma \delta e_{t-1} + \frac{\gamma \theta}{\lambda} m_{t-1} \]
\[ e_t = \Pi_0 + \Pi_1 e_{t-1} \]
\[ + \left( \left( \frac{1}{\lambda} \right) \left( \gamma \delta + \gamma \theta / \lambda \right) + \frac{\phi}{\lambda} \right) \left( 1 - \gamma \delta - \gamma \theta / \lambda \right) / \]
\[ (1 - \Pi_1 + \frac{\phi}{\lambda} - \gamma \delta + \gamma \theta / \lambda) p_{t-1} \]
\[ + \left( \left( \gamma \delta / \lambda \right) \left( -\frac{\phi}{\lambda} - \frac{\phi}{\lambda} - 1 / \lambda \right) \left( 1 - \Pi_1 + \frac{\phi}{\lambda} \right) \right) \]
\[ + \left( \frac{1}{\lambda} \right) \left( 1 - \Pi_1 + \frac{\phi}{\lambda} \right) \]
\[ \times \left( 1 - \Pi_1 + \gamma \delta + \gamma \theta / \lambda + \frac{\phi}{\lambda} \right) / (1 - \Pi_1 + \frac{\phi}{\lambda}) \left( 2 - \Pi_1 + \frac{\phi}{\lambda} - A_1 \right) \]
\[ \times \left( 1 - \Pi_1 + \gamma \delta + \gamma \theta / \lambda + \frac{\phi}{\lambda} \right) m_t \]
\[ + \left( \left( \gamma \theta / \lambda \right) \left( -\frac{\phi}{\lambda} - \frac{\phi}{\lambda} - 1 / \lambda \right) \left( 1 - \Pi_1 + \frac{\phi}{\lambda} \right) \right) \]
\[ \times \left( 1 - \Pi_1 + \frac{\phi}{\lambda} - A_1 \right) - \left( 1 / \lambda \right) \left( 1 - \Pi_1 + \frac{\phi}{\lambda} \right) \]
\[ \times \left( 1 - \Pi_1 + \gamma \delta + \gamma \theta / \lambda + \frac{\phi}{\lambda} \right) \times \left( 1 - \Pi_1 + \gamma \delta + \gamma \theta / \lambda + \frac{\phi}{\lambda} \right) m_{t-1} \]
\[ + T \times D + \rho z_{t-1} \]

\[ \Pi_1 \text{ (given)} = 0.5 \]

\[ A_0 = 0.164 (0.076) \]
\[ A_1 = 0.923 (0.036) \]
\[ B_0 = 0.012 (0.007) \]
\[ B_1 = 0.889 (0.067) \]
\[ C_0 = 12.769 (2.711) \]
\[ \phi = 5.716 (1.464) \]
\[ \lambda = 0.175 (0.046) \]
\[ D_0 = -0.334 (0.156) \]
\[ \gamma_6 = 0.098 (0.007) \]
\[ \gamma_8 = -0.001 (0.015) \]
\[ \Pi_0 = 1.955 (13.758) \]
\[ \frac{\alpha}{\eta} = 0.048 (0.084) \]
\[ T = 0.035 (0.010) \]
\[ \rho = 0.914 (0.092) \]

log of likelihood function : 233.230
Bibliography


----------, 'Recent Developments in Monetary Models of Exchange Rate Determination', IMF Staff Papers, June 1979, 26: 201-223.


---------- and S. A. McCafferty, 'Spot and Forward Rates in a Stochastic Model of the Foreign Exchange Market', J. Int. Econ.,


----------------------------------, "Some Evidence in Favor of a Monetary Rational Expectations Exchange Rate Model", mimeo

Fama,E.F., "Forward and Spot Exchange Rates", J. of Monetary Economics, November 1984, 14:319-338


----------, "Monetary and Portfolio-Balance Models of Exchange Rate Determination", in J.S.Bhandari and B.H.Putnam, eds., Economic Interdependence and Flexible Exchange Rates, MIT press


Gordon,R.J., "The Short-Run Demand for Money: A Reconsideration", J. of Money, Credit and Banking, November 1984, 403-434


