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THE IMPACT OF MONETARY POLICY ON THE FOREIGN EXCHANGE MARKET:
I. THE UNANTICIPATED CHANGE IN THE MONEY SUPPLY
II. THE CHANGE IN THE U.S. MONETARY POLICY REGIME

DISSERTATION

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

By
Hwan Ho Lee, B.A., M.A.

* * * * *

The Ohio State University
1986

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To My Parents
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Our experiences with the floating exchange rate system introduced among major industrialized countries in March 1973 have been surprising to foreign exchange market participants, international economists and policy makers in many respects. Two of the most notable characteristics of the floating exchange rate period are the high volatility of exchange rates, i.e., the deviation of spot exchange rates from purchasing power parity (PPP) and their fluctuation, and the magnitude of the forward-rate forecast error. Moreover, volatility has become higher and its magnitude larger during the late 1970s and 1980s. This evidence is in conflict with the earlier general presumption that they would gradually decline as more experience was gained with the intricacies of the system, forward facilities expanded and became more differentiated, and other arrangements evolved to assist international trade and payments.

Volatility, until the late 1970s, had been broadly studied under the framework of the asset market approach to exchange rate determination. The asset market approach views exchange rates as the relative prices of assets (monies or bonds)\(^1\) rather than those of goods in the traditional flow market approach. Therefore, the asset market -

approach emphasizes the degree of capital mobility and the role of expectations about future events as the determinants of exchange rates. The earlier monetary model is developed on the basis of two key assumptions: flexible prices\(^2\) and perfect capital substitutability (uncovered interest parity).\(^3\) Dornbusch (1976) introduces the notion of a slow adjustment process in the goods markets relative to the asset market into the monetary model (the sticky-price monetary model). He predicts the deviation of current spot exchange rates from PPP in terms of the so-called overshooting hypothesis. That is, short-run exchange rates must overshoot, depreciating proportionally more than the expansion in money. During the adjustment period, exchange rates appreciate and prices rise monotonically toward a new long-run equilibrium, whereas trade balances exhibit a surplus (exchange rate dynamics). The empirical studies\(^4\) of this period are broadly consistent with the implications of the monetary approach.

Along with the development of the monetary approach to exchange rate determination, one of the key assumptions, that is, uncovered interest parity, has been extensively tested in terms of the simple 'efficient market hypothesis'. The hypothesis states that if economic

\(^2\) The flexible-price monetary model, which assumes the strict purchasing power parity, is well suited in the context of hyperinflation. See Frenkel (1978).

\(^3\) Frankel (1983) draws the distinction between perfect capital mobility between countries and perfect capital substitutability between domestic bonds and foreign bonds. The former term corresponds to covered interest rate parity, while the latter describes the uncovered interest rate parity.

\(^4\) For empirical studies on exchange rate determination models, see the review article by Horne (1983).
agents are risk neutral, transaction costs are zero, information is used rationally, and the market is competitive, the forward rate is the unbiased predictor of the future spot rate. The earlier empirical studies did not, in general, reject this hypothesis.

The apparent phenomena, which have emerged during 1978 and thereafter, have been an increased volatility of exchange rates and a correlation between exchange rates and the trade balance. Bigman and Lee (1984) investigate the variability of exchange rates by using their own coefficient of variation. They state:

By 1980 the tide had turned, and the years 1980 and 1981 saw unusual large change in the exchange rates of most key currencies. The variability of most exchange rates rose to or even surpassed the peak of 1978 and 1973-4 and remained at those high levels for most of the period.

Fama (1984) also reports findings on increased variability of spot exchange rates and forward-rate forecast errors and concludes that this is due to increased uncertainty in the later period. In addition, it is observed that during this turbulent period the U.S. trade balance experienced a deficit in 1978 when the dollar depreciated sharply and the currencies of Germany and Japan appreciated. The pattern was reversed in the years 1979 and 1980 [Frankel (1983)]. This phenomenon can be interpreted as the J-curve effect of the trade balance in the traditional flow approach [Wilson and Takacs (1980)].


---

5 See Levich (1979) for details on the concept of foreign exchange market efficiency and a survey of empirical results on earlier periods.
parameters, and find a structural break in 1979-1980, which coincides with a period of major policy changes in the U.S.A. They state:

These consisted of the well known switch in October 1979 from a federal fund operating strategy to a reserve strategy, and the Federal Reserve's March 1980 draining of bank reserves and imposition of credit controls. The major policy switches were made in an effort to gain control over money supply growth.

Empirical studies that try to update the monetary model to include the events of 1978 and 1979 are quite unsuccessful [Frankel (1983)]. A number of empirical studies on the efficient market hypothesis also report the systematic deviation of forward rates from the expected future spot rates. Provided that forward markets are efficient or rational, these deviations have been generally interpreted as the evidence of existence of a risk premium in the foreign exchange markets. The existence of a risk premium deeply influences the interpretation of the earlier monetary approach which assumed uncovered interest parity. This implies that forward exchange markets cannot be ignored in the determination of exchange rates.

The recent experience stimulated international monetary economists to re-examine the asset market approach to exchange rate determination and the simple efficient market hypothesis. Two main lines of approach to exchange rate determination are the portfolio balance approach and the stock/flow approach. Reflecting the correlation between exchange rates and the trade balance, both approaches bring the trade balance back into the analysis. The portfolio balance approach argues that

6 For an exposition and further references, see Frankel (1983) and Krueger (1983).
the trade balance affects exchange rates via its effect on asset holdings without reverting to the traditional flow approach. This approach observes that the counterpart of a trade surplus is a transfer of wealth from foreign residents to domestic residents. The proponents of this approach argue that the change in wealth affects exchange rates through the change in domestic expenditures, money or bond demand. The stock/flow approach [Niehans (1977), and Driskill (1981a)] synthesizes the traditional flow approach and the asset market approach. This approach reemphasizes the trade balance response to relative prices in the traditional approach together with imperfect asset substitutability.

With the breakdown of the simple efficient market hypothesis, focus turned to whether or not forward rates contain a time-varying risk premium, but did not lead to a general consensus. Frankel (1982a) and Engel and Frankel (1984b) fail to identify a risk premium, while Hansen and Hodrick (1983), Hodrick and Srivastava (1984), Fama (1984), Korajczyk (1985) and Mark (1985), among others, find evidence consistent with a time-varying risk premium.

With the introduction of forward markets in the stock/flow model, this dissertation investigates two issues concerning the impact of monetary policy on the foreign exchange markets. One is to re-examine exchange rate dynamics: how the expansion in money affects the adjustment of exchange rates, prices, and the trade balance in the short run and the intermediate run when the trade balance exhibits a J-curve effect. The other one is to examine how the change in the U.S.
monetary policy regime in October 1979 affects exchange rate volatility and the risk premium in foreign exchange markets.

The next chapter provides a review of the literature on this subject. The approaches to exchange rate determination are briefly compared and contrasted. We then focus on the studies on exchange rate dynamics and the interrelationship between spot and forward rates.

Chapter III introduces the basic model. There are four building blocks in the model: the foreign exchange market, the goods market, the money market, and the rational expectations assumption. The specification of the foreign exchange market follows the traditional flow approach, where traders, speculators and covered interest arbitrageurs interact in the spot and forward market [Tsiang (1956), Grubel (1966), and McCormick (1977)]. Since the speculative demand for forward contracts is a 'stock' demand rather than a 'flow' demand, we can emphasize the interaction of trade flow with stock demand [Driskill and McCafferty (1982)]. Following Dornbusch (1976), it is assumed that the goods market adjusts slowly relative to asset markets. The money market has a widely used form. Apart from an ad hoc expectational scheme, the assumption of rational expectations is endogenized and is solved by using the underlying structure of the model [Muth (1961), Black (1973), Driskill (1981a), and Driskill and McCafferty (1982)].

---

7 In spite of the popular belief that devaluation improves the trade balance, it might be worsened over the period of time immediately following devaluation.

8 This additional mechanism is suggested by Niehans (1984).

9 The speculative demand function can be derived from portfolio-balance theory.
Chapter IV focuses on exchange rate dynamics followed by unanticipated one-step increases in the money supply. We find that short-run exchange rates may not necessarily overshoot the new long-run equilibrium rate. The initial depreciation depends upon the parameter value of the model. During the period of adjustment, the exchange rate moves non-monotonically toward the long-run equilibrium rate because the absence of asset accumulation in new full stock/flow equilibrium requires a trade surplus in one period to be followed by a trade deficit in latter period. This finding is consistent with the implication of Niehans (1977), and Driskill (1981a). However, the sequence might be reversed if the trade balance exhibits a J-curve effect. The monetary expansion may be associated with the trade deficit or surplus, depending upon the degree of sensitivity of traders in spot and forward markets. The plausible story is that the sharp and successive depreciation is more likely to be associated with a trade deficit, like the experience of the U.S.A. in 1978. This picture is partial and complementary in the sense that this approach emphasizes the J-curve effect, while the portfolio balance approach emphasizes the wealth effect. Numerical simulation is performed to investigate how changes in the sensitivity of market participants affect short-run spot exchange rates.

Chapter V investigates the effect of the change in U.S. monetary policy regimes in October 1979 on foreign exchange markets. After endogenizing the money supply through the monetary authority’s reaction function, we show that the change in policy regimes is partly responsible for the higher volatility of exchange rates and the larger
magnitude of forward-rate forecast errors in 1980 and thereafter. This arises from the more risk-averse behavior due to the increase in the conditional forecast variance of exchange rates.

Chapter VI presents the descriptive statistics of exchange rates and empirical results of our test for a time-varying risk premium. The statistics show a higher volatility of exchange rates and a larger magnitude of forward-rate forecast errors in the latter period, which is consistent with the implication of the previous analysis. The analysis provides the estimation equation for testing for the existence of a time-varying risk premium and the structural change in the risk premium after the switch in U.S. monetary policy regimes. In order to improve the level of precision, we apply the Seemingly Unrelated Regression technique to take advantage of the fact that the disturbance terms are related across countries. Under the maintained hypothesis that the market assessment of the future spot rate in the forward rate are efficient or rational, the test results confirm both hypotheses.

The last chapter provides a summary of our main results, our conclusions, and potential directions for research in the future.
CHAPTER II
REVIEW OF THE LITERATURE

The main lines of approach to exchange rate determination will be briefly discussed and compared. Theoretical and empirical studies on exchange rate dynamics, the interrelationship between spot and forward exchange rates, and the effects of the change in the U.S. monetary policy regime are reviewed in order.

The theories of exchange rate determination and balance of payments have been developed parallel to the change in international financial or institutional environments. Historically, perhaps due to general restrictions of capital flows in the first two decades after World War II, the theories were largely confined to the analysis of the current account until the mid-1960's. Reflecting the fixed exchange rate system during the period, the elasticity approach and expenditure approach to the determination of balance of payments focused on the effect of devaluation on the trade balance. Partly because of earlier neglect, most of the works on exchange rate determination and balance of payments focused until the late 1970s on the analysis of capital flow. The monetary approach, which assumes

10 The determination of exchange rates is dual to that of balance of payments in the sense that under flexible exchange rate system exchange rate moves in order to keep balance of payment zero, but under fixed exchange rate system the money stock moves. For example, the duality of exchange rate and balance of payments determination in monetary approach is well explained by Frenkel and Mussa (1984).
perfect capital substitutability between domestic and foreign bonds, left no room for the trade balance effect on exchange rates. Along with the recent experience of the correlation between exchange rates and the trade balance, both the portfolio balance and stock/flow approaches emphasize the interactions between trade flows and capital flows in exchange rate determination.

In a fundamental sense, these approaches to exchange rate determination and the balance of payments\textsuperscript{11} are largely equivalent rather than mutually exclusive, but describe the same economic process in different terms and emphasize different aspects. For ease of exposition, the trade balance in national accounting can be written in the following three alternative ways:\textsuperscript{12}

\[ Y_t - A_t = X_t - I_t = \Delta B_t = \Delta M_t \]  \hspace{1cm} (1.1)

where

- \( Y \): national income
- \( A \): sum of expenditures on consumption, investment, and government expenditures
- \( X \): exports
- \( I \): imports
- \( \Delta B \): change in foreign asset holdings
- \( \Delta M \): change in cash balance

and subscript 't' denotes a period of time throughout this paper.

The elasticity approach, which focuses on the excess of exports over imports \((X_t - I_t)\), explains the reaction of the balance of payments

\textsuperscript{11} For an exposition and further references, see Niehans (1984), Krueger (1983) and Dornbusch (1980a).

\textsuperscript{12} This exposition is based on Niehans (1984).
to devaluation on the basis of the price elasticity of exports and imports. One of the major concerns of this approach is whether or not the foreign exchange market is dynamically stable when the trade balance exhibits the J-curve effect because of lags in production and consumption decisions regarding exports and imports [Britton (1970), Williamson (1973), and Driskill and McCafferty (1980b)].

In contrast, the expenditure approach, which focuses on the excess of income over expenditures \( (Y_t - A_t) \), explains the effect of a devaluation on the trade balance in terms of the determinants of aggregate supply and aggregate demand. This may be considered as an open-economy version of the Keynesian multiplier analysis, where the price level is usually treated as fixed. Both elasticity and expenditure approaches have common characteristics in that they emphasize the "flow" aspects of the balance of payments or exchange rates determination.

The monetary approach, the origin of which is based on the specie-flow mechanism, describes the impact of a devaluation on the trade balance in terms of the change in the real cash balance \( (\Delta M) \). Under a flexible exchange rate system, the approach emphasizes the pure stock aspect of exchange rate determination in which exchange rates adjust instantaneously to equate the existing stock to the desired level by assuming perfect substitutability between domestic and foreign bonds.\(^{13}\) This approach, therefore, effectively eliminates trade flows in

exchange rate determination.

The portfolio balance approach,\(^{14}\) which stresses the imperfect asset substitutability mainly due to exchange risk,\(^{15}\) has reintroduced the trade balance as an important determinant of exchange rates. The trade imbalance influences exchange rates through its effect on the net asset position (wealth), apart from the influences of exchange rates on the size of the trade balance. In this perspective, asset markets determine exchange rates at a point of time, but the trade balance determines the path of the exchange rates through asset accumulation or decumulation [Dornbusch and Fisher (1980)]. The net asset position affects exchange rate determination through domestic expenditure, domestic money demand, and the strong tendency to hold wealth in the form of domestic bonds.

The stock/flow approach re-emphasizes the terms-of-trade effect on the trade balance in the traditional flow approach together with capital flows. That is, exchange rates are determined where the trade imbalance, which is affected by the terms-of-trade, matches up with the capital flow [Niehans (1977), and Driskill (1980)]. In particular, Driskill (1981a) incorporated the trade balance response to relative prices into the asset market equilibrium model without considering the wealth effect.

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\(^{14}\) For exposition and further references, see Frankel(1983), and Krueger (1983).

\(^{15}\) There are a lot of reasons why domestic and foreign assets are imperfect substitutes: tax treatment, default risk, political risk, and exchange rate risk. However, under the assumption of perfect capital mobility, exchange rate risk is relevant in this context.
The above two approaches have common characteristics in that they bring the trade balance into the picture and emphasize the role of expectations. The monetary approach, as an extreme case of the portfolio approach, effectively eliminates the role of the trade balance from exchange rate determination. The portfolio balance and the stock/flow approaches emphasize the interaction between trade flows and capital flows but in a different manner. The trade flow affects exchange rates passively through the change in wealth in the portfolio balance approach, while the exchange rate moves to equate the trade balance to the capital flow in the stock/flow approach.

Since the advent of the floating exchange rate system in March 1973, exchange rates have shown highly volatile behavior. The large deviation of exchange rates from PPP stimulated interest in the theories of exchange rate dynamics. The exchange rate dynamics can occur in any model in which some markets do not adjust instantaneously.

One of the pathbreaking works was Dornbusch’s ‘overshooting hypothesis’ (1976). In contrast with the flexible-price monetary approach [Frenkel (1976) and Bilson (1978)], Dornbusch introduced the slow adjustment of prices in the goods market into the monetary model (sticky-price monetary approach). The short run exchange rate followed by an unanticipated one-step increase in the money supply must overshoot a new long-run equilibrium rate under the assumption of perfect capital substitutability and mean-regressing rational expectations. It is because the domestic interest rate falls relative to those abroad, and asset markets will be in balance only if the exchange rate initially overshoots, so that there are corresponding
expectations of currency appreciation. During the adjustment period, the spot exchange rate appreciates and prices increase monotonically toward a new long-run equilibrium value, but the trade balance maintains a surplus.

Calvo and Rodriguez (1977) explains the overshooting phenomenon in terms of the slowness of portfolio adjustment in the currency substitution model, which is a representative model of the portfolio balance approach. Faster money growth implies faster depreciation of exchange rates, which, with the rational expectation assumption, implies that individuals will shift their portfolio composition toward foreign currency. As the current account surplus gradually increases real wealth, the real exchange rate appreciates toward long run equilibrium.

Niehans' stock/flow model (1977), which assumes lagged asset adjustment, showed the possibility of overshooting or undershooting with monotonic and cyclical adjustment of exchange rates and prices. He emphasized that the trade balance has to exhibit both a surplus and a deficit during the adjustment period to keep net accumulation of foreign assets zero in full stock/flow equilibrium.

With the emphasis on the imperfect asset substitutability and rational expectations assumptions, Driskill (1981a) introduced the terms-of-trade effect on the trade balance into the asset market equilibrium model. He then showed that the short-run exchange rate does not necessarily overshoot the long-run equilibrium rate even when

\[ \text{16 In the Calvo-Rodriguez model, an unanticipated one-step increase in the money supply is neutral because the expected inflation rate, and hence the desired holding of foreign currency, is unaffected.} \]
the goods market adjusts slowly relative to the asset market. The degree of deviation of the short-run exchange rate from PPP depends upon the structural parameters of the model. He pointed out that the exchange rate adjusts nonmonotonically toward a new long run equilibrium because the trade balance moves from a surplus in the first period to a deficit in the other period.

Empirical studies of exchange rate determination\(^\text{17}\) will be briefly discussed. Frankel (1979), Bilson (1978), and Driskill (1981b) generally tended to support the monetary interpretation of exchange rates, which shows a long-run unitary positive response of exchange rates to the relative money supply between countries. In particular, Driskill estimated the adjustment pattern of exchange rates for the case of the U.S. dollar of Swiss francs, and showed that a one-time increase in the U.S. money supply tended to be followed by an overshooting of the Swiss francs in the proportion of 2.3 in the first quarter. However, data outside the sample period, for example when Frankel’s data period for the U.S. dollar-Deutsch mark rate is extended beyond 1978, showed poor performance or structural instabilities. Driskill and Sheffrin (1981) pointed out that the omission of across-equation restrictions implied by rational expectations results in inconsistent estimates and endogeneity of nominal interest differential results in biased estimates. McNeils and Condon (1984) reestimated Driskill’s stock/flow model with time-varying parameters. They showed that the structural break of the parameter coefficients in the

\[^{17}\text{See the review article of empirical studies on exchange rates determination by Horne (1983)}\]
stock/flow model are closely synchronized with change in economic policy rules. They were successful in identifying the 1979-80 break that coincides with the U.S. change in monetary policy regime and successive series of monetary measures. Recent studies by Hoffman and Schlagenhoff (1983) and Woo (1985) tested the cross-equation restrictions implied by the monetary model under rational expectations and found substantial support for the model, but Anderson (1985) pointed out a problem with their test due to over-differencing. Meanwhile, Wilson and Takacs (1980) attribute the perverse movement of trade balance of the trade balance during the years 1978 and 1979 to the J-curve effect and emphasized the existence of an import/export acceleration/deceleration. It says that the pattern of leads and lags in the trade flow behavior may initially reinforce the pure valuation effects of currency changes, and thereby exacerbate the J-curve for countries in trade balance disequilibrium.

Along with the theoretical development of exchange rate determination, one of the key assumptions in the monetary approach, i.e., uncovered interest parity, has been tested frequently in terms of the simple efficient market hypothesis. Early empirical studies by Frenkel (1977, 1979 and 1983), and Frankel (1980) generally supported this hypothesis. However, a growing literature reports the systematic deviation of the forward rate from the expected future spot rate [Hansen and Hodrick (1980), Bilson (1980), Hakkio (1981), and Fama (1984)]. The rejection of the hypothesis does not necessarily imply

18 For further reference, see review article by Levich (1979).
market inefficiency, because zero risk premium and market efficiency are jointly tested.

Current studies tend to focus on identifying the determinants of the risk premium theoretically and empirically while maintaining market efficiency. The existence of a risk premium, at an early stage, has been studied in the international asset pricing framework. [Kouri (1977), Dornbusch (1980b), Fama and Farber (1978), and Stulz (1983, 1984)]. The portfolio investors, who hold nominal bonds denominated in the domestic and foreign currencies, face different purchasing power risk of the currencies due to uncertainty about the future price level.

The issue of risk premium has been pursued along two lines. One is based on the portfolio balance approach, where investors optimize over the mean and variance of return. Frankel (1982a), and Engel and Frankel (1984) fail to identify a risk premium, which depends upon asset supplies and investors' risk aversion. The other relies on an intertemporal asset pricing model such as Lucas (1978, 1982) and Brock (1983). Hansen and Hodrick (1983), Hodrick and Srivastava (1984), and Mark (1985) find evidence of time variation of risk premia as the conditional covariance of speculative return and the marginal rate of substitution of money. The common characteristic of these studies is to assume risk-averse investors or speculators rather than risk-neutral ones in the monetary approach to exchange rate determination.

The evidence of the existence of a risk premium in the foreign exchange market deeply influences the monetary approach to exchange rate determination, which has been developed under the assumption of uncovered interest parity. This suggests that the determination of the
forward rate must be considered simultaneously together with the spot exchange rate. The traditional approach in the determination of spot and forward exchange rates has been carried out within the 'partial' equilibrium framework of the 'flow' market of foreign exchange, where commercial traders, speculators, and covered interest arbitraguers interact [Tsiang (1959), Grubel (1966), McCormick (1977)]. Driskill and McCafferty (1982), and Kawai (1984) reinterpreted the speculative demand as a 'stock' demand for foreign exchange rather than a 'flow' one in the traditional approach. However, since the sensitivity of speculative demand is treated as parametrically given, the implication of speculative demand as a stock demand is not fully explored.

The effect of the change in the U.S. monetary policy regime on financial markets has been studied more extensively in a closed economy context than in an open one. The studies reported that the adoption of money-supply oriented procedure has caused higher volatility of interest rates [Tinsley and others (1981)]. Huizinga and Mishkin (1985) found significant shifts in the stochastic process of real interest rate after October 1979. Walsch (1984) explained the increase in interest rate fluctuation, probably much larger than was expected, in terms of the structural changes in the behavioral relationships which characterize the financial sector. Truman and others (1981) find that the short run variability of exchange rates increased during the period after the adoption of the money-supply oriented procedure, but one-year forward exchange rate variability for

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some currencies was reduced. They discussed the effect of high exchange rate volatility on output, prices, the trade balance and capital flows, but Black (1982) reinterpreted their results from the viewpoint of government intervention in the foreign exchange market. However, their studies are descriptive and the interrelationship between the spot and forward rates is not considered.
CHAPTER III
BASIC STRUCTURE OF THE MODEL

The basic structure of the model is presented in this chapter. When necessary, it will be modified slightly in a tractable manner to focus on the respective issues.

For simplicity, the country pictured is assumed to be a small one which produces imperfectly substitutable goods viz-a-viz the rest of the world. It faces a perfectly elastic supply of imports at a fixed world price and a given world interest rate. Moreover, the domestic price level responds to excess demand in the goods market, which is assumed to adjust slowly relative to the asset market.20 The assumption of a small country and sticky-prices introduces the trade balance response to the terms-of-trade into our analysis. Following the traditional approach, it is assumed that there are three classes of market participants in the foreign exchange market. Each participant is assumed to have rational expectations in the sense that each makes unbiased forecasts on the basis of the knowledge of the structural parameters of the underlying model [Muth (1961)].

There are four building blocks of the model: the foreign exchange market, the money market, the goods market, and the rational

20 Meese (1984) showed empirically that the sticky price assumption is reasonable in exchange rate determination.
expectations assumption. All behavioral functions are specified in linear form and in discrete time.

3.1 THE FOREIGN EXCHANGE MARKET

There are three classes of participants in the foreign exchange market: commercial traders, speculators, and covered interest arbitrageurs. Following McCormick (1977) and Driskill and McCafferty (1982), the supply of (demand for) foreign exchange by each market participant is expressed in excess terms. This makes it easy to specify the foreign market exchange-clearing condition in a simple manner. For simplicity, all forward contracts are assumed to have a maturity of one period.

3.1.1 Traders

The supply of (demand for) foreign exchange by traders arises from selling (purchasing) goods and services to (from) foreign residents. The traders may avoid foreign exchange risk through the forward market. For example, upon entering into an agreement that entails the purchase or receipt of a certain amount of foreign exchange at a certain time, the traders may simultaneously enter into a contract to sell or purchase the required amount of foreign exchange at the specified date at some agreed upon exchange rate.

Excess supply by traders in the spot and forward markets, respectively, are assumed to be a function of the log of relative
prices between countries:

\[ T^S_t = -\alpha(e_t + P^*_t - P_t) + \mu_t \quad \alpha > 0 \] (3.1)

\[ T^F_t = \beta(e_t^*E_t^*P_{t+1}^* - E_tP_t) \quad \beta > 0 \] (3.2)

where \( T^S \): trade balance in the spot market

\( T^F \): trade balance in the forward market

\( \alpha \): the price elasticity of domestic output in the spot market

\( \beta \): the price elasticity of domestic output in the forward market

\( e \): logarithm of spot exchange rate (measured in terms of units of domestic currency per unit of foreign currency)

\( f \): logarithm of forward exchange rate

\( P \): logarithm of domestic price level

\( E \): conditional expectation operator

\( \mu \): serially uncorrelated random variable with zero mean and finite variance \( \sigma^2 \)

and \( * \) denotes the corresponding foreign variables throughout this paper.

The trade balance at time \( t \) is the sum of excess supply in the spot market and the previous period's excess supply in the forward market by traders \((T^S_t + T^F_{t-1})\). The excess demand \((\alpha > 0)\) by traders in the spot market represents the valuation or price effect, which means that depreciation may cause perverse impacts on the trade balance [Eq.(3.1)]. On the other hand, the excess supply by traders in the forward market, which is considered as hedging (elimination of exchange risk on future transactions), captures the volume effects because there are lags in the production process and consumption decisions regarding
exports and imports [Eq.(3.2)]. If the price effect dominates the valuation effect, depreciation creates a trade deficit (J-curve effect), and vice versa. Ideally, the real shock \( \mu_t \) might be specified in the goods markets. However it does not alter the qualitative results in this paper. The Marshall-Lerner condition requires that \( \beta - \alpha > 0 \) holds.

3.1.2 Speculators

The supply of (demand for) foreign exchange by speculators arises from attempts to profit from differences between the expected future spot rate and the forward rate. The excess demand by speculators in the forward market is assumed to be an increasing function of the differences:

\[
S^F_t = \eta (E_t e_{t+1} - f_t) \quad \eta = \frac{K}{\text{Var}(e_{t+1})} > 0 \quad (3.3)
\]

where \( S^F_t \): excess demand by speculators in the forward market

\( \eta \): the responsiveness of speculators to expected profits

\( K \): degree of risk aversion of speculators

and \( \text{Var}(e_{t+1}) \): conditional forecast variance of exchange rate.

---

21 Following Muth (1961), the utility of speculators can be written as a function of realized profits \( \pi_t \)

\[
U_t = f(\pi_t) \quad \text{where} \quad \pi_t = I_t (e_{t+1} - f_t)
\]

Taking expectation and approximating the utility function by Taylor's series expansion about the origin, we can obtain the following speculative position from expected utility maximization:

\[
I_t = - \frac{f'(0)(E_t e_{t+1} - f_t)}{f''(0)\text{Var}(e_{t+1})} = \frac{K(E_t e_{t+1} - f_t)}{\text{Var}(e_{t+1})}.
\]

where \( K = - \frac{f'(0)(E_t e_{t+1} - f_t)}{f''(0)} \)
The speculative demand function can be rigorously derived from maximization of the expected utility of speculative profits. Since the same form of the speculative demand for forward contracts can be derived from portfolio-balance theory in the mean-variance context, the speculative demand is considered as a 'stock' demand for forward contracts rather than a 'flow' demand. Note that \( \eta \) is inversely related to the conditional forecast variance of exchange rates.

3.1.3 Covered Interest Arbitrageurs

The demand by the covered interest arbitrageurs for foreign exchange arises from their desire to earn a higher rate of return on their capital and to diversify their portfolio by holding interest-bearing foreign securities covered against exchange risk. They can eliminate exchange risk during the investment period by purchasing foreign exchange in the spot market to acquire a foreign security and simultaneously selling an equal amount of the foreign exchange in the forward market.

The excess demand by covered interest arbitrageurs is assumed to be an increasing function of the covered-interest differential in the favor of foreign securities:

\[
B_t = \gamma (f_t - e_t + R^* - R_t) \quad \gamma > 0
\]  

(3.4)

where \( B_t \): excess demand by covered interest arbitrageurs in the spot market

\( \gamma \): sensitivity of covered interest arbitrageurs to the covered-interest differential
and \( R \) : nominal interest rate.

It is assumed that the covered interest arbitrageurs' schedule is perfectly elastic \((\gamma \rightarrow \infty)\). That is, covered interest parity \((f_t = e_t + R_t - R^*_t)\) holds. The empirical test by Frenkel and Levich (1977, 1981) has shown that with the allowance of transaction costs, covered interest parity holds to a high degree of approximation, at least in the Eurocurrency market.\(^{22}\) This assumption is also needed to solve a system of first-order stochastic difference equations [Driskill and McCafferty (1982)]. Therefore, the infinitely elastic interest-rate arbitrage fund moves to equate the excess demand and supply in the spot and forward market simultaneously.

3.1.4 Foreign Exchange Market—Clearing Condition

The excess demand by speculators in the forward market at time \( t \) is equal to the excess supply by speculators in the spot market at time \( t+1 \) [McCormick (1977)]. The excess demand by covered interest arbitrageurs in the spot market must equal their excess supply in the forward market.\(^{23}\) Therefore, the equilibriums in the spot and forward exchange market satisfy the following conditions, respectively:

\[
\begin{align*}
T^S_t + S^F_{t-1} &= B^S_t & \text{< spot market >} \\
B^F_t + T^F_{t} &= S^F_t & \text{< forward market >}
\end{align*}
\]

\(^{22}\) Covered interest parity holds less well if treasury bills, commercial papers, or other financial securities that differ from the forward contract with respect to tax treatment, default risk, or other factors [Frankel (1983)].

\(^{23}\) The accrued interest on foreign securities will be ignored.
Equating Eq. (3.5) to Eq. (3.6) by \( B^S_t = B^F_t \), and substituting a behavioral function [Eq.(3.1)-Eq.(3.4)] into the results, foreign exchange market-clearing condition is obtained as the following:

\[
\begin{align*}
-\alpha (e_t + P_t - P^*_t) + u_t + \eta (E_{t-1} e_t - f_{t-1}) + \beta (f_t + P_t P^*_{t+1} - E_t P_{t+1}) \\
= \eta (E^*_t e_{t+1} - f_t)
\end{align*}
(3.7)
\]

Using covered interest parity, i.e., \( f_t = e_t + R_t - R^*_t \), Eq. (3.7) can be rewritten as the following:

\[
\begin{align*}
e_t &= \frac{\eta}{-\alpha + \beta + \eta} e_{t-1} - \frac{\eta + \beta}{-\alpha + \beta + \eta} R_t + \frac{\eta}{-\alpha + \beta + \eta} R_{t-1} - \frac{\alpha}{-\alpha + \beta + \eta} P_t - \frac{1}{-\alpha + \beta + \eta} u_t \\
&\quad + \frac{\eta}{-\alpha + \beta + \eta} E_t e_{t+1} - \frac{\eta}{-\alpha + \beta + \eta} E_{t-1} e_t + \frac{\beta}{-\alpha + \beta + \eta} E^*_t P_{t+1} \\
&\quad + \frac{\alpha}{-\alpha + \beta + \eta} P^*_{t+1} - \frac{\beta}{-\alpha + \beta + \eta} E^*_{t+1} + \frac{\eta + \beta}{-\alpha + \beta + \eta} R^*_t - \frac{\eta}{-\alpha + \beta + \eta} R^*_{t-1}
\end{align*}
(3.8)
\]

In order to solve the exchange rate equation in a reduced form, we have to specify what governs interest rate and price. This will be considered in the next two sections.

### 3.2 The Money Market

The money market is specified in a widely used form. The domestic real demand for money is assumed to be linear in the nominal interest rate and real output:

\[
m^d_t = \phi y_t - \frac{1}{\lambda} R_t + \nu_t
(3.9)
\]

where \( m^d \) : logarithm of real demand for money

\( y \) : logarithm of real output

\( \phi \) : income elasticity of real money demand

\( \frac{1}{\lambda} \) : interest rate semi-elasticity of real money demand
and \( v_t \): a serially uncorrelated random variable with zero mean and finite variance \( \sigma^2_v \).

The domestic real supply of money is:

\[
m^s_t = M_t - P_t
\]

(3.10)

where \( m^s \): logarithm of real money supply

and \( M \): logarithm of the nominal money stock.

Therefore, the money market equilibrium is obtained by equating \( m^d_t \) to \( m^s_t \) as the following:

\[
M_t = P_t + \phi y_t - \frac{1}{\lambda} R_t + v_t
\]

(3.11)

3.3 The Goods Market and Price Adjustment

It is assumed that prices adjust slowly to clear the gap between aggregate demand and aggregate supply in the goods market. The actual rate of inflation consists of three components: an excess aggregate demand term, the publicly known money growth rate, and a random disturbance term:

\[
P_{t+1} - P_t = \delta(y^d_t - y_t) + g_t + \omega_{t+1}
\]

(3.12)

where \( \delta \): the speed of price adjustment

\( y^d \): logarithm of aggregate demand

\( y \): logarithm of aggregate supply

\( g \): publicly known money growth rate

and \( \omega_{t+1} \): serially uncorrelated random variable with zero mean and finite variance \( \sigma^2_\omega \).

The first term reflects the assumption that goods prices adjust gradually to an imbalance in the goods market [Dornbusch(1976)].
Aggregate demand can be expressed as a function of real income, real interest rates, and relative prices. The specification of aggregate demand will be slightly modified to keep the model tractable without a significant change of results. The second term shows the trend of the money growth rate, which is anticipated, must be fully reflected in each period's inflation. Therefore, the price adjustment scheme is composed of a predetermined or nonjumping variable that adjusts gradually to eliminate goods-market disequilibrium and a jumping variable which is related to the anticipated money growth rate [Dornbusch (1980b), and Obstfeld and Rogoff (1983)].
CHAPTER IV
THE EFFECT OF AN UNANTICIPATED CHANGE IN THE MONEY SUPPLY

This chapter reexamines the issues of exchange rate dynamics with the introduction of J-curve effect on the trade balance. The money supply is specified as an unanticipated one-step increase with a zero growth rate. After solving the price equation and foreign exchange equation as reduced forms under the rational expectations assumption, we investigate: i) whether or not the short-run exchange rate followed by the increase in money supply necessarily overshoots a new long-run equilibrium rate, ii) how exchange rates, prices and trade balance adjust in the intermediate run when the trade balance exhibits J-curve effects, and iii) how the change in the sensitivity of market participants affects volatility. In view of the complicated relationship among parameters in the reduced form solution of the exchange rate, the last issue is examined through numerical simulation.

4.1 THE STRUCTURE

The money supply is assumed to follow a random walk with a zero growth rate ($g_t=0$):

$$M_t - M_{t-1} = v_t$$

where $v_t$ is a serially uncorrelated error term with zero mean and a known finite variance $\sigma^2_v$.
This assumption makes all monetary changes unanticipated. The non-zero known growth rate of money supply would induce step increases in all nominal variables at every adjustment period.

In the goods market, aggregate demand \( y^d_t \) is assumed to be positively related to real output and negatively related to the real interest rate:

\[
y^d_t = \rho y_t - \sigma(R_t - (E_t P_{t+1} - P_t))
\]

where \( \rho \) : the income elasticity of aggregate demand and \( \sigma \) : the real interest rate semi-elasticity of aggregate demand.

Ideally, the trade balance, as a function of the relative price between countries, might be included in the aggregate demand function.24 The effect of inclusion of the trade balance on the price adjustment path will be intuitively explored later.

Suppressing constant terms, i.e., a fixed foreign price level and interest rate, the structure can be summarized as follows:

\[ \text{< Foreign exchange market equilibrium >} \]

\[-\alpha(e_t - P_t) + \mu_t + \eta(E_{t-1} e_t - f_{t-1}) + \beta(f_t - E_t P_{t+1}) = \eta(E_t e_{t-1} - f_t) \quad (4.3) \]

\[ \text{< Money market equilibrium >} \]

\[ M_t = P_t + \phi y_t - \frac{1}{\lambda} R_t + v_t \quad (4.4) \]

\[ \text{< Price adjustment in goods market >} \]

\[ P_{t+1} - P_t = \delta[\rho y_t - \sigma(R_t - (E_t P_{t+1} - P_t)) - y_t] + \omega_{t+1} \quad (4.5) \]

Note that the sensitivity of speculators (\( \eta \)) is treated as parametrically given in this analysis because the one-time increase in the money supply will not change the conditional variance of the exchange rate.

24 Driskill (1981a) disregards the terms-of-trade effect on aggregate demand for the simplification of the analysis.
4.2 **THE SOLUTION**

4.2.1 **Price Equation**

Substituting Eq. (4.4) into Eq. (4.5) and rearranging terms, we obtain:

\[ P_{t+1} = (1-\delta_\sigma-\delta\sigma\lambda)P_t + \delta\sigma\lambda M_t + (\delta(\rho-1)-\delta\sigma\lambda\phi)y_t \]
\[ - \delta\sigma\lambda v_t + \omega_{t+1} + \delta\sigma E_t P_{t+1} \]

In order to endogenize the expectation term of the above equation \( E_t \), it is useful to express the ultimate price equation as a function of all exogenous and predetermined variables in the model as follows:

\[ P_{t+1} = a_0P_t + a_1 M_t + a_2 y_t + a_3 v_t + a_4 \omega_{t+1} \]

Taking expectations of Eq. (4.7) at time \( t \) and substituting it back into Eq. (4.6), rationality requires:

\[ a_0 = \frac{1-\delta_\sigma-\delta\sigma\lambda}{1-\delta_\sigma} \]
\[ a_1 = \frac{\delta\sigma\lambda}{1-\delta_\sigma} \]
\[ a_2 = \frac{\delta(\rho-1)-\delta\sigma\lambda\phi}{1-\delta_\sigma} \]
\[ a_3 = \frac{-\delta\sigma\lambda}{1-\delta_\sigma} \]

and \( a_4 = 1 \).

By inspection, \( a_0 + a_1 = 1 \). This implies that the long-run proportionality between the price level and money stock holds.

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25 Details are provided in Appendix A.

26 The assumptions of rational expectations are endogenized by using the method of Muth(1961), Lucas(1973), and Driskill and McCafferty (1980, 1982).
Moreover, the dynamic stability of the price equation requires that 0<\alpha_0<1, which, in turn, implies that 1-\delta \sigma>0. Therefore, domestic prices followed by the monetary expansion moves monotonically toward the new long-run equilibrium value.

### 4.2.2 Foreign Exchange Equation

Substituting Eq. (4.4) and Eq. (4.7) with covered interest parity ($f_t = e_t + R_t$) into Eq. (4.3), and rearranging terms, we obtain the following difference equations in terms of the exogenous and predetermined variables in the model:

\[
\begin{align*}
  e_t &= \frac{\eta}{-\alpha + \beta + \eta} e_{t-1} + \frac{(\eta + \beta) \lambda + \beta a_1}{-\alpha + \beta + \eta} M_t - \frac{\eta \lambda \alpha (\eta + \beta) \lambda + \beta a_0 a_1}{-\alpha + \beta + \eta} M_{t-1} \\
  &\quad + \frac{\eta \lambda \alpha (\eta + \beta) \lambda + \beta a_0 a_2}{-\alpha + \beta + \eta} P_{t-1} - \frac{(\eta + \beta) \lambda \phi - \beta a_2}{-\alpha + \beta + \eta} v_t \\
  &\quad + \frac{\eta \lambda \alpha (\eta + \beta) \lambda + \beta a_0 a_3}{-\alpha + \beta + \eta} v_{t-1} - \frac{\eta}{-\alpha + \beta + \eta} \mu_t + \frac{\alpha + (\eta + \beta) \lambda - \beta a_0}{-\alpha + \beta + \eta} \omega_t \\
  &\quad + \frac{\eta}{-\alpha + \beta + \eta} E_t e_{t-1} - \frac{\eta}{-\alpha + \beta + \eta} E_{t-1} e_t.
\end{align*}
\]

Under the assumption of rational expectations, the foreign exchange rate equation can be solved as follows:\footnote{Details are provided in Appendix B.}

\[
e_t = \Pi_0 e_{t-1} + \Pi_1 M_t + \Pi_2 M_{t-1} + \Pi_3 P_{t-1} + \Pi_4 v_t + \Pi_5 v_{t-1} + \Pi_6 \mu_t + \Pi_7 \mu_{t-1} + \Pi_8 \omega_t + \Pi_9 \omega_{t-1}.
\]
where

\[ \Pi_0 = \frac{\eta(1-\Pi_0)}{-\alpha + \beta + \eta(1-\Pi_0)} \]  \hspace{1cm} (4.11)

\[ \Pi_1 = \frac{(\eta + \beta) \lambda + \beta a_0 + \eta(\Pi_1 + \Pi_2)}{-\alpha + \beta + \eta(1-\Pi_0)} \]

\[ \Pi_2 = \frac{-[\eta \lambda \{-(\alpha - (\eta + \beta) \lambda + \beta a_0) a_1 + \eta(\Pi_1 + \Pi_2) - \eta \Pi_3 a_1\}]}{-\alpha + \beta + \eta(1-\Pi_0)} \]

\[ \Pi_3 = \frac{\eta \lambda \{-(\alpha - (\eta + \beta) \lambda + \beta a_0) a_0 + \eta \Pi_3 (a_0 - 1)\}}{-\alpha + \beta + \eta(1-\Pi_0)} \]

\[ \Pi_4 = \frac{-\{(\eta + \beta) \lambda - \beta a_0 - \eta(\Pi_4 + \Pi_5)\}}{-\alpha + \beta + \eta(1-\Pi_0)} \]

\[ \Pi_5 = \frac{\eta \lambda \Phi \{-(\alpha - (\eta + \beta) \lambda + \beta a_0) a_2 + \eta \Pi_3 a_2 - \eta(\Pi_4 + \Pi_5)\}}{-\alpha + \beta + \eta(1-\Pi_0)} \]

\[ \Pi_6 = \frac{-\{(\eta + \beta) \lambda - \beta a_2 - \eta \Pi_7\}}{-\alpha + \beta + \eta(1-\Pi_0)} \]

\[ \Pi_7 = \frac{\eta \lambda \Phi \{-(\alpha - (\eta + \beta) \lambda + \beta a_0) a_3 + \eta \Pi_3 a_3 - \eta \Pi_7\}}{-\alpha + \beta + \eta(1-\Pi_0)} \]

\[ \Pi_8 = \frac{-1}{-\alpha + \beta + \eta(1-\Pi_0)} \]

and

\[ \Pi_9 = \frac{-\alpha - (\eta + \beta) \lambda + \beta a_0 + \eta \Pi_3}{-\alpha + \beta + \eta(1-\Pi_0)} \]

In Eq. (4.11), \( \Pi_0 \) is a quadratic equation which occurs frequently in rational expectations models involving speculation [Muth (1961), and Driskill and McCafferty (1980a, 1980b)]. In particular, the roots of this equation occur in reciprocal pairs, but the root which makes the foreign exchange market stable must be between zero and one:
\[ \Pi_0 = 1 + \frac{-\alpha+\beta}{2\eta} - \frac{-\alpha+\beta}{2\eta} \sqrt{1 + \frac{4\eta}{-\alpha+\beta}} \]  

(4.12)

Moreover, it is useful to note that as \( \eta \) varies from zero to infinity, \( \Pi_0 \) varies monotonically from zero to one, i.e., \( \frac{d\Pi_0}{d\eta} > 0 \).

\[ \Pi_3 \] in Eq. (4.11) can be expressed as the following:

\[ \Pi_3 = \frac{\eta\lambda+\{-\alpha-(\eta+\beta)\lambda+\beta a_\alpha\}a_0}{-\alpha+\beta+\eta(1-\Pi_0)+\eta(1-a_0)} \]  

(4.13)

Since \( \Pi_0 \) is a function of the structural parameters in the model as shown in Eq. (4.12), \( \Pi_3 \) can also be expressed in terms of the structural parameters only. In a similar manner, all coefficients of the foreign exchange equation, i.e., \( \Pi_0 \) through \( \Pi_9 \), can be explicitly solved as structural parameters in the model.

The following restrictions on the \( \Pi_i \)'s can be shown to hold:

\[ 0 < \Pi_0 < 1, \text{ for } 0 < \eta < \infty; \lim_{\eta \to \infty} \Pi_0 = 1 \]  

(4.14)

\[ \Pi_1 > 0, \Pi_2 > 0, \Pi_3 > 0, \Pi_4 > 0, \Pi_5 > 0, \Pi_6 > 0, \Pi_7 > 0, \Pi_8 < 0, \Pi_9 > 0 \]  

and \( \sum_{i=0}^{3} \Pi_i = 1 \).

4.3. IMPLICATION

The restrictions on the parameters in Eq. (4.14) address the issues of exchange rate dynamics: long-run purchasing power parity and the adjustment path of exchange rates and the trade balance.

A summation to unity of restrictions for the lagged exchange rate, the current and lagged money supply, and the lagged price level, i.e., \( \sum_{i=0}^{3} \Pi_i = 1 \) implies that the proportionality between the exchange rate and

---

28 Proof is provided in the Appendix C.
the money supply holds in the long run. In other words, the given percentage change in the money supply leads to equiproportional changes in prices and exchange rates in the long run, while all real variables return to initial levels during the adjustment period.

The adjustment path of exchange rates, prices and the trade balance followed by the monetary expansion can be considered by dividing it into two stages: an initial or short run adjustment before the domestic price responds to the change in aggregate demand, and the gradual or intermediate run adjustment to reach a new long-run equilibrium. Figures 1 and 2 present the adjustment path of the exchange rate, domestic prices, and the trade balance in the sticky-price monetary model and stock/flow model, respectively.

The restriction \[ \Pi_1 = 1 + \frac{\alpha + \beta \eta}{-\alpha + \beta + \eta (1 - \Pi_o)} > 0 \] makes us focus on the possibility of overshooting or undershooting of the short-run exchange rate followed by an unanticipated one-step increase in the money supply. The restriction implies that the increase in the money supply induces an initial depreciation of the spot exchange rate. The short-run exchange rate, however, does not necessarily overshoot a long-run equilibrium rate. Depending upon the parameter value of the model, initial depreciation may fall short of a new long-run equilibrium rate. This prediction contrasts with Dornbusch's overshooting hypothesis in the monetary model (1976), but is consistent with the implication of Driskill (1981a), who introduces the trade balance response to terms of trade into the stock/flow model.

29 Proof is provided in Appendix D.
The sticky-price monetary model, with the assumptions of perfect capital substitutability and mean-regressing rational expectation, predicts that the short-run exchange rate followed by a monetary expansion must overshoot the long-run equilibrium rate because a rising domestic interest rate in the intermediate run is associated with anticipated appreciation. Intuitively, the increase in real balances as a result of the monetary expansion lowers the domestic interest rate before the domestic price level responds to the excess demand in the goods market. The fall of the domestic interest rate induces the incipient capital outflow, which results in the initial depreciation of the domestic currency. In the intermediate run, as the price level is set in motion, the rise in the domestic interest rate with the reduction of the real balance induces capital reflow, which is accompanied by the appreciation of the exchange rate under mean-regressing rational expectations. Therefore, the exchange rate must depreciate more than in proportion to the money increase, because the corresponding appreciation follows in the intermediate run. The exchange rate appreciates and prices rise monotonically toward a new long-run equilibrium in the remaining period. Since prices always lag behind the exchange rate during the adjustment period, the trade balance shows a surplus, which, in turn, induces net asset accumulation.

By emphasizing imperfect asset substitutability with a continuous portfolio balance, Driskill (1981a) introduced the sticky-price assumption into the stock/flow model, where the trade balance responds to the term of trade. He predicts the possibility of undershooting and
FIGURE 1

ADJUSTMENT PATH OF THE EXCHANGE RATE, PRICE LEVEL AND TRADE BALANCE IN STICKY-PRICE MONETARY MODEL
nonmonotonic adjustment of the exchange rate as shown in Figure 2. Since a lower domestic interest rate followed by a monetary expansion can be offset by a rationally-expected appreciation next period, it discourages the initial capital outflow, which dampens the initial depreciation. Driskill conjectured that the higher responsiveness of the trade balance to relative prices and the lower asset substitutability might be more likely to lead to undershooting because they make flow considerations more important in the flow market for foreign exchange. Regardless of overshooting or undershooting, the exchange rate begins to appreciate before it again depreciates to its long-run equilibrium value. Since the trade balance has to show a surplus period and then a deficit period to keep net foreign asset accumulation zero in full stock/flow equilibrium, prices lag behind the exchange rate in the first phase and must move ahead of exchange rate adjustment in the next phase of the adjustment period.

The present model, into which the forward market with covered interest parity and the J-curve effect are explicitly incorporated, also provides the same implication of exchange rate and price dynamics as the stock/flow model discussed above. The spot exchange rate may overshoot or undershoot a new long-run equilibrium rate, depending upon the parameter value of the model. The numerical simulation in the next section demonstrates which structural parameter of the model is more likely to lead to overshooting or undershooting. Despite the initial

30 Niehans' stock/flow model (1977), which assumes the lagged asset adjustment, showed the possibility of overshooting and undershooting with monotonic and cyclical adjustment of exchange rate and price.
undershooting, the forward rate predicts the appreciation of the spot exchange rate followed by the initial depreciation. By normalizing all predetermined variables and ignoring random shock terms, it easily can be shown as the following:

$$f_t = e_t + \Delta e_t = \pi M_t - \lambda M_t = (\pi - \lambda)M_t < \pi M_t = e_t$$

Initial depreciation of the exchange rate, however, does not lead to the simple relationship with the trade balance. Depending upon whether or not the J-curve effect exists, the trade balance may show either a surplus or a deficit in the first phase. Moreover, it is evidently impossible that monetary expansion would result in a surplus without a deficit, or vice versa, because this would leave the economy with a permanently higher (or lower) stock of foreign assets [Niehans (1984)]. Unless trade is continuously in balance, there must be both a surplus period and a deficit period. The sequence in this model depends upon whether or not the trade balance exhibits the J-curve effect.

The trade balance is expressed as the sum of two effects: the valuation effect \([-\alpha(e_t - P_t)]\) and the volume effect \([\beta(f_{t-1} - E_{t-1}P_t)]\). If the volume effect dominates the valuation effect, the trade balance followed by initial depreciation of the spot exchange rate exhibits a surplus in the first phase and a deficit in the remaining period. However, if the valuation effect dominates the volume effect (J-curve effect), the pattern must be reversed. With constant sensitivity of traders to relative prices it is difficult to determine which case is more likely. If long-run sensitivities are used, the initial depreciation results in a trade surplus because \(\alpha\) is more likely to be
FIGURE 2

ADJUSTMENT PATH OF THE EXCHANGE RATE, PRICE LEVEL AND TRADE BALANCE IN STOCK/FLOW MODEL
negative. With short-run sensitivities, an initial deficit with an inflow of covered interest arbitrage funds is more likely to be relevant because \( \alpha \) is initially held positive by the J-curve effect. With a positive elasticity of \( \alpha \), the depreciation followed by successive monetary expansion might result in a trade deficit for some time, like the experience of the U.S. in 1978. Therefore, when the trade balance exhibits the J-curve effect, a one-time monetary expansion is likely to initiate a period of trade deficits with capital inflow, followed later by a surplus with capital outflow.

The inclusion of trade balance in the aggregate demand function might affect the price adjustment path, depending upon the size of the J-curve effect. If the trade balance does not exhibit the J-curve effect, the trade surplus with the initial depreciation will reinforce the aggregate demand. This will make prices adjust more rapidly toward the new long run equilibrium value, compared to the case of the omission of trade balance. In contrast, if the J-curve effect exists, trade deficits dampen the increase in aggregate demand, which, in turn, results in slower price adjustment. However, if the trade deficits with the J-curve effect offsets the expansionary effect on aggregate demand, the monetary expansion might contract the economy temporarily. This possibility might be eliminated by the imposition of the stability condition in the goods market.
4.3 NUMERICAL SIMULATION

This section investigates which array of structural parameters, particularly the change in sensitivity of foreign exchange market participants ($\alpha$, $\beta$ and $\eta$), is most likely to affect short-run exchange rate volatility, i.e., undershooting or overshooting. It is interesting because the coefficients (of sensitivities or elasticity) depend upon measurement of the time-period. Since the $\Pi_i$'s show a complicated relationship among structural parameters, the investigation is done through numerical simulation by choosing a reasonable range for each parameter.

The benchmark value of each parameter is chosen on the basis of the following considerations. The values for the income elasticity ($\phi$) and the interest rate semi-elasticity of demand for real money ($\frac{1}{\lambda}$) are based on a study by Goldfeld (1974) and are given the values 0.60 and 5, respectively. The interest rate semi-elasticity is calculated on the assumption that the interest elasticity of real money demand is 0.2 and that the quarterly interest rate is 4%. The income elasticity of aggregate demand ($\rho$) is assumed to be 0.70. If the real interest elasticity is 0.02, the interest rate semi-elasticity of aggregate demand ($\sigma$) is 0.5 with an assumed interest rate of 4%. The speed of price adjustment parameter ($\delta$) is chosen to be 0.0833 under the assumption that it takes 12 quarters to fully absorb the impact of an

31 Goldfeld (1974) showed that long-run income elasticity is 0.68 and interest rate elasticity is 0.22 during the sample period 1952 II.-1972 IV. The subsequent study by Hafer and Hein showed similar results.

32 See empirical study by Driskill (1981b).
unanticipated money supply change. The sensitivity of traders in the spot and forward markets, which satisfies the Marshall-Lerner condition ($\beta > \alpha$), are chosen to be 0.01 and 0.12, respectively. In order to focus on the issue of how the change in the sensitivity of market participants affects the short run exchange rate, the sensitivity of speculators ($\eta$) are chosen to equal 2.07 to keep $\frac{\eta}{\lambda}$ close to 1. The chosen benchmark values are summarized as follows:

\[
\begin{align*}
\phi &= 0.6000 & \lambda &= 0.2000 & \rho &= 0.7000 & \sigma &= 0.5000 \\
\delta &= 0.0833 & \alpha &= 0.0100 & \beta &= 0.1200 & \eta &= 2.0700
\end{align*}
\]

As shown in Table 1, the numerical simulation is performed by varying the values of each parameter, one at a time. The values of $\phi$, $\rho$, and $\sigma$ are increased by 0.10, but the value of $\lambda$ is increased by 0.05 because it is very sensitive to changes. The value of $\delta$ is set equal to 0.2500, 0.1250, 0.0625, and 0.0500 by assuming the full-adjustment period is 4, 8, 16, and 20 quarters, respectively. $\alpha$, $\beta$, and $\eta$ values are taken to be 1/10, 1/2, 3/4, 2, 4, and 10 times the benchmark value.

The likelihood of overshooting is negatively related to the interest rate semi-elasticity ($\frac{1}{\lambda}$). The higher the semi-elasticity, the smaller the change in the domestic interest rate is with respect to a given percentage change in the money supply. Therefore, the higher semi-elasticity induces a smaller capital outflow, which reduces the size of the initial depreciation.

A higher real interest rate semi-elasticity of aggregate demand ($\sigma$) and a higher speed of price adjustment ($\delta$) tend to lead to overshooting. The higher $\sigma$ makes prices adjust rapidly through the larger increase in aggregate demand. The more rapidly prices adjust to
the gap of purchasing power parity, the weaker the flow consideration in the foreign exchange market. Hence overshooting is more likely to occur in response to the monetary expansion.

The higher (negative) sensitivity by traders in the spot market ($\alpha$) is likely to lead to the overshooting of the spot exchange rate because it offsets the sensitivity by traders in the forward market ($\beta$). In other words, it reduces the weight of the flow consideration in the flow market for foreign exchange. On the other hand, the higher sensitivity by traders ($\beta$) in the forward market is likely to lead to undershooting of the spot exchange rate because it makes the flow consideration more important in the flow market of the foreign exchange market.

The higher sensitivity of speculators ($\eta$) is likely to lead to overshooting because it makes the capital flow more important in the foreign exchange market. In the extreme case when uncovered interest parity holds, i.e., $\eta \to \infty$, overshooting occurs necessarily because it becomes equivalent to perfect capital substitutability in the sticky-price monetary model where the trade balance plays no role in exchange rate determination.
TABLE 1
THE EFFECT OF CHANGE IN STRUCTURAL PARAMETERS ON EXCHANGE RATE VOLATILITY

Benchmark Values: $\phi = 0.600$ $\lambda = 0.200$ $\rho = 0.700$ $\sigma = 0.500$
$\delta = 0.0833$ $\alpha = 0.010$ $\beta = 0.120$ $\eta = 2.070$

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<th>$\Pi_2$</th>
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$\eta = 2.070$
CHAPTER V

THE EFFECT OF THE CHANGE IN THE U.S. MONETARY POLICY REGIME

This chapter investigates the effect of the change in the U.S. monetary policy regimes in October, 1979 on the foreign exchange market. When the monetary authority uses the money supply to pursue policy goals such as internal or external stabilization, the money supply can be no longer considered exogenous. After specifying the money supply rule (or reaction function) of the monetary authority and simplifying the goods market in a tractable manner, we focus on: i) how the change in the U.S. monetary policy regimes affects exchange rate volatility, and ii) how it changes the interrelationship between the spot and forward exchange rates. The foreign exchange rate is solved in reduced form under the rational expectations assumption. We then turn to investigate the effect through comparative statics.

5.1 THE STRUCTURE

The money supply process is endogenized. The money supply process considered in this analysis takes the following form:

\[ M_t^S = M_t + \frac{1}{\tau'}(R_t - R_t) + \varepsilon_t \]  

(5.1)

where \( M_t \): a deterministic component of the money stock known to the public at time \( t \)

\[ \frac{1}{\tau'} \]: the sensitivity of the monetary authority to the deviation
of the current interest rate from the target one ( \tilde{R}_t )
and \( \varepsilon_t \): a serially uncorrelated money supply shock with zero mean
and finite variance \( \sigma^2_\varepsilon \).

The money supply rule\(^{33}\) implies that \( \tilde{M}_t \) is a deterministic part of the
money stock which is publicly known. The known money growth rate
\[ g_t = (\tilde{M}_{t+1} - \tilde{M}_t) / \tilde{M}_t \] must be fully absorbed by the t-period's inflation
scheme because there is no room for it to be transferred into another
period. \( \frac{1}{\tau'} ( R_t - \tilde{R}_t ) \) has a notion that the monetary authority attempts
to stabilize the current interest rate around its target rate. A large
value of \( \frac{1}{\tau'} \) corresponds to an interest-rate oriented policy procedure,
while a small value of \( \frac{1}{\tau'} \) corresponds to a money-supply oriented one.

This specification implies that the monetary authority respond more
sensitively to the gap between the current interest rate and the target
rate under an interest-rate oriented procedure than under a money-
supply oriented one. \( \varepsilon_t \) is a random deviation from its target path.
Thus, \( \frac{1}{\tau'} ( R_t - \tilde{R}_t ) \) and \( \varepsilon_t \) can be interpreted as the controllable and
uncontrollable parts of the money supply, respectively.

Plugging the money supply process [Eq.(5.1)] into the money market
equilibrium condition in Eq.(3.12), an interest-rate generating process
by the monetary authority can be obtained as the following\(^{34}\)

\[ R_t = \tau P_t + \tau \dot{y}_t + \tau \tilde{M}_t - \tau \varepsilon_t + \frac{\tau}{\tau'} \tilde{R}_t \] (5.2)

where \( y \): full-employment level of output

and \( \tau = \frac{\lambda \tau'}{\tau' + \lambda} \).

---

33 This type of money supply rule is discussed in the closed economy
Therefore, the parameter of the reaction function ($\tau$) has a larger value under a money-supply oriented procedure than under an interest-rate oriented one, because $\frac{d\tau}{d\tau'} > 0$. The above equation implies that the monetary authority places more weight on the deterministic and uncontrollable parts of money-supply under the money-supply oriented procedure.

It is assumed that aggregate output is maintained at the full-employment level rather than being demand-determined and the aggregate demand is a function of the terms of trade and the full-employment output. The rate of inflation can be expressed as the publicly known money growth rate plus an increasing function of the terms of trade:

$$P_{t+1} - P_t = \delta[y^d_t - y_t] + g_t + \omega_{t+1}$$

$$= \delta[p y_t + \theta(e_t - P_t) - y_t] + g_t + \omega_{t+1}$$

(5.3)

where $\theta$ is the sensitivity of aggregate demand to the terms of trade.

Accordingly the equilibrium term of trade is:

$$\hat{e}_t = \hat{P}_t = \frac{(1-\rho)}{\theta} y_t + \frac{\rho}{\theta} g_t$$

where $\hat{e}_t$ and $\hat{P}_t$ are the anticipated long-run equilibrium spot exchange rate and price level at time $t$, respectively.

34 Ignoring the money-demand shock term ($\nu_t$) in Eq.(3.11) and plugging Eq. (5.1) into it, we obtain:

$$\tilde{M}_t + \frac{1}{\tau'}(R_t - \tilde{R}_t) + \varepsilon_t = P_t + \phi y_t - \frac{1}{\lambda} R_t$$

$$\left(\frac{1}{\tau'} + \frac{1}{\lambda}\right) R_t = -\tilde{M}_t + \frac{1}{\tau'} R_t + P_t + \phi y_t - \varepsilon_t$$

$$R_t = -\tau M_t + \frac{\tau}{\tau'} \tilde{R}_t + \tau P_t + \tau \phi y_t - \tau \varepsilon_t$$

where $\tau = \frac{\lambda \tau'}{\tau' + \lambda}$

Hence, $\frac{d\tau}{d\tau'} = \frac{\lambda(\tau' + \lambda) - \lambda \tau'}{(\tau' + \lambda)^2} > 0$

35 This type of price adjustment scheme is introduced by Dornbusch (1980b).
The terms-of-trade effect on aggregate demand might be expressed as current as well as lagged relative prices because of the lag of consumption and production decisions regarding exports and imports in the foreign exchange market specification. However, the lagged terms-of-trade effect on aggregate demand can be subsumed into the current terms-of-trade effect by assuming that economic agents react to the known long-run terms of trade. The price adjustment scheme reflects the fact that goods prices adjust only slowly to the imbalance in the goods market and that aggregate demand is determined by the full-employment level of output and relative prices. Taking expectations of the actual inflation rate at time $t$, the expected inflation rate can be expressed as follows:

$$\Delta_t = E_t p_{t+1} - P_t = \delta \{ e_t - P_t \} + (\rho-1)\gamma_t + \varepsilon_t$$ (5.4)

Using the above expected inflation rate, the excess supply by traders in the forward market can be rewritten as follows:

$$T^F_t = \beta(f_t + (E_t P^*_{t+1} - P^*_t) - (E_t P_{t+1} - P_t) + P^*_t - P_t)$$

$$= \beta(f_t + \Delta^*_t - \Delta_t + P^*_t - P_t).$$ (5.5)

Under the assumption of a small country, the foreign expected inflation rate and price level are assumed to be fixed. Moreover, the current domestic price level is treated as given partly because the issue considered in this chapter is far from the exchange rate dynamics and partly because the model is kept tractable. This stronger sticky-price adjustment assumption reflects the fact that economic agents are concerned about the expected inflation rate, but act as if the current price is given.
Suppressing fixed foreign country variables, the publicly known
money growth rate, the full-employment level of output and the current
price level, the structure in this analysis can be summarized as
follows:

\textbf{< Foreign Exchange Market Equilibrium >}

\[-\alpha e_t + \mu_t + \eta [ E_{t-1} e_{t-1} - f_{t-1}] + \beta [ f_t - \Delta_t] = \eta ( E_t e_{t+1} - f_t) \]

where \( \eta = \frac{K}{\text{Var}(e_{t+1})} \) (5.6)

\textbf{< Interest-rate Generating Process >}

\[ R_t = - \tau e_t \] (5.7)

\textbf{< Expected Inflation Rate >}

\[ \Delta_t = \delta \theta e_t \] (5.8)

Note that the speculators' sensitivity to expected profits (\( \eta \)) is
endogenized in this analysis because a change in the monetary policy
regime can affect their sensitivity through the change in the
conditional forecast variance of the exchange rate.

\section*{5.2 THE SOLUTION}

Substituting Eq. (5.7) and Eq. (5.8) along with the covered
interest parity (\( f_t = e_t + R_t \)) into Eq. (5.6), we obtain the following
difference equation for the spot exchange rate:

\[ e_t = \frac{\eta}{-\alpha + \beta (1 - \delta \theta) + \eta} e_{t-1} + \frac{\tau (\eta + \beta)}{-\alpha + \beta (1 - \delta \theta) + \eta} e_t \]

\[ - \frac{\eta \tau}{-\alpha + \beta (1 - \delta \theta) + \eta} e_{t-1} - \frac{1}{-\alpha + \beta (1 - \delta \theta) + \eta} \mu_t \]

\[ + \frac{\eta}{-\alpha + \beta (1 - \delta \theta) + \eta} E_t e_{t+1} - \frac{\eta}{-\alpha + \beta (1 - \delta \theta) + \eta} E_{t-1} e_t ' \] (5.9)
Under the assumption of rational expectations, the spot exchange rate equation can be solved as follows:

\[ e_t = \Pi_0 e_{t-1} + \Pi_1 e_{t-1} + \Pi_2 e_{t-1} + \Pi_3 \mu_t \]  \hspace{1cm} (5.10)

where the \( \Pi_i \)'s satisfy the following restrictions:

\[ \Pi_0 = \frac{\eta(1-\Pi_0)}{-\alpha + \beta(1-\delta\theta) + \eta(1-\Pi_0)} \]  \hspace{1cm} (5.11)

\[ \Pi_1 = \frac{\eta(\tau + \Pi_2) + \beta \tau}{-\alpha + \beta(1-\delta\theta) + \eta(1-\Pi_0)} \]

\[ \Pi_2 = \frac{-\eta(\tau + \Pi_2)}{-\alpha + \beta(1-\delta\theta) + \eta(1-\Pi_0)} \]

and \[ \Pi_3 = \frac{-1}{-\alpha + \beta(1-\delta\theta) + \eta(1-\Pi_0)} \]

The stable root of \( \Pi_0 \) in the quadratic equation of Eq. (5.11), which must be between zero and one, is:

\[ \Pi_0 = 1 + \frac{-\alpha + \beta(1-\delta\theta)}{2\eta} - \frac{-\alpha + \beta(1-\delta\theta)}{2\eta} \sqrt{1 + \frac{4\eta}{-\alpha + \beta(1-\delta\theta)}} \]  \hspace{1cm} (5.12)

One of the important properties of \( \Pi_0 \) is that as \( \eta \) varies from zero to infinity, \( \Pi_0 \) varies monotonically from zero to one.

\( \Pi_1 \) through \( \Pi_3 \) can all be solved explicitly as a function of \( \Pi_0 \):

\[ \Pi_2 = -\tau \Pi_0 \]

\[ \Pi_1 = \frac{\tau(-\alpha + \beta\delta\theta)\Pi_0 + \beta}{-\alpha + \beta(1-\delta\theta)} \]

and \[ \Pi_3 = \frac{-\Pi_0}{-\alpha + \beta(1-\delta\theta)} \]

36 Details are provided in Appendix E.

37 Proof is provided in Appendix F.
The spot exchange rate equation is expressed as a function of $\Pi_0$ and the structural parameters in the model:

$$e_t = \Pi_0 e_{t-1} + \frac{\tau(-(-\alpha+\beta\delta\theta)\Pi_0+\beta)}{-\alpha+\beta(1-\delta\theta)} e_t - \tau\Pi_0 e_{t-1} - \frac{(1-\Pi_0)}{-\alpha+\beta(1-\delta\theta)} \mu_t$$

(5.13)

Moreover, the spot exchange rate equation can be written as a linear function of all current and past disturbances as follows:

$$e_t = \frac{\tau(-(-\alpha+\beta\delta\theta)\Pi_0+\beta)}{-\alpha+\beta(1-\delta\theta)} e_t - \tau\Pi_0 e_{t-1} - \frac{(1-\Pi_0)}{-\alpha+\beta(1-\delta\theta)} \mu_t$$

$$+ \Pi_0\left\{ \frac{\tau(-(-\alpha+\beta\delta\theta)\Pi_0+\beta)}{-\alpha+\beta(1-\delta\theta)} e_{t-1} - \tau\Pi_0 e_{t-2} - \frac{(1-\Pi_0)}{-\alpha+\beta(1-\delta\theta)} \mu_{t-1} \right\}$$

$$+ \Pi_0^2\left\{ \frac{\tau(-(-\alpha+\beta\delta\theta)\Pi_0+\beta)}{-\alpha+\beta(1-\delta\theta)} e_{t-2} - \tau\Pi_0 e_{t-3} - \frac{(1-\Pi_0)}{-\alpha+\beta(1-\delta\theta)} \mu_{t-2} \right\}$$

$$+ \cdot \cdot \cdot$$

$$= \frac{\tau(-(-\alpha+\beta\delta\theta)\Pi_0+\beta)}{-\alpha+\beta(1-\delta\theta)} e_t + \frac{\tau(1-\Pi_0)(\alpha+\beta\delta\theta)}{-\alpha+\beta(1-\delta\theta)} \left\{ \Pi_0 e_{t-1} + \Pi_0^2 e_{t-2} + \Pi_0^3 e_{t-3} + \cdot \cdot \cdot \right\} - \frac{(1-\Pi_0)}{-\alpha+\beta(1-\delta\theta)} \{ \mu_t + \Pi_0 \mu_{t-1} + \Pi_0^2 \mu_{t-2} + \cdot \cdot \cdot \}. \quad (5.14)$$

5.3 IMPLICATION: COMPARATIVE STATICS

The effect of the change in the U.S. monetary policy regime on the spot and forward exchange rates volatility and their interrelationship will be investigated through comparative statics. Note that the speculators' sensitivity to expected profits ($\eta$) is endogenized and the parameter of the reaction function of the monetary authority ($\tau$) is larger under the money-supply oriented procedure.
First, consider the conditional forecast variance of the spot exchange rate which can be written as the following:

\[
\text{Var}(e_{t+1}) = \mathbb{E}[e_{t+1} - \mathbb{E}[e_{t+1}]]^2 = \frac{1}{(-\alpha + \beta(1-\delta\theta))^2} \left[ \tau^2 (- (\alpha + \beta \delta\theta) \Pi_0 + \beta)^2 \sigma_e^2 + (1 - \Pi_0)^2 \sigma_u^2 \right]
\]

(5.15)

The sensitivity of speculators to expected profits depends upon the conditional forecast variance; that is, \( \eta = \frac{K}{\text{Var}(e_{t+1})} \). Since the change in the monetary authority's reaction parameter (\( \tau \)) affects the conditional forecast variance, substituting Eq. (5.15) into the speculators' sensitivity and differentiating it totally with respect to \( \eta \) and \( \tau \) yields:

\[
2\tau \eta (\alpha + \beta \delta\theta)^2 (Z - \Pi_0)^2 \sigma_e^2 d\tau + \left[ \tau^2 (\alpha + \beta \delta\theta)^2 (\Pi_0 - Z) \left( \frac{\Pi_0 (3 - \Pi_0)}{1 + \Pi_0} - Z \right) \sigma_e^2 
\]

\[
+ \frac{(1 - \Pi_0)^3}{1 + \Pi_0} \sigma_u^2 \right] d\eta = 0, \quad \text{where} \quad Z = \frac{\beta}{\alpha + \beta \delta\theta}.
\]

(5.16)

Note that \( \eta = \frac{(-\alpha + \beta(1-\delta\theta)) \Pi_0}{(1-\Pi_0)^2} > 0 \) in Eq.(5.11). Thus, \( \beta(1-\delta\theta) > \alpha \).

If \( \alpha > -\beta\delta\theta \), then \( Z > 1 \). Otherwise, \( Z < \Pi_0 \). Therefore, \( \frac{d\eta}{d\tau} < 0 \) because \( 0 < \Pi_0 < \frac{\Pi_0 (3 - \Pi_0)}{1 + \Pi_0} < 1 \) at the range of \( 0 < \Pi_0 < 1 \). This implies that the sensitivity of speculators decreases unambiguously under the money-supply oriented policy regime due to the increase in the conditional forecast variance.

In order to get more insight into the simultaneous determination between the speculators' sensitivity and the conditional forecast variance:

38 Details are provided in Appendix G.
variance, consider Figure 3. The RE line represents the relationship between $\Pi_0$ and $\eta$ derived from the restrictions of the rational expectation solution in Eq.(5.11). As $\Pi_0$ increases, $\eta$ increases monotonically but at a increasing rate in the range of $0 < \Pi_0 < 1$. The SS line represents the speculators' sensitivity derived from the utility maximization of their expected profits, i.e., $\eta = \frac{K}{\text{Var}(e_{t+1})}$. The increase in the monetary authority's reaction parameter ($\tau$) shifts the SS line downward unambiguously. When $\alpha > -\beta\delta\theta$, the first- and second-order differentiation of $\eta$ with respect to $\Pi_0$ shows that as $\Pi_0$ increases, $\eta$ increases monotonically but at an decreasing rate. The case of $\alpha < -\beta\delta\theta$ is ignored because it gives us the same implication of the change in $\eta$. The unprimed and primed notation represents SS line under an interest-rate oriented and a money-supply oriented procedure, respectively.

The graphical solution shows that points A and C, at which the RE line intersects the SS line, indicate the equilibrium speculators' sensitivity under an interest-rate oriented procedure ($\eta_1$) and a money-supply oriented procedure ($\eta_M$), respectively. If the speculators' sensitivity is treated as parametrically given under each regime, we might get point B as equilibrium sensitivity ($\eta'$) under a money-supply oriented policy procedure. Since the speculators' sensitivity is actually endogenous, the increase in the conditional forecast variance reduces $\eta$ along the RE line. So, the sensitivity of speculators under the money-supply oriented procedure is determined at point C ($\eta_M'$) rather than point B ($\eta'$). In short, the speculators' sensitivity is smaller when it is endogenized than parametrically given.
FIGURE 3
THE DETERMINATION OF SPECULATORS' SENSITIVITY
UNDER ALTERNATIVE MONETARY POLICY REGIMES
Second, consider the asymptotic variance of the spot exchange rate. Assuming that monetary and real shocks are serially independently distributed with zero means and finite variances, the asymptotic variance can be solved as follows: \(39\)

\[
\text{Asy Var}(e_t) = \frac{1}{(-\alpha+\beta(1-\delta\theta))^2} \left\{ \frac{\Pi_0^2 (1-\Pi_0^2) + \beta^2}{1+\Pi_0} \right\} \sigma_{\epsilon}^2 + \frac{1-\Pi_0}{1+\Pi_0} \sigma_{\mu}^2 \tag{5.17}
\]

The comparative statics with respect to \(\tau\) are:

when \(\sigma_{\epsilon}^2 = 0\),

\[
\frac{d\{\text{Asy Var}(e_t)\}}{d\tau} = \frac{1}{(-\alpha+\beta(1-\delta\theta))^2} \cdot \frac{-2 \Pi_0 \eta}{(1+\Pi_0)^2} \cdot \frac{\sigma_{\mu}^2}{\sigma_{\mu}^2 > 0} \tag{5.18}
\]

when \(\sigma_{\mu}^2 = 0\),

\[
\frac{d\{\text{Asy Var}(e_t)\}}{d\tau} = \frac{1}{(-\alpha+\beta(1-\delta\theta))^2} \left\{2 \tau \left[ (-\alpha+\beta(1-\delta\theta)) \Pi_0 + \beta \right]^2 + \frac{\Pi_0^2 (1-\Pi_0^2) + \beta^2}{1+\Pi_0} \right\}
\]

\[
+ 2 \tau^2 (\alpha+\beta\delta\theta)^2 \left\{ \frac{\Pi_0^2 + 2 \Pi_0}{(1+\Pi_0)^2} - \frac{\beta}{\alpha+\beta\delta\theta} \right\} \frac{\partial \Pi_0}{\partial \tau} \frac{\partial \eta}{\partial \tau} \sigma_{\epsilon}^2 \tag{5.19}
\]

The comparative statics show that the adoption of the money-supply oriented procedure increases unambiguously the portion of spot exchange rate volatility due to the real shock, because the speculators become more risk averse. However, the portion of spot exchange rate volatility due to the monetary shock is indeterminate. The effect of the change in the monetary policy regime on its volatility can be ---

-----

\(39\) Details are provided in Appendix H.
divided into two parts: a direct effect and an indirect effect. The adoption of a money-supply oriented procedure increase volatility directly because the monetary authority is placing more weight on the uncontrollable money supply. The indirect effect, which comes from the lower sensitivity of speculators to expected profits, depends upon the structural parameter value of the model. If $\alpha > -\beta \delta \theta$, the adoption of a money-supply oriented procedure aggravates indirectly the volatility due to the monetary shock. Otherwise it tends to dampen the volatility. Which case is more likely depends upon what array of structural parameters are used. If the long-run value is used, the second case will dominate because $\alpha$ tends to be negative and large in absolute value. With the short-run sensitivity, the first case is more likely to happen because $\alpha$ is small or even positive by the J-curve effect.

Third, the asymptotic variance of the forward rate can be expressed with the help of covered interest parity as follows:

$$\text{Asy Var}(f_t) = \frac{1}{1-\Pi_0} \cdot \frac{1}{1+\Pi_0} \cdot \left\{ \tau^2 (\alpha + \beta \delta \theta)^2 \sigma^2 + \sigma^2 \right\}$$

The comparative statics with respect to $\tau$ are:

$$\frac{d[\text{Asy Var}(f_t)]}{d\tau}$$

when $\sigma^2 = 0$, 

$$= \frac{1}{(-\alpha + \beta (1-\delta \theta))^2} \cdot \frac{-2}{(1+\Pi_0)^2} \cdot \frac{\partial \Pi_0}{\partial \eta} \cdot \frac{\partial \eta}{\partial \tau} \cdot \frac{\sigma^2 > 0}{\sigma^2}$$

40 This implication is consistent with that of Driskill and McCafferty (1982) when they do not consider the possibility of the J-curve effect.

41 Details are provided in Appendix I.
The comparative statics show that the adoption of the money-supply oriented procedure increases forward rate volatility regardless of where shocks come from. It increases directly forward rate volatility due to the monetary shock and indirectly exacerbates the volatility due to both monetary and real shocks, because it lowers the sensitivity of speculators to expected profits.

Both the spot rate and the forward rate volatility due to real shock increase because the adoption of the money-supply oriented procedure reduces the speculators' sensitivity. Moreover, the adoption increases directly spot and forward-rate volatility due to the monetary shock, and also indirectly its forward rate volatility. One of the interesting results is the indirect effect on spot volatility, which depends upon the sensitivities of traders. As stated previously, with long-run sensitivity used, the monetary authority can reduce the spot exchange rate volatility by discouraging the speculative excess in the foreign exchange market, or vice versa. This suggests that there is a trade-off between short-run and long-run spot-rate volatility in the choice of alternative monetary policy regimes.

Fourth, define the forward-rate forecast error as the difference between the future spot rate and the corresponding current forward rate.
rate. The forward-rate forecast error can be solved with the help of covered interest parity as follows:

\[
e_{t+1} - f_t = (\Pi_0 - 1)e_t - \tau(\Pi_0 - 1)e_t + \frac{\tau(-(\alpha + \beta \delta \theta)\Pi_0 + \beta)}{(1 - \Pi_0)} e_t + \frac{\tau(-(\alpha + \beta \delta \theta)\Pi_0 + \beta)}{-\alpha + \beta(1 - \delta \theta)} e_{t+1} - \frac{\tau(-(\alpha + \beta \delta \theta)\Pi_0 + \beta)}{\alpha + \beta(1 - \delta \theta)} \mu_{t+1}
\]

(5.23)

Its asymptotic variance (squared prediction error) is:

\[
\text{Asy Var}(e_{t+1} - f_t) = \frac{\tau^2 (1 - \Pi_0)^3}{\{-\alpha + \beta(1 - \delta \theta)\}^2} \left[\frac{(\alpha + \beta \delta \theta)^2 + (\alpha^2 + \beta \delta \theta \Pi_0 + \beta)^2}{1 + \Pi_0}\right] \sigma_e^2 \\
- \frac{2}{\{-\alpha + \beta(1 - \delta \theta)\}^2} \frac{(1 - \Pi_0)^2}{1 + \Pi_0} \sigma_e^2 \sigma_\mu > 0
\]

(5.24)

In Eq. (5.27), \(f_t\) is not necessarily an unbiased estimator of the expected future spot rate because \(E_t e_{t+1} - f_t = (\Pi_0 - 1)e_t - \tau(\Pi_0 - 1)e_t\).

The last two terms separate the forward rate from the expected future spot rate. Following the terminology of Frankel (1980) and Driskill and McCafferty (1982), the terms can be considered as 'risk premia', which are time-dependent as well as policy-dependent.

In order to see the average predictability of the forward rate as the future spot rate, the comparative statics of the forward rate forecast error with respect to \(\tau\) are:

when \(\sigma_e^2 = 0\), \[
\frac{d(\text{Asy Var}(e_{t+1} - f_t))}{d\tau} = \frac{-2}{\{-\alpha + \beta(1 - \delta \theta)\}^2} \frac{(1 - \Pi_0)(3 + \Pi_0)}{\Pi_0} \frac{\partial \Pi_0}{\partial \tau} \frac{\partial \eta}{\partial \tau} \sigma_\mu^2 > 0
\]

(5.25)

when \(\sigma_\mu^2 = 0\),

----------------------------------------

42 Details are provided in Appendix J.
It is clear that the squared prediction error due to a real shock is larger because of the lower speculators' sensitivity. However, the adoption of a money-supply oriented procedure makes the forward rate predictability of the future spot rate poorer by directly increasing the squared prediction error due to the monetary shock. Its indirect effect on the prediction error through the reduced speculators' sensitivity is indeterminate. As the comparative statics show, with the short-run sensitivity, for instance, \( \alpha > -\beta \delta \Theta \), the squared prediction error is unambiguously larger under the money-supply oriented procedure. However, if the long-run value is used, the prediction error may initially fall and then increase, as \( \eta \) becomes close to unity [Driskill and McCafferty (1982)].
Chapter VI
EMPIRICAL ANALYSIS

One of the most controversial and frequently-tested issues in recent international monetary economics is the simple efficient market hypothesis in the foreign exchange market. There is no general consensus that the forward rate is an unbiased predictor of the corresponding future spot rate. This has led to tests of whether or not the risk premium is time-varying in the foreign exchange market.

It was shown in the last chapter that if economic agents are risk averse, the risk premium is time-varying because the time-varying component, whose parameter eventually depends upon the conditional variance of the exchange rate, separates the forward rate from the expected future spot rate. Moreover, the change of the U.S. monetary policy regime to a money-supply oriented procedure tends to increase the uncertainty in the foreign exchange market. The increased uncertainty makes economic agents more risk-averse and thus induces the structural change in the time-varying risk premium. This chapter derives an estimation equation based on the basis of the model discussed in the last chapter and focuses on testing the existence of a time-varying risk premium and the structural change in the risk premium due to the change in the U.S. monetary policy regime.

43 If economic agents are risk neutral, transaction costs are zero, information is used rationally, and the market is competitive, the simple efficient market hypothesis implies that the forward rate equals the expected future spot rate. For more clarification, see Frankel (1980)
6.1 ESTIMATION EQUATION AND HYPOTHESIS

6.1.1 Estimation Equation

This section derives the estimation equation to be used to test the two hypotheses mentioned above. The derived equation has the same form as has been extensively tested under the simple efficient market hypothesis. It gives us, however, a different implication about the hypothesis to be tested because the rejection of the simple efficient market hypothesis may imply the existence of a time-varying risk premium in the foreign exchange market.

The equation (5.23) in the last chapter can be rewritten as follows:

\[
\begin{align*}
  f_t - e_{t+1} &= (1-\Pi_0)e_t - \tau(1-\Pi_0)e_t \\
  \quad - \frac{\tau(-\alpha+\beta\delta\theta)\Pi_0^+\beta}{-\alpha+\beta(1-\delta\theta)} \varepsilon_{t+1} + \frac{1-\Pi_0}{-\alpha+\beta(1-\delta\theta)} \mu_{t+1} \\
  &= (1-\Pi_0)(e_t-\tau\varepsilon_t) \\
  \quad - \frac{\tau(-\alpha+\beta\delta\theta)\Pi_0^+\beta}{-\alpha+\beta(1-\delta\theta)} \varepsilon_{t+1} + \frac{1-\Pi_0}{-\alpha+\beta(1-\delta\theta)} \mu_{t+1} \quad (6.1)
\end{align*}
\]

Incorporating the covered interest parity condition \( f_t = e_t - \tau\varepsilon_t \) into the above equation yields:

\[
\begin{align*}
  f_t - e_{t+1} &= (1-\Pi_0)f_t - \frac{\tau(-\alpha+\beta\delta\theta)\Pi_0^+\beta}{-\alpha+\beta(1-\delta\theta)} \varepsilon_{t+1} + \frac{1-\Pi_0}{-\alpha+\beta(1-\delta\theta)} \mu_{t+1} \quad (6.2)
\end{align*}
\]

44 See chapter 5.1 for a variation of the covered interest parity condition used here.
Taking the expectation of equation (6.2) at time $t$, we obtain:

$$f_t - E_t e_{t+1} = (1 - \pi_0) f_t$$

(6.3)

It is clear that a fraction of $f_t (1 - \pi_0)$ separates the forward exchange rate from the future spot exchange rate. This implies that the forward rate contains a time-varying risk premium as long as economic agents are risk averse. Note that if the speculators' sensitivity to expected profit is infinite ($\eta \to \infty$), then the risk premium disappears. That is, if economic agents are risk neutral, the forward rate is an unbiased predictor of the future spot exchange rate. This provides us with a good null hypothesis for testing the existence of a time-varying risk premium.

Subtracting the forward rate from both sides of Eq. (6.2) yields:

$$e_{t+1} = \frac{\tau [-(\alpha + \beta \delta \theta) \pi_0 + \beta]}{-\alpha + \beta (1 - \delta \theta)} e_t - \frac{1 - \pi_0}{-\alpha + \beta (1 - \delta \theta)} \mu_{t+1}$$

(6.4)

By adding a constant term to Eq. (6.4), we obtain the following equation used for estimation:

$$e_t = \beta_0 + \beta_1 f_{t-1} + \xi_t$$

(6.5)

where $\xi_t$ is a serially uncorrelated disturbance term.

It is necessary to reintroduce the constant term into Eq. (6.5) because all constant terms in model specification are suppressed. Even if Eq. (6.5) has, at a glance, exactly the same form as used to test that $\beta_0 = 0$ and $\beta_1 = 1$ under the simple efficient market hypothesis, $\beta_0$ may differ from zero.

The inclusion of the constant term ($\beta_0$) in the simple efficient market hypothesis might be explained in terms of a distributional assumption of an error term, political risk, or transaction costs. First, the well-known Jensen's inequality states that under the simple
efficient market hypothesis, \( E(SR_t) = FR_{t-1} \) does not necessarily imply \( E(\ln SR_t) = \ln FR_{t-1} \), where \( SR, FR, \) and \( \ln \) denote the spot exchange rate, forward exchange rate, and logarithm, respectively. Note that for simplicity most of the variables in the model are expressed in logarithms. If the disturbance term is assumed to be distributed normally with conditional mean zero and constant conditional variance and, at the same time, the forward rate is an unbiased forecast of the future spot rate, the constant term should equal \(-0.5\sigma^2_\xi\) rather than zero as [Frenkel (1979) and Huang (1984)].

Second, the risk in the foreign exchange market has two sources: exchange risk and political risk [Eaton and Turnovsky (1983) and Stockman (1978)]. The exchange risk comes from the risk of changes in asset prices. Speculators' sensitivity to expected profit (\( \eta \)) reflects the exchange risk in this paper because it is expressed as the ratio of risk aversion parameter to the conditional forecast variance of exchange rates. Political risk (or default risk) may arise from risks due to political intervention, such as exchange rate controls, or the "foreignness" of assets, and so on. The consideration of political risk may introduce a constant term into the estimation equation (6.5). The negative value of \( \beta_0 \), after adjusting for the exchange risk, corresponds to the situation of dollars being riskier than foreign currency. That is, the buyer of forward foreign currency is willing to

---

45 Equating the mathematical expectation of the spot exchange rate yields \( E(SR_t) = \exp(\beta_0 + \xi_t) FR_{t-1} \), where \( SR \) and \( FR \) denote spot and forward exchange rates, respectively. Under the simple efficient market hypothesis, unbiasedness requires that \( E(SE_t) = FE_{t-1} \) and thus implies that \( \beta_0 = -0.5\sigma^2_\xi \) and \( \beta_1 = 1 \).
purchase forward foreign currency at a higher price than the spot exchange rate expected to prevail in the future, because the buyer is exchanging a more risky asset (dollars) for a less risky asset (foreign currency). In particular, a strong dollar, which has appeared in the 1980s, may make the holding of dollars riskier due to the possibility of government intervention in the foreign exchange market.

Third, if transaction costs are taken into account, the constant term should also be included in the estimation equation. The constant term may have a positive or negative sign because the expected profits disappear within a neutral band due to transaction cost. Therefore, the constant term is to be freely determined in this analysis.

6.1.2 Testable Hypothesis

This section discusses two testable hypotheses implied by theory: i) the existence of a time-varying risk premium and ii) a structural change in the risk premium due to the change in the U.S. monetary policy regime. The test of these hypotheses are joint tests of our rational expectations assumption and the equilibrium model being used. A rejection of any such test may, therefore, represent a rejection of the rational expectations assumption, or a rejection of the model being used, or both. The rational expectations assumption is absorbed as a maintained hypothesis through this analysis because expectations are not directly observable.

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The first hypothesis to be tested is the existence of a time-varying risk premium. Eq. (6.3) shows that a fraction of $f_{t-1}$, i.e., 
$[(1-H_0)f_{t-1}]$, which varies through time, separates the forward exchange rate from the expected future spot exchange rate. That is, there is a time-varying risk premium in the foreign exchange market as long as agents are risk averse. Recall that if agents are risk neutral ($\eta \rightarrow \infty$) and thus $H_0=1$, the expected future spot exchange rate is equal to the forward exchange rate. So, the existence of a time-varying risk premium can be tested by setting up the null hypothesis of the simple efficiency market hypothesis. In sum,

$H_0: \beta_1 = 1$

$H_1: \beta_1 < 1.

where $H_0$ and $H_1$ denote null and alternative hypotheses, respectively.

The second hypothesis to be tested is the structural shift of the time-varying risk premium. The comparative statics in the last chapter show that an increased conditional variance due to a shift to a money-supply oriented policy regime reduces the speculators' sensitivity to expected profit ($\eta$), which, in turn, lowers the value of $H_0$. Therefore, it is natural to investigate whether there is any structural change, or shift in the time-varying risk premium between the interest-rate and money-supply oriented policy regime. The structural change in the time-varying risk premium can be tested by setting up the null hypothesis of no structural change;

$H_0: \beta^F_1 = \beta^S_1$

$H_1: \beta^F_1 > \beta^S_1$
where superscripts F and S stand for interest-rate and money-supply oriented policy procedures, respectively.

6.2 THE DATA

Spot exchange rates and thirty-day forward rates for the nine major currencies are taken from the Harris Bank Tape Base supported by the Department of Economics at the Ohio State University. The nine currencies used here are the Canadian dollar (CAN), U.K. pound (ENG), Belgian franc (BEL), French franc (FRA), Deutsche mark (GER), Italian lira (ITA), Dutch guilder (NET), Swiss franc (SWI), and Japanese yen (JPN). All rates are U.S. dollars per unit of foreign currency.

The sample period used in this analysis begins June 21, 1974 and ends January 11, 1985. The observations of the first fifteen months are eliminated from the sample on the grounds that the period is considered to be a transitional one. Particularly, Frankel (1980) reports that for most currencies, the prediction errors are even higher during the first year and a half, which is a period of adjustment in international exchange markets, than in the subsequent period. The whole sample period is divided into two subperiods at the point of the

47 The examination of the original data set showed that the observation of the week of December 16, 1983 and rate of Deutsche mark of December 2, 1983 are missing and rate of Dutch guilder of April 6, 1984 is inconsistent with the trend of the series. Since our computer package does not allow missing observations in some estimation methods, particularly, Maximum Likelihood Estimation, the weekly data is chosen for the sample.

48 For detailed explanation of the development in the early period of the floating exchange rate system, see Hansen and Hodrick (1983).
change in the U.S. monetary policy regime, October 1979. The first subperiod is from June 21, 1974 to September 21, 1979 and the second subperiod is from October 19, 1979 to January 11, 1985.

Since the observation interval (every week) is more frequent than the forward-contract time interval (one month), the use of all observations for estimation will result in the error terms following a moving-average process. In order to avoid the problem of serial correlation, rates are sampled at four-week intervals by matching the sampling period with the forecast interval.

6.3 THE ESTIMATION METHODS

Whether or not spot and forward exchange rates are stationary is critical to estimation and inference in testing the hypothesis in the foreign exchange market. The stationarity assumption of exchange

49 See Hansen and Hodrick (1980), Hakkio (1979), and Stockman (1978) for the estimation which allows the error term to be a moving-average by taking more frequent observations than the contract length.

50 Since the exchange rate is observed on Friday of each week, the one-month forward rate is matched up with the spot exchange rate that appears four week later. There may be a discrepancy of one business day, which, it is hoped, will not make much of a difference.

51 There seems to be some disagreement in the literature about whether exchange rates are stationary or not. Frenkel (1977, 1979), Bilson (1981), and Frankel (1980) test the simple efficient market hypothesis by assuming that exchange rates are stationary in the levels or logarithm of the levels. On the other hand, Geweke and Feige (19780, Fama (1984), Hakkio (1979), Hansen and Hodrick (1980), Hansen and Srisvastava (1984), and Mark (1985) consider models of the time difference of a single exchange rate \( e_t - e_{t-1} \) or the difference between spot exchange rate and the lagged forward rate \( e_t - f_{t-1} \).
rates is often required for at least two reasons. First, regressions involving economic variables in levels can be misleading because a high value for $R^2$ is often obtained even when there is no underlying causal relationship between the dependent variable and explanatory variable.\textsuperscript{52} Second, the validity of large-sample inference procedures depends on the stationarity of the variables. This leads to the need to prefilter macroeconomic data to assure the stationarity of the unconditional mean of each variable (even when it is only required that the conditional mean $- E[Y|X]$ - be stationary).

In practice, tools often used to check stationarity of time series include the examination of plots of the series and its differences, and inspection of the sample autocorrelation function (ACF) of the series and its differences. The sample ACF of the log of spot and forward exchange rates in levels damp out slowly but partial autocorrelation damp out quickly after first lag [Table 2]. For the first differenced series, however, the sample ACF are small after the first lag and damp out quickly [Table 3]. This preliminary examination suggests that the differenced series of exchange rates ($e_t - e_{t-1}$ and $f_t - f_{t-1}$) are more likely to be stationary than the series in levels ($e_t$ and $f_{t-1}$). While these tools are useful, they all run into difficulties occasionally. In borderline cases in which the series are stationary but the autoregressive parameter is close to one, the series wanders away from their mean for long stretches.\textsuperscript{53} Harvey (1980) states that "from the

\textsuperscript{52} See Section 6.4 of Granger and Newbold(1977).

\textsuperscript{53} See Dicky, Bell and Miller (1986) for the test for a unit root in the time series models.
TABLE 2
SAMPLE AUTOCORRELATION FUNCTION
OF SPOT EXCHANGE RATES

<table>
<thead>
<tr>
<th>Country</th>
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<td>.96</td>
<td>.92</td>
</tr>
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</table>

Notes: 1) Sample period is 6/21/74 - 1/11/85.
   2) A and P denote sample autocorrelation function (lag 1 to 24 for spot rates, and lag 1 to 12 for differenced rates) and sample partial autocorrelation function (lag 1 to 12), respectively.
   3) * denotes standard deviation.
### TABLE 3

**SAMPLE AUTOCORRELATION FUNCTION OF DIFFERENCED SPOT EXCHANGE RATES**

<table>
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<tr>
<th>Country</th>
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<th>C</th>
<th>D</th>
<th>E</th>
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<td>.05</td>
<td>-.02</td>
<td>-.06</td>
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</tr>
</tbody>
</table>

Notes:
1) Sample period is 6/21/74 - 1/11/85.
2) A and P denote sample autocorrelation function (lag 1 to 24 for spot rates, and lag 1 to 12 for differenced rates) and sample partial autocorrelation function (lag 1 to 12), respectively.
3) * denotes standard deviation.
practical point of view, the regularity conditions are not particularly important. Unless the explanatory variables are known to have been generated in a particular way, it is impossible to check whether or not they hold for a particular sample. " As long as there is no clear-cut agreement about the stationarity assumption of exchange rates, the appropriate approach at this stage is to conduct a regression analysis with differenced as well as undifferenced data and compare results.

The above consideration practically gives us the undifferenced and differenced equation to be tested:

\[ e_t = \beta_0 + \beta_1 f_{t-1} + \xi_t \]  \hspace{1cm} (6.5)

\[ \Delta e_t = \beta_1 \Delta f_{t-1} + \xi_t - \kappa \xi_{t-1} \]  \hspace{1cm} (6.6)

where \( \Delta e_t = e_t - e_{t-1} \) and \( \Delta f_{t-1} = f_{t-1} - f_{t-2} \).

Note that with the alternative hypothesis of \( \beta_1 < 1 \), the only possible way to achieve stationarity of series is to difference the series. First differencing of data may cause serial correlation problems. Specifically, it may lead to a first-order moving-average process. Apart from the assumption of the stationarity of variables, Akaike Information Criterion (AIC) is an appropriate tool to discriminate between a linear regression model in levels and the corresponding model in first differences on the basis of goodness of fit because the two models are competing with each other with different numbers of parameters.

\[ \text{RSS}_u > \text{RSS}_d \]

54 See Harvey (1980). AIC allows for the number of parameters estimated (N) and provides a decision rule to select the model for which AIC = -2lnL + 2N is a minimum, where L is the maximized log-likelihood function. On the basis of AIC he proposes the modified criterion;

\[ \Theta = \frac{\text{RSS}_u}{\text{RSS}_d} \] with the levels formulation selected if \( \Theta < 1 \), where \( \text{RSS}_u \) and \( \text{RSS}_d \) are the residual sum of squares in the levels and first difference regression, respectively.
As a first step, the ordinary least squares (OLS) estimation for each currency will be performed in levels (undifferenced equation) and in first differences (differenced equation). The results will be compared. Then, the modified AIC will be applied to discriminate between the undifferenced and differenced equations.

The undifferenced equation in section 6.1 is suggested as the correct specification of the underlying model for testing the hypotheses. First differencing of the data makes the series more likely to be stationary, but causes serial correlation between error terms. Specifically, it causes a first-order moving average process. If the standard assumptions in the classical linear regression model are satisfied except for the serial correlation of error terms, OLS estimates of coefficients like ($\beta'_1$) in Eq. (6.6) are consistent but the variance estimates of estimated coefficients are inconsistent.\footnote{One possible set of requirements to ensure the consistency of an OLS estimator is i) dependent and independent variables are jointly stationary and ergodic, ii) no singularity of explanatory variable, and iii) the disturbance terms are uncorrelated with independent variables.} If the form of the variance-covariance matrix is unknown, two estimation methods can be considered to correct for a first-order moving-average process in disturbance terms. One is Generalized Method of Moments (GMM) and the other is Maximum Likelihood (ML) Estimation. GMM\footnote{One possible set of requirements to ensure the consistency of an OLS estimator is i) dependent and independent variables are jointly stationary and ergodic, ii) no singularity of explanatory variable, and iii) the disturbance terms are uncorrelated with independent variables.} is used to estimate $\beta'_1$ with an OLS procedure but with a correction for the variance due to the serial correlation of error terms. This method is powerful since it allows us to increase the sample size of data without a great increase in computational burden. ML estimation is well-known.
as the most powerful method, but is computationally burdensome. If the exact form of variance-covariance is known, the ML estimation is equivalent to the Generalized Least Square (GLS) estimation. Since the disturbance term exhibit a moving average process with $K=1$, Generalized Least Square (GLS) is also applied to obtain a more efficient estimates.

Since the disturbance terms are jointly distributed across the currencies in the foreign exchange market, we can regress the estimation equations simultaneously for all nine countries to obtain more efficient estimates. Note that the disturbance terms in Eq.(6.4) consist of real and monetary shocks and exchange rates are expressed relative to dollars. If shocks arise from the U.S. economy, they will

56 Consider the linear regression model, $y_{t+j} = x_t'b + u_t; \ t=1,2,...,T$, where $T$ is sample size and $E(u_t | x_t, x_{t-1},...,x_{t-K},...,x_{t-j}) = 0$ for $j > k \geq 1$. Suppose that $y_t$ and $x_t$ are jointly stationary and ergodic, and let $\mu_t$ and $b$ be the least squares residual and coefficient vector, respectively. Hansen (1979) has shown that $\sqrt{T}(b-b)$ converges to a normally distributed zero mean random vector with covariance matrix

$$[E(x_t'x_t)]^{-1}V[E(x_t'x_t)]^{-1}, \text{where } V = \sum_{k=1-j}^{j-1} E(\mu_t x_t' x_{t-k} x_{t-k}).$$

This asymptotic covariance matrix is consistently estimated by

$$\left[(1/T) \sum_{t=1}^{T} x_t x_t' \right]^{-1} V \left[(1/T) \sum_{t=1}^{T} x_t x_t' \right]^{-1},\text{where } V = \sum_{k=1-j}^{j-1} (1/T) \sum_{t=K+1}^{t=K-j} \mu_t x_t' x_{t-k} x_{t-k}'.$$

He notes that GMM estimation strategy is not fully efficient. Hansen and Hodrick (1980) discussed more efficient estimation strategy which is computationally much more burdensome than the OLS estimation with modified standard errors.

57 For more clarification between ML estimation and GLS estimation, see Chapter 8 of Judge, Griffiths, Hill, Lütkepohl, and Lee (1985).
spread across all currency markets. So, disturbance terms are contemporaneously correlated across currencies. Moreover, Frankel (1980) showed that shocks occurring in one currency market spread to the other currency markets through triangular arbitrage. Zellner's "Seemingly Unrelated Regression (SUR)" is one of the applicable methods. It will improve the precision of the coefficient estimates and thus the two hypothesis suggested in section 6.2 can be jointly tested.\footnote{\cite{Fama1984} for the application of SUR to test the time-varying risk premium.}

6.4 EMPIRICAL RESULTS

6.4.1 Descriptive Statistics

Table 4 presents various measures of exchange rate volatility for the whole period and each subperiod; the difference between the spot exchange rate and its lagged rate \(e_t - e_{t-1}\), the difference between the forward exchange rate and its lagged rate \(f_t - f_{t-1}\), and the difference between the spot exchange rate and the forward exchange rate \(e_t - f_{t-1}\). Since the spot and forward exchange rate are in logs and the differences are multiplied by 100, the three variables are on a percentage per month basis. Here, the mean value of \(e_t - e_{t-1}\), its standard deviation and \(e_t - f_{t-1}\) are usually interpreted as the average depreciation of dollars relative to foreign currency per month, the

\footnote{\cite{Fama1984} for the application of SUR to test the time-varying risk premium.}
volatility of the spot exchange rate and the forward forecast error to the corresponding spot rate, respectively. For example, the Canadian dollar (negative mean value of $e_t - e_{t-1}$) depreciated relative to the U.S. dollar by 0.21% per month with a standard deviation of 1.16% per month for the whole sample period.

The mean values (with the same sign) and the standard error of $f_t - f_{t-1}$, in contrast to those of $e_t - f_{t-1}$, are very close to those of $e_t - e_{t-1}$ for the whole period and each subperiod. This evidence suggests that forward exchange rates follow contemporaneously spot exchange rates more closely than the future spot exchange rate. A negative sign of the mean value of $e_t - e_{t-1}$ means that the dollar appreciated relative to all nine currencies during the second subperiod, reflecting the tight monetary policy together with the introduction of a money-supply oriented procedure.

The standard deviations of $e_t - f_{t-1}$ are slightly smaller in seven out of nine currencies than those of $e_t - e_{t-1}$ for the whole sample period. If the period of the first fifteen months is eliminated as a transitional period from the floating exchange rate period, the forward rates are not necessarily poorer predictors of the future spot rate than the current spot rate.\(^{59}\) The standard deviations of $e_t - f_{t-1}$ are slightly smaller than those of $e_t - e_{t-1}$ in four out of nine currencies for the first subperiod and seven currencies for the second subperiod.

\(^{59}\) Frankel (1980) and Fama (1984) showed that in terms of standard deviation of forecast error the current spot rate is a better predictor of the future spot rate than the current forward rate by including earlier sample period.
### TABLE 4
**SUMMARY STATISTICS**

<table>
<thead>
<tr>
<th></th>
<th>WHOLE PERIOD</th>
<th>FIRST SUBPERIOD</th>
<th>SECOND SUBPERIOD</th>
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<td>MEAN</td>
<td>S.D.</td>
<td>MEAN</td>
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<td></td>
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<td>-0.2553</td>
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Notes: 1) Exchange rates are observed at four-week interval. Forward rates are 30-days contract.  
2) Whole sample period: 6/21/74 - 1/21/85  
   First sample period: 6/21/74 - 9/21/79  
   Second sample period: 10/19/79 - 1/11/85.  
3) S.D denotes standard deviation.
Thus, the predictive power of the forward rate to the corresponding spot exchange rate might slightly increase in the second subperiod.

The standard deviation of $e_{t-1}$, $f_{t-1}$, and $f_{t-1}$ are consistently larger in the second subperiod than in the first subperiod. The only exception is the Canadian dollar. This seems to reflect increased volatility of exchange rates under the second subperiod, as the theory suggested in the last chapter. In section 5.3, it is shown that with the assumption of constant variances of real and monetary shocks, the adoption of a money-supply oriented procedure tends to increase the asymptotic variance of spot and forward exchange rates and the squared prediction error. Even if the estimated variances are not exact demonstration of the asymptotic variances, the increased volatility for the second subperiod can partly be explained by the change in U.S. monetary policy regimes.

6.4.2 Comparison of OLS Results

The undifferenced equation [Eq.(6.5)] and differenced equation [Eq.(6.6)] are estimated for nine currencies with respect to dollars by OLS procedure. For easy of comparison, the estimation results of the two equations for the whole sample period are reported together in Table 5. The results for the first and second subperiod are also reported in Tables 6 and 7, respectively. The formal test of the hypotheses will be postponed until section 6.4.4.
The point estimate of $\beta_1$ using the differenced equation for each currency is much smaller than those using the undifferenced equation for the whole sample period, whereas the estimated standard deviation of $\beta_1$ from the undifferenced equation is much smaller than those using the $\beta_1$ of the differenced equation. The point estimates of $\beta_1$ using the undifferenced equation are larger than 1 in six currencies and are smaller in three currencies, but all are within two standard errors. In the case of the Canadian dollar, the estimate of $\beta_0$ has a negative sign and is significantly different from zero. The point estimates of $\beta_1$ using the differenced equation are between -0.01 and 0.25. The estimated standard deviations, in general, are 5-12 times as large as those using the undifferenced equation. Here, the application of the usual t- or F-test are invalid because the error terms are correlated according to an MA(1) process. If the t- or F-statistics are applied here without caution, we would reject the simple efficient market hypothesis, implying that there is a time-varying risk premium in the foreign exchange market. The two subperiods show similar results. Only in the case of the Japanese yen is the estimate of $\beta_1$ with a negative constant term less than one at the significance level of 5%. Furthermore, the estimates of $\beta_1$ using the undifferenced equation are slightly lower in the second subperiod than in the first subperiod except for U.K. pound, France francs and Italian lira.

The D.W. statistic for most currencies falls between 1.6 and 1.8 in an undifferenced equation. Only the U.K. pound for the second subperiod shows positive autocorrelation at the significance level of 1%. The D.W. statistics are consistent with the hypothesis of the
absence of first-order autocorrelated residuals. The use of the D.W. statistic for the differenced equation is theoretically incorrect because the estimated differenced equation does not include a constant term. The D.W. statistic obtained in an estimation with a constant term (not reported here) is similar to those reported in the table 5 through 7. The Q-statistic as a method for checking white noise disturbance, has been considered. The Q-statistic obtained (not reported here) did not successfully detect the first-order moving-average process of the error terms in the differenced equation. The reason seems to be because the error term is a non-invertible MA(1), i.e., $K=1$ in equation (6.6).

The high value of $R^2$ in the undifferenced equation is in sharp contrast with the extremely low value of $R^2$ squared in the differenced equation. The $R^2$ in the undifferenced equation is, in general, larger than 92% (except for a value of 74% in the Japanese yen in the second subperiod). The forward rates explain the variation of spot exchange rates in levels very well. The $R^2$ is in the range of 1.5% to 8.0% in the differenced equation. In particular, the $R^2$ for the Canadian dollar for the whole and two subperiods, and the U.K. pound in the second subperiod is below 1%. This suggests that the changes in forward rates have an extremely low level of power to predict changes in actual spot exchange rates. This implies that new information in the foreign exchange market like the other asset markets plays an important role in determining changes in spot exchange rates.

______________________________

60 See Harvey (1981) pp 211-212 in section 6.6
### TABLE 5

OLS ESTIMATES: WHOLE PERIOD

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<th></th>
<th>DIFFERENCED EQUATION</th>
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<td><strong>R-SQR</strong></td>
<td><strong>RSS</strong></td>
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<td>&lt; 0.5200&gt;</td>
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</table>

Notes:
1) The whole sample period is 6/21/74 - 1/11/85
2) The values in ( ) are standard deviations
3) The values in < > are t-values, which is tested against β₀=0 and β₁=1, respectively.
4) RSS and D.W. denotes residual sum of squares and Durbin-Watson statistics, respectively.
5) DF = number of observations - number of parameters estimated.
## Table 6

### OLS Estimates: First Subperiod

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<th>Undifferenced Equation</th>
<th>Differented Equation</th>
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<tr>
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<td>ENG</td>
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<td>0.9618 (0.0233)</td>
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<td>0.9784 (0.0419)</td>
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<td>1.0058 (0.0250)</td>
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<td>&lt; 0.4690 &gt;</td>
<td>&lt; 0.2340 &gt;</td>
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<tr>
<td>SWI</td>
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<td>0.0202 (0.0157)</td>
<td>1.0084 (0.0187)</td>
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<td></td>
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<td>&lt; 0.6030 &gt;</td>
<td>&lt; 0.55800 &gt;</td>
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Notes:
1) The first sample subperiod is 6/21/74 - 9/21/79
2) The values in ( ) are standard deviations
3) The values in < > are t-values, which is tested against $\beta_0=0$ and $\beta_1=1$, respectively.
4) RSS and D.W. denotes residual sum of squares and Durbin-Watson statistics, respectively.
5) DF = number of observations - number of parameters estimated.
TABLE 7
OLS ESTIMATES: SECOND SUBPERIOD

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<tr>
<th>Country</th>
<th>( \beta_0 ) (SE)</th>
<th>( \beta_1 ) (SE)</th>
<th>R-SQR</th>
<th>RSS</th>
<th>D.W.</th>
<th>DF</th>
<th>( \beta'_1 ) (SE)</th>
<th>R-SQR</th>
<th>RSS</th>
<th>D.W.</th>
<th>DF</th>
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<td>0.0078</td>
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<td></td>
<td>-0.6005 (0.1172)</td>
<td>0.0039</td>
<td>0.0082</td>
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<tr>
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<td>67</td>
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<td>0.0078</td>
<td>&lt; 2.0140</td>
<td>67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG</td>
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<td>0.0176 (0.0176)</td>
<td>0.9800</td>
<td>0.0624</td>
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<td></td>
<td>0.0779 (0.1221)</td>
<td>0.0060</td>
<td>0.0632</td>
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<td>&lt; -1.8780 &lt; 1.0020</td>
<td>1.9080</td>
<td>67</td>
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<td></td>
<td>0.0082</td>
<td>&lt; 1.8060</td>
<td>67</td>
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</tr>
<tr>
<td>BEL</td>
<td>-0.0299 (0.0519)</td>
<td>0.9533 (0.0138)</td>
<td>0.9870</td>
<td>0.0600</td>
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<td></td>
<td>0.2369 (0.1155)</td>
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<td>0.0657</td>
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<td>67</td>
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<td>0.0060</td>
<td>&lt; 1.9740</td>
<td>67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRA</td>
<td>-0.0095 (0.0254)</td>
<td>1.0028 (0.0138)</td>
<td>0.9872</td>
<td>0.0663</td>
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<td></td>
<td>0.1740 (0.1074)</td>
<td>0.0377</td>
<td>0.0657</td>
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<td>&lt; -0.3720 &lt; 0.2070</td>
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<td>&lt; 1.8380</td>
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<tr>
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<td>0.9726</td>
<td>0.0534</td>
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<td>0.2097 (0.1183)</td>
<td>0.0445</td>
<td>0.0562</td>
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<td>67</td>
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<td>0.0060</td>
<td>&lt; 2.0040</td>
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</tr>
<tr>
<td>ITA</td>
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<td>0.9962 (0.0112)</td>
<td>0.9914</td>
<td>0.0424</td>
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<td></td>
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<td>0.0505</td>
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</tr>
<tr>
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<td>&lt; 2.0330</td>
<td>67</td>
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</tr>
<tr>
<td>NET</td>
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<td>0.9934 (0.0184)</td>
<td>0.9770</td>
<td>0.0497</td>
<td></td>
<td></td>
<td>0.2627 (0.1149)</td>
<td>0.0724</td>
<td>0.0519</td>
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</tr>
<tr>
<td></td>
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<td>1.6720</td>
<td>68</td>
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<td>0.0060</td>
<td>&lt; 2.0010</td>
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<tr>
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<td>0.9884 (0.0287)</td>
<td>0.9454</td>
<td>0.0635</td>
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<td>0.2442 (0.1157)</td>
<td>0.0623</td>
<td>0.0632</td>
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<td>&lt; -0.4440 &lt; 0.4000</td>
<td>1.6090</td>
<td>67</td>
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<td></td>
<td></td>
<td>0.0060</td>
<td>&lt; 1.9320</td>
<td>67</td>
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<td></td>
</tr>
<tr>
<td>JPN</td>
<td>-0.6815 (0.3402)</td>
<td>0.8746 (0.0623)</td>
<td>0.7425</td>
<td>0.0698</td>
<td></td>
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<td>0.1226 (0.1184)</td>
<td>0.0158</td>
<td>0.0734</td>
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</tr>
<tr>
<td></td>
<td>&lt; -2.0030 &lt; 2.0110</td>
<td>1.6840</td>
<td>67</td>
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<td>&lt; 1.9680</td>
<td>67</td>
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</table>

Notes:
1) The whole sample period is 10/19/79 - 1/11/85
2) The values in ( ) are standard deviations
3) The values in < > are t-values, which are tested against \( \beta_0=0 \) and \( \beta_1=1 \), respectively.
4) RSS and D.W. denotes residual sum of squares and Durbin-Watson statistics, respectively.
5) DF = number of observations - number of parameters estimated.
As stated previously, the Akaike Information Criterion is one of the appropriate tools to discriminate between models in levels and in first differences on the basis of goodness of fit. If the residual sum of square in levels is smaller than that of first differences, the level formulation is selected. Model in levels is more favorable in five out of nine currencies for the whole sample period, six currencies for the first subperiod and seven currencies for the second subperiod. Since the RSS in levels and in first difference are very close to each other, it is hard to say that models in levels are superior to the corresponding ones in first differences.

6.4.3 Correction for MA(1) Process of Error Term in Differenced Equation

As suggested in the last section, some econometric technique should be considered to correct for the first-order moving-average process of error terms in the differenced equation. As long as regressors are not correlated with the error terms, OLS estimates of the coefficients are consistent. But, serial correlation between the error terms makes the estimates of the coefficient variances inconsistent. When error terms follow a moving-average process, Generalized Method of Moments (GMM) estimation provides consistent estimates of the variances. Maximum Likelihood (ML) estimation is also considered as another powerful method to correct this problem. With the known first-order moving-average parameter (K=1) as theory
suggests, ML estimation is equivalent to the Generalized Least Square (GLS) estimation.

GMM estimation of the differenced equation is conducted under version 4.11 of RATS (Regression Analysis of Time Series). The estimation results are presented in Table 7. As stated previously, the point estimates of the coefficients are the same as the OLS ones. The corrected estimates of standard errors by GMM, however, in general, are 40-90 times as large as the OLS ones, which are also reported in parenthesis. It is evident that when error terms exhibit a moving-average process, the variance estimates of the coefficients with OLS procedure are biased downward.

As a preliminary analysis, the usual F-test against the hypothesis that $\beta_1=1$ is conducted with the corrected standard error. The significance level, as shown in the last column in the Table, is between 0.79 and 0.92. Based on GMM estimation, the null hypothesis of the simple efficient market hypothesis is not rejected. This low significance level contrasts with the OLS results using the undifferenced equation. As suggested by Hansen and Hodrick [1980], GMM estimates seem not to be fully efficient. In order to obtain more efficient estimates of the variances, two methods might be considered, but are not pursued here. One is to increase the sample size by using more frequent observations than the length of the forward contract. The other one is to follow the suggestion by Hansen and Hodrick (1980), which is computationally burdensome.

As presented in Table 9, the results of the ML estimation are obtained by using the ARIMA procedure under version V of SAS. One of
TABLE 8
GMM ESTIMATES

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<th></th>
<th>x(1)</th>
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<tr>
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<td>0.7976</td>
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WHOLE PERIOD: 6/21/74 - 1/11/85

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FIRST SUBPERIOD: 6/21/74 - 9/21/79

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<td>0.0478</td>
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<td>(0.1155)</td>
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</tbody>
</table>

SECOND SUBPERIOD: 10/19/79 - 1/11/85

| Notes; | 1) GMM estimation obtained by using RATS. |
|        | 2) S.D denotes standard deviation. The values in ( ) are S.D by OLS estimation |
|        | 3) Test statistics are obtained against $\beta_1=1$. |
|        | 4) S.L. denotes the significance level. |
## TABLE 9

**ML ESTIMATES**

<table>
<thead>
<tr>
<th>Country</th>
<th>$\beta_1$ (SE)</th>
<th>$\kappa$ (SE)</th>
</tr>
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<tbody>
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<td><strong>WHOLE PERIOD: 6/21/74 - 1/11/85</strong></td>
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<td></td>
</tr>
<tr>
<td>CAN</td>
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</tr>
<tr>
<td>ENG</td>
<td>0.5277 (0.3059)</td>
<td>0.3428 (0.3353)</td>
</tr>
<tr>
<td>BEL</td>
<td>0.6557 (0.2630)</td>
<td>0.5006 (0.3127)</td>
</tr>
<tr>
<td>FRA</td>
<td>-0.4789 (0.0886)</td>
<td>-0.7480 (0.0822)</td>
</tr>
<tr>
<td>GER</td>
<td>0.5326 (0.3501)</td>
<td>0.3801 (0.3876)</td>
</tr>
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<td>0.9567 (0.0538)</td>
<td>0.8317 (0.0876)</td>
</tr>
<tr>
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<td>0.6128 (0.2843)</td>
<td>0.4397 (0.3326)</td>
</tr>
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<td>0.4926 (0.3133)</td>
<td>0.2905 (0.3474)</td>
</tr>
<tr>
<td>JPN</td>
<td>-0.6925 (0.0414)</td>
<td>-0.9999 (1.0999)</td>
</tr>
<tr>
<td><strong>FIRST SUBPERIOD: 6/21/74 - 9/21/79</strong></td>
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</tr>
<tr>
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<td>0.8809 (0.2306)</td>
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</tr>
<tr>
<td>ENG</td>
<td>0.2133 (0.3428)</td>
<td>-0.1335 (0.3550)</td>
</tr>
<tr>
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<td>0.4287 (0.6020)</td>
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<td>-0.8296 (0.1341)</td>
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<td>0.4324 (0.5798)</td>
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<td>0.8247 (0.2301)</td>
<td>0.6336 (0.2700)</td>
</tr>
<tr>
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<td>0.6406 (0.5534)</td>
</tr>
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<td>0.6167 (0.3578)</td>
<td>0.4042 (0.4125)</td>
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<td>0.7034 (0.2544)</td>
<td>0.5271 (0.3036)</td>
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<tr>
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<td>-0.4752 (0.3256)</td>
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<td>0.2309 (0.5345)</td>
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<td>0.9998 (20.0341)</td>
</tr>
<tr>
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<td>0.1985 (0.4414)</td>
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<tr>
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<td>-0.7038 (0.0895)</td>
<td>-0.9999 (3.7531)</td>
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Notes:
1) The value in ( ) are standard deviations.
2) $\kappa$ is the first-order moving-average parameter in the differenced equation.
### TABLE 10

**COMPARISON BETWEEN OLS AND GLS ESTIMATES**

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<tr>
<th></th>
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<th>UNDIFFERENCED EQUATION</th>
<th>RSS</th>
<th>DF</th>
<th>RSS</th>
<th>DF</th>
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<td>$\beta_1$</td>
<td></td>
<td>$\beta_0$</td>
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</tbody>
</table>
| CAN      | 0.9848 (0.0105)       | -0.0049 (0.0016)       | 0.9855 (0.0107) | 0.0178 | 136
|          | <1.4476>              | <-2.9470>              | <1.3470> | 136 |
| ENG      | 1.0146 (0.0130)       | -0.0130 (0.0085)       | 1.0146 (0.0132) | 0.1029 | 136
|          | <1.1230>              | <-1.5150>              | <1.1060> | 136 |
| BEL      | 1.0128 (0.0105)       | 0.0418 (0.0387)        | 1.0129 (0.0106) | 0.0996 | 136
|          | <1.2109>              | <1.0810>               | <1.2200> | 136 |
| FRA      | 1.0182 (0.0093)       | 0.0229 (0.0158)        | 1.0183 (0.0093) | 1.012 | 136
|          | <1.9569>              | <1.4520>               | <1.9530> | 136 |
| GER      | 1.0054 (0.0151)       | 0.0057 (0.0128)        | 1.0048 (0.0151) | 0.0918 | 136
|          | <0.576>               | <0.4450>               | <0.3190> | 136 |
| ITA      | 1.0037 (0.0065)       | 0.0162 (0.0457)        | 1.0045 (0.0066) | 0.0816 | 136
|          | <0.5692>              | <0.3550>               | <0.6840> | 136 |
| NET      | 1.0051 (0.0141)       | 0.0045 (0.0130)        | 1.0047 (0.0141) | 0.0831 | 136
|          | <0.3617>              | <0.3480>               | <0.3380> | 136 |
| SWI      | 0.9898 (0.0149)       | -0.0036 (0.0116)       | 0.9870 (0.0150) | 0.1293 | 136
|          | <0.6845>              | <-0.3070>              | <0.8590> | 136 |
| JPN      | 0.9912 (0.0190)       | -0.0510 (0.1055)       | 0.9900 (0.0191) | 0.1161 | 136
|          | <0.4631>              | <-0.4840>              | <0.5200> | 136 |

**Notes:**
1) The whole sample period is 6/21/74 - 1/11/85.
2) The values in ( ) are standard deviations.
3) The values in < > are t-values, which are tested against $\beta_0 = 0$ and $\beta_1 = 1$, respectively.
4) RSS denotes residual sum of squares.
5) DF = number of observations - number of parameters estimated.
the notable features of the results is that the point estimates of the parameter ($\beta_1$) tend to increase toward 1, as the point estimates of the first-order moving-average parameter ($K$) increase toward 1. Moreover, the estimated standard errors of $\beta_0$ and $K$ tend to decrease as these point estimates approach 1, respectively. The only exception is a very large standard error of $K$ for the Italian lira for the second subperiod because of a lack of convergence around $K=1$. In general, the point estimates of $\beta_1$ and $K$ for most of the currencies are within two standard errors for the whole sample period and the first subperiod. However, they are outside two standard errors and have the wrong sign in four out of nine currencies in the second subperiod. This evidence suggests that the foreign exchange market seems to be more unstable for the second subperiod due to the increased uncertainty.

The results of the GLS estimation, which allows MA(1) with $K=1$, is reported in Table 10, together with those of the OLS estimation using the undifferenced equation. The results are a little bit surprising. The GLS estimation of the differenced equation with the restriction that $K=1$ is equivalent to the OLS estimation of the undifferenced equation. In the next section we focus on estimation and hypothesis testing based on the undifferenced equation.

6.4.4 SUR Results

The analysis so far shows that spot and forward exchange rates in first differences are more likely to be stationary than those in levels. In addition, differencing data seems to help avoid the problem
of spurious relationships between the dependent and explanatory variables, and a false decision in hypothesis testing. On the other hand, the application of the Akaike Information Criterion is not conducive to discriminating between models in levels and in first difference because they are competing with each other. GMM estimates of variances are not fully efficient, particularly when the sample size is small. ML estimation is somewhat helpful in finding a first-order moving-average process of the error terms in the differenced equations. The GLS estimation is shown to be equivalent to OLS estimation of the undifferenced equation when the first-order moving-average parameter in the differenced equation is restricted to be unity. Although differencing data is more favorable with regard to the power of testing, this section focuses on estimating the undifferenced equation and testing our two hypotheses: the existence of a time-varying risk premium and the structural change in the risk premium due to the change in the U.S. monetary policy regimes.

The results of the OLS estimation and the tests of our hypotheses performed for each currency are reported in Table 11. Assuming that the disturbance terms are normally distributed, the usual F-test is applied to test whether or not forward rates contain a time-varying risk premium in the foreign exchange market. The simple efficient market hypothesis is rejected only in the case of the Japanese yen at the significance level of 5% for the second subperiod. The point estimates of the constant term for the Canadian dollar differ

61 It is formally proved by Harvey (1976).
significantly from zero for the whole period and the second subperiod. In addition, the point estimates of the constant terms consistently have negative signs in the second subperiod. All, except the Japanese yen, are within two standard errors.

The well-known Chow test is performed for each currency to test for the structural change in the time-varying risk premium between the two subperiods. Since our concern is about whether or not the slope coefficient is equal between the two subperiods, the constant term is allowed to take on different values between the two subperiods. The null hypothesis of no structural change for most currencies is not rejected. Only the case of the Japanese yen is significant at the 5% level.

In sum, we cannot, in general, reject both null hypotheses by testing each currency separately. In other words, forward rates do not seem to contain a time-varying risk premium, and there is no structural change between the two subperiods.

---

62 See Ch. 6 of Johnston (1984). The F-test statistics can be obtained by running restricted and unrestricted regression, i.e.,

**Restricted Equation**

\[
\begin{bmatrix}
  y_1 \\
  y_2
\end{bmatrix} = \begin{bmatrix}
  i_1 & i_2 & x_1 & x_2
\end{bmatrix} \begin{bmatrix}
  \beta_{01} \\
  \beta_{02} \\
  \beta_1
\end{bmatrix} + u
\]

**Unrestricted Equation**

\[
\begin{bmatrix}
  y_1 \\
  y_2
\end{bmatrix} = \begin{bmatrix}
  i_1 & i_2 & x_1 & x_2
\end{bmatrix} \begin{bmatrix}
  \beta_{01} \\
  \beta_{02} \\
  \beta_1
\end{bmatrix} + u
\]

where the subscript of the second 1 and 2 denotes first and second subperiod, respectively. Then the test statistics is:

\[
F = \frac{RSS^* - RSS/k-1}{RSS/T-2k} \sim F (k-1, T-2k)
\]

where \( RSS^* \) and \( RSS \) is residual sum of square error of restricted and unrestricted regression, respectively. \( T \) and \( k \) are the number of observations and parameters, respectively.
As stated previously, when disturbance terms are correlated across currencies in the markets, the Seemingly Unrelated Regression technique is suggested as an appropriate method to obtain efficient estimators because we can pool the data for the nine currencies and estimate all nine equations simultaneously. The hypotheses are jointly tested by applying a Likelihood Ratio (LR) test. TSP (Time Series Process) is used for SUR because the program automatically provides the values of likelihood functions, which is needed to test the hypothesis. Table 12 presents the results of SUR.

The point estimate of $\beta_1$ for each currency is below unity for the whole sample period and for each subperiod. The only exception is the French franc for the second subperiod. Moreover, the estimates of $\beta_1$ for all currencies, except for the U.K. pound, are smaller for the second subperiod than for the first subperiod. The direction of the change in the slope coefficient estimates seems to be consistent with what theory predicts.

Tests of the two hypotheses are formally conducted using a Likelihood Ratio Test. The values of the likelihood function obtained when $\beta_1$ is free, and restricted to equal unity, are reported in Table 12. LR statistics against $\beta_1=1$ for all currency is 56.32 for the whole sample period, 24.84 for the first subperiod, and 36.02 for the second

63 Likelihood Ratio test statistics are obtained as a ratio of the restricted likelihood function value to the unrestricted one:

$$ \lambda = \frac{L(\theta^*)}{L(\theta)} \Rightarrow -2\ln\lambda \sim \chi^2(k) $$

where $\theta$ and $\theta^*$ are parameters in the unrestricted and restricted equations, respectively. $k$ is the number of restrictions.
subperiod. The LR test statistics against equality of slope coefficients between the two subperiods, which is obtained using a Chow test as described above, is 235.10. The test statistic, $\chi^2(9)$, is 23.59 at the 0.5% significance level.

In sum, we reject both null hypotheses in the foreign exchange market system as a whole at the high significance level. Under the maintained hypothesis that foreign exchange markets are efficient, this implies that there exist a time-varying risk premium in the foreign exchange market and the structural change in the risk premium due to the change in the U.S. monetary policy regimes. Particularly, the change in U.S. monetary policy might play the role of increasing uncertainty in the latter period. However, this conclusion remains still tentative because our tests for each currency can not reject these null hypotheses and the assumption of stationarity of exchange rates in levels is controversial.

64 Hodrick and Srivastava(1984) found the structural shift due to the change in the U.S. monetary policy regime in the case of the France and the U.K., but not Japan and Switzerland in the context of testing parameter stability.
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<tr>
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<th>$\beta_0^2$</th>
<th>$\beta_1$</th>
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<th>Chow TEST</th>
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<td>-0.0051* ( 0.0018)</td>
<td>0.9773 (0.0215)</td>
<td>1.1094</td>
<td>0.0288 &lt;0.8654&gt;</td>
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<td>0.9845 (0.0349)</td>
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<td>0.9617 (0.0233)</td>
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<td>0.1059</td>
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<td>1.0170 (0.0176)</td>
<td>1.0046</td>
<td>0.3197 &lt;0.0812&gt;</td>
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<td>0.7383 &lt;0.4856&gt;</td>
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(Continued on next page)
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</table>

**Note:**
1) The values in ( ) are standard deviations.
2) The values in < > are significance levels.
3) SUB1 (first subperiod): 6/21/74-9/21/79
    SUB2 (second subperiod): 10/19/79-1/11/85
4) * denotes significance at the level of 5%.
### TABLE 12

**SUR ESTIMATES**

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</tr>
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<td>$\beta_2$</td>
<td>$\beta_3$</td>
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<td>-0.0067 (0.0036)</td>
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<td>0.9953 (0.0108)</td>
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<td>-0.1028 (0.0258)</td>
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<td>0.9821 (0.0071)</td>
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<td>0.9662 (0.0082)</td>
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<td>SWI</td>
<td>-0.0185 (0.0089)</td>
<td>-0.0281 (0.0078)</td>
<td>0.9608 (0.0096)</td>
</tr>
<tr>
<td>JPN</td>
<td>-0.2148 (0.0942)</td>
<td>0.2128 (0.0924)</td>
<td>0.9605 (0.0169)</td>
</tr>
</tbody>
</table>

**LOG OF LIKELIHOOD FUNCTION WHEN $\beta_1$ IS FREE**

<table>
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<th>3516.76</th>
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<th>1810.10</th>
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**LOG OF LIKELIHOOD FUNCTION WHEN $\beta_1=1$**

<table>
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</table>

Note: 1) The values in ( ) are standard error.
Chapter VII
CONCLUDING REMARKS

By taking the traditional partial equilibrium approach to spot and forward exchange rate determination into the general equilibrium framework, this dissertation has examined two aspects of the impact of monetary policy on the foreign exchange market. First, an unanticipated increase in money supply results in instantaneous depreciation of the currency when the price in the goods market adjusts slowly relative to the asset market. Following initial depreciation, regardless of whether it is overshooting or undershooting, the exchange rate appreciates ahead of the price level in the first phase and lags behind the price level in the remaining period. One of the conclusions in this analysis is that there is no clear cut relationship between the exchange rate and the trade balance. With the J-curve effect a depreciating currency may be associated with a trade deficit in the first phase, but with a surplus in another. As a consequence, efforts to predict the trade balance on the basis of the exchange rate or vice versa do not look promising. While any effort may seem to be successful in some case, it is likely to fail in others.

Exchange rate volatility followed by monetary disturbance depends upon the structural parameters of the model. Results of numerical simulation showed that the likelihood of overshooting is positively related to the sensitivity of speculators to expected profits and
negatively to the sensitivity of traders to relative price. With the short-run sensitivity of foreign exchange market participants, the overshooting is more likely to happen because the sensitivity of commercial traders is initially held low relative to that of speculators to expected profits. This is consistent with the Driskill conjecture (1981a) that the more important the flow consideration is, the less likely the overshooting is. In other words, the greater the weight of flow consideration is in exchange rate determination, the less likely is the real exchange rate to diverge from purchasing power parity.

The second issue considered in this dissertation was how the change in the U.S. monetary policy regime has affected the exchange rate volatility and the magnitude of forward rate forecast error. The money supply, as an instrument to achieve policy goals, was endogenized. The specified money supply process implied that the monetary authority puts more weight on the deterministic and uncontrollable parts of money supply under a money-supply oriented procedure. The sensitivity of speculators to expected profit, which is inversely related to the conditional forecast variance of exchange rate, is endogenized rather than parametrically given. Comparative statics with respect to monetary authority's reaction parameter showed that the speculators become more risk averse due to the increase in the conditional variance. On the one hand, the more weight on the uncontrollable part of money supply directly increases the volatility of spot and forward rate and the magnitude of forward-rate forecast error. On the other hand, the more risk-averseness of speculators
tends to indirectly increase their portion due to real shock, but the indirect effect on their portion due to monetary shock depends on what array of structural parameters of the model is used. In general, the higher volatility and the larger magnitude in the 1980s, as predicted by the theory, is partly induced by the change to a money-supply oriented policy regime.

The analysis in chapter V suggested that if speculators are assumed to be risk averse, the forward rate contains a time-varying risk premium. The estimation equation derived, which has the same form as used in the simple efficient market hypothesis, is used to test two hypotheses: the existence of a time-varying risk premium and the structural change in the risk premium. Since exchange rates in the first difference are more likely to be stationary rather than those in levels, estimations are performed with the differenced and undifferenced data and results were compared. Since the estimation of differenced equation requires the correction of first-order moving-average process of error term to obtain consistent estimates of the variance, Generalized Method of Moments and Maximum Likelihood Estimation methods have been considered. Furthermore, estimation of the differenced equation with the restriction of the first-order moving-average parameter to unity was shown to be equivalent to the estimation of the undifferenced equation. Since the theory suggested that the disturbance terms are correlated across currencies, the Seemingly Unrelated Regression method by pooling data is applied to undifferenced equation in order to reduce sampling error and improve the power of the test.
By testing each currency individually, we cannot reject both null hypotheses: the simple efficient market hypothesis and no structural change in a time-varying risk premium. The only exception is Japanese yen. One of the surprising results is that, when SUR method is applied, the point estimate of slope coefficient for each currency becomes less than unity (except the France franc in the second subperiod) and, moreover, is smaller (except U.K. pound) during the later period, which matches the sample period of a money-supply oriented policy regime. Both hypothesis are rejected at high significance level. This empirical results is the consistent with the implication of the model that under the maintained hypothesis that economic agents are rational, there exists a time-varying risk premium in the foreign exchange market system as a whole and the risk premium increases under a money-supply oriented procedure due the increase in the conditional forecast variance.

Several limitations in our analysis deserve further extension. One is the small country assumption, which eliminated the repercussion effect associated with the income and trade balance effects. Moreover, the monetary policy regime in the other countries is assumed to remain the same in the analysis in chapter V. The incorporation of a repercussion effect and the interdependence of policy regimes into the analysis become closer to reality by reflecting highly integrated international asset and goods markets.

The correlation between the trade deficit and depreciation followed by monetary expansion has been explained in terms of the J-curve effect. In contrast, the portfolio balance approach, by
observing the counterpart of a trade imbalance as a transfer of wealth, emphasizes that the change in wealth affects exchange rate through the change in domestic expenditure, money or bond demand. Either approach is complementary rather than competitive in the sense that each stresses different aspects. Consideration of both effects could give us a more complete picture of the movement of economic variables.

Our empirical analysis for the test of a time-varying risk premium has used non-overlapping samples to circumvent problems with serial correlation but has sacrificed three-fourths of observations in the process. The GMM and ML estimation based on differenced exchange rates results in the large standard deviation and thus we reject our hypotheses for individual currencies. In order to increase the asymptotic power of the test, it might be suggested to make use of all available data by applying the GMM technique [Hansen (1979)].
Appendix A.

Derivation of Price Equation

Substituting Eq. (4.4) into Eq. (4.5) in the text and rearranging terms, we obtain:

\[ P_{t+1} = (1-\delta \sigma - \delta \sigma \lambda)P_t + \delta \sigma \lambda M_t + \{\delta (\rho - 1) - \delta \sigma \lambda \phi \} y_t 
- \delta \sigma \lambda \nu_t + \omega_{t+1} + \delta \sigma E_t^r P_{t+1} \quad (A.1) \]

The ultimate solution is expressed in terms of exogeneous and predetermined variables in the model as following:

\[ P_{t+1} = a_0 P_t + a_1 M_t + a_2 y_t + a_3 \nu_t + a_4 \omega_{t+1} \quad (A.2) \]

Taking expectation of \( P_{t+1} \) at time \( t \) with \( E_t \omega_{t+1} = 0 \), we obtain:

\[ E_t P_{t+1} = a_0 P_t + a_1 M_t + a_2 y_t + a_3 \nu_t \quad (A.3) \]

Substituting Eq. (A.3) into Eq. (A.1) and rearranging terms, we obtain:

\[ P_{t+1} = (1-\delta \sigma - \delta \sigma \lambda + \delta \sigma a_1)P_t + (\delta \sigma + \delta \sigma a_1)M_t + (\delta (\rho - 1) - \delta \sigma \lambda + \delta \sigma a_2) y_t 
- (\delta \sigma - \delta \sigma a_3) \nu_t + \omega_{t+1} \quad (A.4) \]

Rationality requires following restrictions, i.e., each coefficient of Eq.(A.4) must be equal to that of Eq.(A.2):

\[ a_0 = 1-\delta \sigma - \delta \sigma \lambda + \delta \sigma a_1 \quad (A.5) \]
\[ a_1 = \delta \sigma + \delta \sigma a_1 \]
\[ a_2 = \delta (\rho - 1) - \delta \sigma \lambda + \delta \sigma a_2 \]
\[ a_3 = -\delta \sigma + \delta \sigma a_3 \]
and \( a_4 = 1 \).
Appendix B  

Derivation of Exchange Rate Equation

Substituting the covered interest parity relationship \( f_t = e_t + R_t \) into Eq. (4.3) in the text yields:

\[
(-\alpha + \beta + \eta) e_t = \eta e_{t-1} - (\eta + \beta) R_t + \eta R_{t-1} - \alpha P_t - \mu_t
+ \eta e_{t+1} + \eta e_{t-1} e_t + \beta e_{t+1} P_t
\]  

(B.1)

Substituting Eq. (4.4) in the text into Eq. (B.1), we obtain:

\[
(-\alpha + \beta + \eta) e_t = \eta e_{t-1} - (\eta + \beta)(\lambda P_t - \lambda M_t + \lambda \phi y_t + \lambda v_t) + \eta (\lambda P_{t-1} - \lambda M_{t-1})
+ \lambda \phi y_{t-1} + \lambda v_{t-1} - \alpha P_t - \mu_t + \eta e_{t+1} + \eta e_{t-1} e_t + \beta e_{t+1} P_t
\]

Substituting Eq. (A.3) for \( \lambda^{P} \) above equation yields:

\[
(-\alpha + \beta + \eta) e_t = \eta e_{t-1} + (\eta + \beta) M_t - \eta M_{t-1} + \{(-\alpha - (\eta + \beta) \lambda) P_t + \eta \lambda P_{t-1}
- (\eta + \beta) \lambda \phi y_t + \eta \lambda \phi y_{t-1} + \eta \lambda v_t - \eta \lambda v_{t-1} - \mu_t
+ \eta e_{t+1} + \eta e_{t-1} e_t + \beta e_{t+1} P_t
\]

Substituting Eq. (A.2) for \( e_{t+1} \) in above equation yields:

\[
(-\alpha + \beta + \eta) e_t = \eta e_{t-1} + (\eta + \beta) M_t - \eta M_{t-1} + \{(-\alpha - (\eta + \beta) \lambda) P_t + \eta \lambda P_{t-1}
- \eta \lambda \phi y_t + \eta \lambda \phi y_{t-1} + \eta \lambda v_t - \eta \lambda v_{t-1} - \mu_t
+ \eta e_{t+1} + \eta e_{t-1} e_t + \beta e_{t+1} P_t
\]

Since \( P_t \) is predetermined variable in the model, lagging Eq. (A.2) by one period and substituting it into above equation yields:

\[
(-\alpha + \beta + \eta) e_t = \eta e_{t-1} + \{((\eta + \beta) \lambda + \beta a_1) M_t - \eta \lambda M_{t-1}
+ \{(-\alpha - (\eta + \beta) \lambda + \beta a_0) P_t + \eta \lambda P_{t-1} - \{((\eta + \beta) \lambda + \beta a_2) y_t + \eta \lambda \phi y_{t-1} - \{((\eta + \beta) \lambda + \beta a_3) v_t
+ \eta \lambda v_{t-1} - \mu_t + \eta e_{t+1} + \eta e_{t-1} e_t
\]
The ultimate solution of spot exchange rate equation can be expressed in terms of exogenous and predetermined variables in the model as follows:

\[ e_t = \beta e_{t-1} + \gamma \lambda_p t + \lambda_1 M_t + \lambda_2 \lambda_3 \lambda_4 P_t + \lambda_5 Y_t + \lambda_6 \gamma t + \lambda_7 \omega_t \]  

\[ E_t e_{t+1} = \beta e_t + (\beta_1 + \beta_2) M_t + \beta_3 P_t + (\beta_4 + \beta_5) Y_t + \beta_6 \gamma_t \]

\[ E_t e_{t-1} = \beta e_{t-1} + (\beta_1 + \beta_2) M_{t-1} + \beta_3 P_{t-1} + (\beta_4 + \beta_5) Y_{t-1} + \beta_6 \gamma_{t-1} \]

Substituting Eq. (B.4) and Eq. (B.5) into Eq. (I.B.2), we obtain:

\[ \{(-\alpha + \beta + \eta)(1-\pi_0)\} e_t = -[\pi_1 \pi_2 + \eta(\pi_1 + \pi_2)] M_t - [\pi_3 \pi_4 + \eta(\pi_1 + \pi_2)] P_t - [\pi_5 \pi_6 + \eta(\pi_1 + \pi_2)] Y_t - [\pi_7 \pi_8 + \eta(\pi_1 + \pi_2)] \gamma_t \]

\[ + \eta(\lambda + \phi - \beta a_2) y_t + \eta(\lambda + \phi - \beta a_3) v_t \]

\[ + \eta(\lambda + \phi - \beta a_2) y_{t-1} + \eta(\lambda + \phi - \beta a_3) v_{t-1} \]

\[ = \eta e_t + ((\eta + \beta) \lambda + \beta a_1) M_t - [\eta - \rho - (\eta + \beta) \lambda + \beta a_0] a_1 M_{t-1} \]

\[ + [\eta + \rho - (\eta + \beta) \lambda + \beta a_0] a_2 P_{t-1} - (\eta + \beta) \lambda + \beta a_2 y_t \]

\[ + [\eta + \rho - (\eta + \beta) \lambda + \beta a_0] a_2 P_{t-1} - (\eta + \beta) \lambda + \beta a_2 y_{t-1} \]

\[ + [\eta + \rho - (\eta + \beta) \lambda + \beta a_0] a_3 v_{t-1} - (\eta - (\eta + \beta) \lambda + \beta a_0) v_t \]

\[ + \eta e_{t-1} - \eta e_{t-1} \]

[\text{(B.2)}]

The ultimate solution of spot exchange rate equation can be expressed in terms of exogenous and predetermined variables in the model as follows:

\[ e_t = \beta e_{t-1} + \gamma \lambda_p t + \lambda_1 M_t + \lambda_2 \lambda_3 \lambda_4 P_t + \lambda_5 Y_t + \lambda_6 \gamma t + \lambda_7 \omega_t \]

\[ E_t e_{t+1} = \beta e_t + (\beta_1 + \beta_2) M_t + \beta_3 P_t + (\beta_4 + \beta_5) Y_t + \beta_6 \gamma_t \]

\[ E_t e_{t-1} = \beta e_{t-1} + (\beta_1 + \beta_2) M_{t-1} + \beta_3 P_{t-1} + (\beta_4 + \beta_5) Y_{t-1} + \beta_6 \gamma_{t-1} \]

\[ \{(-\alpha + \beta + \eta)(1-\pi_0)\} e_t = -[\pi_1 \pi_2 + \eta(\pi_1 + \pi_2)] M_t - [\pi_3 \pi_4 + \eta(\pi_1 + \pi_2)] P_t - [\pi_5 \pi_6 + \eta(\pi_1 + \pi_2)] Y_t - [\pi_7 \pi_8 + \eta(\pi_1 + \pi_2)] \gamma_t \]

\[ + \eta(\lambda + \phi - \beta a_2) y_t + \eta(\lambda + \phi - \beta a_3) v_t \]

\[ + \eta(\lambda + \phi - \beta a_2) y_{t-1} + \eta(\lambda + \phi - \beta a_3) v_{t-1} \]

\[ = \eta e_t + ((\eta + \beta) \lambda + \beta a_1) M_t - [\eta - \rho - (\eta + \beta) \lambda + \beta a_0] a_1 M_{t-1} \]

\[ + [\eta + \rho - (\eta + \beta) \lambda + \beta a_0] a_2 P_{t-1} - (\eta + \beta) \lambda + \beta a_2 y_t \]

\[ + [\eta + \rho - (\eta + \beta) \lambda + \beta a_0] a_2 P_{t-1} - (\eta + \beta) \lambda + \beta a_2 y_{t-1} \]

\[ + [\eta + \rho - (\eta + \beta) \lambda + \beta a_0] a_3 v_{t-1} - (\eta - (\eta + \beta) \lambda + \beta a_0) v_t \]

\[ + \eta e_{t-1} - \eta e_{t-1} \]

[\text{(B.2)}]
Rationality requires following restrictions:

\[ \eta(1-\Pi_0) \]

\[ \Pi_0 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta\Pi_1+\Pi_2}{-\alpha+\beta+\eta(1-\Pi_0)} \]

\[ \Pi_1 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta(\Pi_1+\Pi_2)}{-\alpha+\beta+\eta(1-\Pi_0)} \]

\[ \Pi_2 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta(\Pi_1+\Pi_2)-\eta\Pi_3 a_1}{-\alpha+\beta+\eta(1-\Pi_0)} \]

\[ \Pi_3 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta(\Pi_1+\Pi_2)-\eta\Pi_3 a_1}{-\alpha+\beta+\eta(1-\Pi_0)} \]

\[ \Pi_4 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta(\Pi_1+\Pi_2)-\eta\Pi_3 a_1}{-\alpha+\beta+\eta(1-\Pi_0)} \]

\[ \Pi_5 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta(\Pi_1+\Pi_2)-\eta\Pi_3 a_1}{-\alpha+\beta+\eta(1-\Pi_0)} \]

\[ \Pi_6 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta\Pi_3}{-\alpha+\beta+\eta(1-\Pi_0)} \]

\[ \Pi_7 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta\Pi_3}{-\alpha+\beta+\eta(1-\Pi_0)} \]

\[ \Pi_8 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta\Pi_3}{-\alpha+\beta+\eta(1-\Pi_0)} \]

and \[ \Pi_9 = \frac{-(\eta+\beta)\lambda+\beta a_1+\eta\Pi_3}{-\alpha+\beta+\eta(1-\Pi_0)} \]
Appendix C

Proof of \( \frac{d\Pi_0}{d\eta} > 0 \)

Note that \( \Pi_0 \) in Eq. (B.7) can be written in quadratic form:

\[
\Pi_0 = \frac{\eta(1-\Pi_0)}{-\alpha + \beta + \eta(1-\Pi_0)}
\]

\( \Rightarrow \Pi_0\{-\alpha + \beta + \eta(1-\Pi_0)\} = \eta(1-\Pi_0) \) \hspace{1cm} (C.1)

\( \Rightarrow \Pi_0\{-\alpha + \beta\} = \eta(1-\Pi_0)^2 \) \hspace{1cm} (C.2)

Dividing both side of Eq. (C.2) by \( \Pi_0(1-\Pi_0) \) and Eq. (C.1) by \( \Pi_0 \) yields:

\[
\frac{\eta(1-\Pi_0)}{\Pi_0} = \frac{-\alpha + \beta}{1-\Pi_0} = -\alpha + \beta + \eta(1-\Pi_0)
\] \hspace{1cm} (C.3)

Rearranging Eq. (C.1) yields:

\[
\eta\Pi_0^2 - (-\alpha + \beta + 2\eta)\Pi_0 + \eta = 0
\] \hspace{1cm} (C.4)

Differentiating Eq. (C.4) totally with respect to \( \Pi_0 \) and \( \eta \) yields:

\[
(1-\Pi_0)^2 d\eta = (-\alpha + \beta + 2\Pi_0\eta(1-\Pi_0)) d\Pi_0
\]

Rearranging terms in the above equation, we obtain:

\[
\frac{d\Pi_0}{d\eta} = \frac{(1-\Pi_0)^2}{2\Pi_0(1-\Pi_0) - \alpha + \beta} \Rightarrow \frac{d\eta}{d\Pi_0} = \frac{2\Pi_0(1-\Pi_0) - \alpha + \beta}{(1-\Pi_0)^2} = \frac{2\Pi_0}{1-\Pi_0} + \frac{-\alpha + \beta}{(1-\Pi_0)^2}
\] \hspace{1cm} (C.5)

Using Eq. (C.3), Eq. (C.5) becomes:

\[
\frac{d\eta}{d\Pi_0} = \frac{2\Pi_0}{1-\Pi_0} + \frac{\Pi_0(1-\Pi_0)}{1-\Pi_0} = \frac{2\Pi_0 + \eta\Pi_0}{(1-\Pi_0)^2} = \frac{\eta(1+\Pi_0)}{(1-\Pi_0)^2} > 0
\]

Therefore, \( \frac{d\Pi_0}{d\eta} = \frac{(1-\Pi_0)\Pi_0}{\eta(1+\Pi_0)} > 0 \). Q.E.D.
Appendix D

Proof of $\Pi_1 > 0$

In order to prove $\Pi_1 = \frac{(\eta+\beta)\lambda+\beta a_1 + \eta(\Pi_1 + \Pi_2)}{-\alpha+\beta+\eta(1-\Pi_0)} > 0$, note that

$$\Pi_3 = \frac{\eta \lambda + \{-\alpha-(\eta+\beta)\lambda+\beta a_0\} a_0}{-\alpha+\beta+\eta(1-\Pi_0)+\eta(1-a_0)} = \Pi_3 = \frac{\eta \lambda + \{-\alpha-(\eta+\beta)\lambda+\beta a_0\} a_0}{-\alpha+\beta+\eta(1-\Pi_0)+(1-a_0)}$$ (D.1)

$$\Pi_0 (-\alpha+\beta+\eta(1-\Pi_0)) = \eta(1-\Pi_0) = \eta(1-\Pi_0)^2 = \Pi_0 (-\alpha+\beta)$$ (D.2)

and $\Pi_0 + \Pi_1 + \Pi_2 + \Pi_3 = 1 \Rightarrow \Pi_1 + \Pi_2 = 1 - \Pi_0 - \Pi_3$ (D.3)

Since the denominator of $\Pi_1$ is positive, it is sufficient to show that the numerator is positive. Substituting Eq. (D.1) and Eq. (D.3) into the numerator of $\Pi_1$ yields:

$$(\eta+\beta)\lambda+\beta a_1 + \eta(\Pi_1 + \Pi_2)$$

$$= (\eta+\beta)\lambda+\beta a_1 + \eta(1-\Pi_0) - \eta \Pi_3$$

$$= (\eta+\beta)\lambda+\beta a_1 + \eta(1-\Pi_0) - \frac{\eta \lambda + \{-\alpha-(\eta+\beta)\lambda+\beta a_0\} a_0}{-\alpha+\beta+\eta(1-\Pi_0)+(1-a_0)}$$

$$= \frac{1}{\Delta} \left[ ((\eta+\beta)\lambda+\beta a_1 + \eta(1-\Pi_0))\left(-\frac{\alpha+\beta}{\eta} + (1-\Pi_0) + (1-a_0)\right) \right.$$

$$- \eta \lambda + \alpha a_0 + (\eta+\beta)\lambda a_0 - \beta a_0^2 \left. \right]$$

where $\Delta = -\frac{\alpha+\beta}{\eta} + (1-\Pi_0) + (1-a_0)$

Multiplying both side by $\Delta$ and rearranging terms yields:

$$\Delta((\eta+\beta)\lambda+\beta a_1 + \eta(\Pi_1 + \Pi_2))$$

$$= ((\eta+\beta)\lambda+\beta a_1)\left(-\frac{\alpha+\beta}{\eta} + (1-\Pi_0)(-\alpha+\beta) + (\eta+\beta)\lambda(1-\Pi_0) + \beta a_1(1-\Pi_0) \right)$$

$$+ \eta(1-\Pi_0)^2 + (\eta+\beta)(1-a_0) + \beta a_1(1-a_0) + \eta(1-\Pi_0)(1-a_0)$$

$$- 107$$
\begin{align*}
&= \{(\eta+\beta)\lambda + \beta a_1\}_{\frac{\alpha+\beta}{n}} + (1-\Pi_0)(-\alpha+\beta) + (\eta+\beta)\lambda(1-\Pi_0) + \beta a_1(1-\Pi_0) \\
&\quad + \eta(1-\Pi_0)^2 + \eta(\lambda-\lambda a_0 + \beta a_1(1-a_0) + \eta(1-\Pi_0)(1-a_0) \\
&\quad - \eta\lambda + \alpha a_0 + (\eta+\beta)\lambda a_0 - \beta a_0^2
\end{align*}

\begin{align*}
&= \{(\eta+\beta)\lambda + \beta a_1\}_{\frac{\alpha+\beta}{n}} + (1-\Pi_0)(-\alpha+\beta) + (\eta+\beta)\lambda(1-\Pi_0) + \beta a_1(1-\Pi_0) \\
&\quad + \eta(1-\Pi_0)^2 + \eta(1-\Pi_0)^2 + \beta \lambda + \beta a_1(1-a_0) + \eta(1-\Pi_0)(1-a_0) + \alpha a_0 - \beta a_0^2
\end{align*}

\begin{align*}
&= \{(\eta+\beta)\lambda + \beta a_1\}_{\frac{\alpha+\beta}{n}} + (1-\Pi_0)(-\alpha+\beta) + (\eta+\beta)\lambda(1-\Pi_0) + \beta a_1(1-\Pi_0) \\
&\quad + \eta(1-\Pi_0)^2 + \beta \lambda + \beta a_1(1-a_0) + \eta(1-\Pi_0) - \{(1-\Pi_0)\alpha+\beta a_0
\end{align*}

\begin{align*}
&\quad + a_0 + \beta a_0(1-a_0)
\end{align*}

\begin{align*}
&= \{(\eta+\beta)\lambda + \beta a_1\}_{\frac{\alpha+\beta}{n}} + (1-\Pi_0)(-\alpha+\beta) + (\eta+\beta)\lambda(1-\Pi_0) + \beta a_1(1-\Pi_0) \\
&\quad + \Pi_0(-\alpha+\beta) + \beta \lambda + \beta a_1(1-a_0) + \eta(1-\Pi_0) - \alpha + \beta + \alpha - \beta \\
&\quad - \{(1-\Pi_0)\alpha+\beta a_0 + a_0 + \beta a_0(1-a_0)
\end{align*}

\begin{align*}
&= \{(\eta+\beta)\lambda + \beta a_1\}_{\frac{\alpha+\beta}{n}} + (1-\Pi_0)(-\alpha+\beta) + (\eta+\beta)\lambda(1-\Pi_0) + \beta a_1(1-\Pi_0) \\
&\quad + \Pi_0(-\alpha+\beta) + \beta \lambda + \beta a_1(1-a_0) + \{(1-\Pi_0)\alpha+\beta(1-a_0)
\end{align*}

\begin{align*}
&\quad + \beta a_0(1-a_0)
\end{align*}

\begin{align*}
&= \{(\eta+\beta)\lambda + \beta a_1\}_{\frac{\alpha+\beta}{n}} + (\eta+\beta)\lambda(1-\Pi_0) + \beta a_1(1-\Pi_0) + \beta \lambda \\
&\quad + \beta a_0(1-a_0) + \{(1-\Pi_0)\alpha+\beta(1-a_0) + \beta a_0(1-a_0) > 0
\end{align*}

because \(\beta - \alpha > 0\), \(0 < \Pi_0 < 1\), \(0 < a_0 < 1\), and \(0 < a_1 < 1\). Q.E.D.
Appendix E

Derivation of Spot Exchange Rate Equation

Substituting Eq. (5.7) and Eq. (5.8) with the covered interest parity \( f_t = e_t + R_t \) into Eq. (5.6) in the text, we obtain:

\[
-\alpha e_t + \mu_t + \eta(E_{t-1}e_t - e_{t-1} + \tau e_{t-1}) + \beta(e_t - \tau e_t - \delta e_t) = \eta (E_t e_{t+1} - e_t + \tau e_t)
\]  
(E.1)

Rearranging terms of the above equation yields:

\[
\{-\alpha + \beta(1-\delta) + \eta \} e_t = \eta e_{t-1} + \tau (\eta + \beta) e_t - \eta \tau e_{t-1} - \mu_t + \eta E_t e_{t+1} - \eta E_{t-1} e_t
\]  
(E.2)

The ultimate solution of the spot exchange equation can be specified in terms of the exogenous and predetermined variables in Eq. (E.2):

\[
e_t = \Pi_0 e_{t-1} + \Pi_1 e_t + \Pi_2 e_{t-1} + \Pi_3 u_t
\]  
(E.3)

Taking expectation of \( e_t \) at \( t-1 \) and \( e_{t+1} \) at \( t \) in Eq. (E.3), respectively, and substituting \( E_t e_{t-1} \) and \( E_t e_{t+1} \) into Eq. (E.2), we obtain:

\[
\{-\alpha + \beta(1-\delta) + \eta(1-\Pi_0)\} e_t = \eta(1-\Pi_0) e_{t-1} + \{\eta(\tau + \Pi_2) + \beta \tau\} e_t - \eta(\tau + \Pi_2) e_{t-1} - \mu_t
\]  
(E.4)

Hence

\[
e_t = \frac{\eta(1-\Pi_0)}{-\alpha + \beta(1-\delta) + \eta(1-\Pi_0)} e_{t-1} + \frac{\eta(\tau + \Pi_2) + \beta \tau}{-\alpha + \beta(1-\delta) + \eta(1-\Pi_0)} e_t - \frac{1}{-\alpha + \beta(1-\delta) + \eta(1-\Pi_0)} \mu_t
\]  
(E.5)

Therefore, rationality requires the following restrictions:

\[
\Pi_0 = \frac{\eta(1-\Pi_0)}{-\alpha + \beta(1-\delta) + \eta(1-\Pi_0)}
\]  
(E.6)
\[
\begin{align*}
\Pi_1 &= \frac{\eta(\tau+\Pi_2)+\beta \tau}{-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)} \\
\Pi_2 &= \frac{-\eta(1+\Pi_2)}{-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)} \\
\Pi_3 &= \frac{-1}{-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)}
\end{align*}
\]

and 
\[
\Pi_3 = \frac{-1}{-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)} \tag{E.9}
\]

In Eq. (II.A.6), \( \Pi_0 \) can be solved as following:

\[
\begin{align*}
-\alpha \Pi_0 + \beta(1-\delta\theta) \Pi_0 + \eta(1-\Pi_0) \Pi_0 &= \eta(1-\Pi_0) \\
\eta \Pi_0^2 - \{2\eta-\alpha+\beta(1-\delta\theta)\} \Pi_0 + \eta &= 0
\end{align*}
\]

\[
\Pi_0 = \frac{-\alpha+\beta(1-\delta\theta) \pm \sqrt{(2\eta-\alpha+\beta(1-\delta\theta))^2-4\eta^2}}{2\eta}
\]

\[
= 1 + \frac{-\alpha+\beta(1-\delta\theta)}{2\eta} \pm \frac{\sqrt{(2\eta-\alpha+\beta(1-\delta\theta))^2-4\eta(-\alpha+\beta(1-\delta\theta))}}{2\eta} \sqrt{1+\frac{4\eta}{-\alpha+\beta(1-\delta\theta)}}
\]

Hence, the stable root, which satisfies \( 0<\Pi_0<1 \), becomes:

\[
\Pi_0 = 1 + \frac{-\alpha+\beta(1-\delta\theta)}{2\eta} \mp \frac{\sqrt{(1+\frac{4\eta}{-\alpha+\beta(1-\delta\theta)})}}{2\eta} \frac{\sqrt{(2\eta-\alpha+\beta(1-\delta\theta))^2-4\eta(-\alpha+\beta(1-\delta\theta))}}{2\eta} \tag{E.10}
\]

In order to see the relationship among \( \Pi_0 \) through \( \Pi_3 \), it’s useful to note that in Eq. (E.6):

\[
\Pi_0(-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)) = \eta(1-\Pi_0) \Rightarrow \Pi_0(-\alpha+\beta(1-\delta\theta)) = \eta(1-\Pi_0)^2
\]

Dividing both sides of above equation by \( \Pi_0(1-\Pi_0) \), we obtain:

\[
\frac{\eta(1-\Pi_0)}{\Pi_0} = \frac{-\alpha+\beta(1-\delta\theta)}{1-\Pi_0} = -\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0) \tag{E.11}
\]

By inspection of Eq. (E.6) through Eq. (E.9) and Eq. (E.11), we obtain:

\[
\Pi_2 = -\tau \Pi_0 \tag{E.12}
\]

\[
\Pi_1 = \frac{\eta\tau(1-\Pi_0)+\beta \tau}{-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)} = \tau \left( \frac{\eta(1-\Pi_0)+\beta}{-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)} \right)
\]
\[ e_t = \frac{\tau \{- (\alpha + \beta e) \Pi_0 + \beta \}}{-\alpha + \beta (1 - \delta \theta)} \epsilon_t^* - \tau \Pi_0 \epsilon_{t-1} - \frac{(1 - \Pi_0)}{-\alpha + \beta (1 - \delta \theta)} \mu_t \]

The spot exchange rate equation can be solved iteratively in terms of current and past disturbance terms to yield:

\[ e_t = \frac{\tau \{- (\alpha + \beta e) \Pi_0 + \beta \}}{-\alpha + \beta (1 - \delta \theta)} \epsilon_t^* - \tau \Pi_0 \epsilon_{t-1} - \frac{(1 - \Pi_0)}{-\alpha + \beta (1 - \delta \theta)} \mu_t \]

\[ + \Pi_0 \left\{ \frac{\tau \{- (\alpha + \beta e) \Pi_0 + \beta \}}{-\alpha + \beta (1 - \delta \theta)} \epsilon_{t-1}^* - \tau \Pi_0 \epsilon_{t-2} - \frac{(1 - \Pi_0)}{-\alpha + \beta (1 - \delta \theta)} \mu_{t-1} \right\} \]

\[ + \Pi_0^2 \left\{ \frac{\tau \{- (\alpha + \beta e) \Pi_0 + \beta \}}{-\alpha + \beta (1 - \delta \theta)} \epsilon_{t-2}^* - \tau \Pi_0 \epsilon_{t-3} - \frac{(1 - \Pi_0)}{-\alpha + \beta (1 - \delta \theta)} \mu_{t-2} \right\} \]

\[ + \cdots \]

\[ = \frac{\tau \{- (\alpha + \beta e) \Pi_0 + \beta \}}{-\alpha + \beta (1 - \delta \theta)} \epsilon_t^* - \tau \Pi_0 \epsilon_{t-1}^* - \tau \Pi_0 \epsilon_{t-2}^* - \tau \Pi_0 \epsilon_{t-3}^* \]

\[ - \frac{(1 - \Pi_0)}{-\alpha + \beta (1 - \delta \theta)} \left\{ \mu_{t} + \Pi_0 \mu_{t-1} + \Pi_0^2 \mu_{t-2} + \cdots \right\} \]

\[ \cdots \] (E.14)

because

\[ - \tau \Pi_0 \{- (\alpha + \beta e) \Pi_0 + \beta \} = - \tau \Pi_0 \left\{ \frac{- \alpha + \beta (1 - \delta \theta) + \alpha \Pi_0 - \beta (1 - \delta \theta \Pi_0)}{-\alpha + \beta (1 - \delta \theta)} \right\} \]

\[ = - \tau \Pi_0 \left\{ \frac{- \alpha (1 - \Pi_0) - \beta \delta \theta (1 - \Pi_0)}{-\alpha + \beta (1 - \delta \theta)} \right\} = \frac{\tau \{- (\alpha + \beta e) \Pi_0 + \beta \}}{-\alpha + \beta (1 - \delta \theta)} \Pi_0 \]
Appendix F  

Proof of \( \frac{d\Pi_0}{d\eta} > 0 \)

In the same manner as Appendix I.C., consider Eq. (E.6):

\[
\Pi_0 = \frac{\eta(1-\Pi_0)}{-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)} \tag{E.6}
\]

Multiplying both sides by \([-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)]\) yields:

\[
\Pi_0(-\alpha+\beta(1-\delta\theta)+\eta(1-\Pi_0)) = \eta(1-\Pi_0) \\
\eta\Pi_0^2 - (-\alpha+\beta(1-\delta\theta)+2\eta)\Pi_0 + \eta = 0 \tag{F.1}
\]

Differentiating Eq. (F.1) totally with respect to \(\Pi_0\) and \(\eta\) yields:

\[
(\Pi_0-1)^2d\eta + [2\eta\Pi_0 - (-\alpha+\beta(1-\delta\theta)+2\eta)]d\Pi_0 = 0 \\
(1-\Pi_0)^2d\eta = (-\alpha+\beta(1-\delta\theta)+2\eta(1-\Pi_0))d\Pi_0 \tag{F.2}
\]

Hence, \(\frac{d\eta}{d\Pi_0} = \frac{2\eta(1-\Pi_0)-\alpha+\beta(1-\delta\theta)}{(1-\Pi_0)^2} = \frac{2\eta}{(1-\Pi_0)} + \frac{-\alpha+\beta(1-\delta\theta)}{(1-\Pi_0)^2} \)

Since \(\frac{-\alpha+\beta(1-\delta\theta)}{(1-\Pi_0)^2} = \frac{\eta(1-\Pi_0)}{\Pi_0}\) in Eq. (E.11),

\[
\frac{d\eta}{d\Pi_0} = \frac{2\eta}{1-\Pi_0} + \frac{\eta(1-\Pi_0)}{\Pi_0} \cdot \frac{1}{1-\Pi_0} = \frac{2\eta\Pi_0+\eta\Pi_0}{(1-\Pi_0)^2}\Pi_0 = \frac{\eta(1+\Pi_0)}{(1-\Pi_0)^2}\Pi_0
\]

Therefore, \(\frac{d\Pi_0}{d\eta} = \frac{(1-\Pi_0)^2\Pi_0}{\eta(1+\Pi_0)} > 0\). \tag{F.3}

Q.E.D.
Appendix G

Conditional Forecast Variance

Updating $e_t$ by one period in Eq. (5.15) in the text and taking expectation of $e_{t+1}$ at time $t$, we obtain forecast variance as follow:

\[
\text{Var}(e_{t+1}) = E[e_{t+1} - E_t e_{t+1}]^2
\]

\[
= E[\frac{\tau(-\alpha + \beta \delta \theta) \Pi_0 + \beta}{-\alpha + \beta (1-\delta \theta)} e_{t+1} - \frac{(1-\Pi_0)}{-\alpha + \beta (1-\delta \theta)} u_{t+1}]^2
\]

\[
= \frac{1}{(-\alpha + \beta (1-\delta \theta))^2} \left[ \tau^2 \left(-\alpha + \beta \delta \theta\right) \Pi_0 + \beta \right] \sigma_\varepsilon^2 + (1-\Pi_0)^2 \sigma_\mu^2
\]

(G.1)

Substituting Eq. (G.1) back into Eq. (5.6) in the text and rearranging terms, we obtain:

\[
\eta \left[ \tau^2 \left(-\alpha + \beta \delta \theta\right) \Pi_0 + \beta \right] \sigma_\varepsilon^2 + (1-\Pi_0)^2 \sigma_\mu^2 = K \left(-\alpha + \beta (1-\delta \theta)^2\right)
\]

(G.2)

Differentiating Eq. (G.2) with respect to $\eta$ and $\tau$, we obtain:

\[
2\tau \eta \left(-\alpha + \beta \delta \theta\right) \Pi_0 + \beta \right] \sigma_\varepsilon^2 d\tau + \left[ \tau^2 \left(-\alpha + \beta \delta \theta\right) \Pi_0 + \beta \right] \sigma_\varepsilon^2 + (1-\Pi_0)^2 \sigma_\mu^2] d\eta
\]

\[
+ \eta \left[-2\tau^2 \left(-\alpha + \beta \delta \theta\right) \Pi_0 + \beta \right] \left(\alpha + \beta \delta \theta\right) \frac{\partial \Pi_0}{\partial \eta} \sigma_\varepsilon^2 + 2(1-\Pi_0)(-\frac{\partial \Pi_0}{\partial \eta}) \sigma_\mu^2] d\eta = 0
\]

Rearranging terms with respect to $d\tau$ and $d\eta$, we obtain:

\[
2\tau \eta \left(-\alpha + \beta \delta \theta\right) \Pi_0 + \beta \right] \sigma_\varepsilon^2 d\tau
\]

\[
+ \left[ \tau^2 \left(-\alpha + \beta \delta \theta\right) \Pi_0 + \beta \right] \left(-\alpha + \beta \delta \theta\right) \Pi_0 + \beta - 2\eta (\alpha + \beta \delta \theta) \frac{\partial \Pi_0}{\partial \eta} \sigma_\varepsilon^2
\]

\[
+ \left(1-\Pi_0\right)^2 - 2\eta (1-\Pi_0) \frac{\partial \Pi_0}{\partial \eta} \sigma_\mu^2] d\eta = 0
\]

Since $\frac{d\Pi_0}{d\eta} = \frac{(1-\Pi_0) \Pi_0}{\eta (1+\Pi_0)}$ in Appendix F,
\[ (1 - \Pi_0) \frac{\partial \Pi_0}{\partial \eta} = (1 - \Pi_0)^2 \left( 1 - \frac{2 \Pi_0}{1 + \Pi_0} \right) \frac{(1 - \Pi_0)^3}{1 + \Pi_0} > 0 \]

and

\[ 2\eta (\alpha + \beta \delta \theta) \frac{\partial \Pi_0}{\partial \eta} = 2\eta (\alpha + \beta \delta \theta) \frac{(1 - \Pi_0) \Pi_0}{\eta (1 + \Pi_0)} = \frac{2(\alpha + \beta \delta \theta) \Pi_0 (1 - \Pi_0)}{1 + \Pi_0}. \]

Hence,

\[ 2 \tau \eta \{ - (\alpha + \beta \delta \theta) \Pi_0 + \beta \} \sigma^2 d\tau \]

\[ + \left[ \tau^2 \{ - (\alpha + \beta \delta \theta) \Pi_0 + \beta \} \{ - (\alpha + \beta \delta \theta) \Pi_0 + \beta - \frac{2(\alpha + \beta \delta \theta) \Pi_0 (1 - \Pi_0)}{1 + \Pi_0} \} \sigma^2 \right] \]

\[ + \frac{(1 - \Pi_0)^3}{1 + \Pi_0} \sigma^2 [d\eta = 0 \quad (G.3) \]

Since \( \{ - (\alpha + \beta \delta \theta) \Pi_0 + \beta \}^2 > 0 \) and \( \frac{(1 - \Pi_0)^3}{1 + \Pi_0} > 0 \), consider the following terms of Eq. (G.3):

\[ \tau^2 \{ - (\alpha + \beta \delta \theta) \Pi_0 + \beta \} \{ - (\alpha + \beta \delta \theta) \Pi_0 + \beta - \frac{2(\alpha + \beta \delta \theta) \Pi_0 (1 - \Pi_0)}{1 + \Pi_0} \} \]

\[ = \tau^2 (\alpha + \beta \delta \theta)^2 \left( \Pi_0 - \frac{\beta}{\alpha + \beta \delta \theta} \right) \left( \frac{\Pi_0 (3 - \Pi_0)}{1 + \Pi_0} - \frac{\beta}{\alpha + \beta \delta \theta} \right) \quad (G.4) \]

Note that \( \eta = \frac{-\alpha (1 - \delta \theta)}{(1 - \Pi_0)^2 \Pi_0} > 0 \) in Eq. (E.6). Thus, \( \beta (1 - \delta \theta) > \alpha. \)

Let \( Z = \frac{\beta}{\alpha + \beta \delta \theta}. \) If \( \alpha > -\beta \delta \theta, \) then \( Z > 1. \) Otherwise, \( Z < \Pi_0. \) Since \( 0 < \Pi_0 < \frac{\Pi_0 (3 - \Pi_0)}{1 + \Pi_0} < 1 \) at the range of \( 0 < \Pi_0 < 1, \) the last two parentheses of Eq. (G.4), becomes:

\[ (\Pi_0 - Z) \left\{ \frac{\Pi_0 (3 - \Pi_0)}{1 + \Pi_0} - Z \right\} = (Z - \Pi_0) \left\{ Z - \frac{\Pi_0 (3 - \Pi_0)}{1 + \Pi_0} \right\} > 0. \]

\[ (G.5) \]

Therefore, \( \frac{d\eta}{d\tau} < 0. \)
Appendix H

Asymptotic Variance of Spot Exchange Rate

From Eq. (E.14), the spot exchange rate can be expressed as the current and past disturbance terms:

$$e_t = \frac{\tau[-(\alpha+\beta\delta\theta)\Pi_0+\beta]}{-\alpha+\beta(1-\delta\theta)}\varepsilon_t$$

$$+ \frac{\tau(1-\Pi_0)(\alpha+\beta\delta\theta)}{-\alpha+\beta(1-\delta\theta)}[\Pi_0^2\varepsilon_{t-1}+\Pi_0^2\varepsilon_{t-2}+\Pi_0^3\varepsilon_{t-3}+\cdots]$$

$$- \frac{(1-\Pi_0)}{-\alpha+\beta(1-\delta\theta)}[\mu_{t}+\Pi_0\mu_{t-1}+\Pi_0^2\mu_{t-2}+\cdots]. \quad (E.14)$$

Since it is assumed that the disturbance terms are independently and identically distributed with mean zero and constant variance, the asymptotic variance of the spot exchange rate becomes:

$$\text{Asy Var}(e_t) = \frac{\tau^2[-(\alpha+\beta\delta\theta)\Pi_0+\beta]^2}{(-\alpha+\beta(1-\delta\theta))^2} + \frac{\tau^2(1-\Pi_0)^2(\alpha+\beta\delta\theta)^2}{(-\alpha+\beta(1-\delta\theta))^2} \cdot \frac{\Pi_0^2}{1-\Pi_0}\sigma_e^2$$

$$+ \frac{(1-\Pi_0)^2}{(-\alpha+\beta(1-\delta\theta))^2} \cdot \frac{1}{1-\Pi_0} \sigma_\mu^2$$

$$= \frac{1}{(-\alpha+\beta(1-\delta\theta))^2} \{\tau^2[-(\alpha+\beta\delta\theta)\Pi_0+\beta]^2$$

$$+ \frac{\Pi_0^2(1-\Pi_0)(\alpha+\beta\delta\theta)^2}{1+\Pi_0}\} \sigma_e^2 + \frac{1-\Pi_0}{1+\Pi_0} \sigma_\mu^2 \} \quad (H.1)$$
When $\sigma_{\epsilon}^2 = 0$, 
$$
\frac{d(\text{Asy Var}(e_t))}{d \tau} = \frac{1}{\{-\alpha+\beta(1-\delta \theta)\}^2 \left(1+\Pi_0\right)^2} \frac{\frac{\eta \Pi_0}{\eta \Pi_0} - (1-\Pi_0)(-\frac{\eta \Pi_0}{\eta \Pi_0})}{\eta \Pi_0} \cdot \frac{\eta}{\eta \Pi_0} \cdot \frac{2}{\eta \Pi_0} \cdot \sigma_{\Pi}^2 > 0 \quad (H.2)
$$

When $\sigma_{\mu}^2 = 0$, 
$$
\frac{d(\text{Asy Var}(e_t))}{d \tau} = \frac{1}{\{-\alpha+\beta(1-\delta \theta)\}^2 \left(1+\Pi_0\right)^2} \left\{2\tau \left[\left(-\alpha+\beta \delta \theta\right)\Pi_0 + \beta\right]^2 + \frac{\Pi_0^2(1-\Pi_0)(\alpha+\beta \delta \theta)^2}{1+\Pi_0}\right\}
$$

$$
= \frac{1}{\{-\alpha+\beta(1-\delta \theta)\}^2 \left(1+\Pi_0\right)^2} \left\{2\tau \left[\left(-\alpha+\beta \delta \theta\right)\Pi_0 + \beta\right]^2 + \frac{\Pi_0^2(1-\Pi_0)(\alpha+\beta \delta \theta)^2}{1+\Pi_0}\right\}
$$

$$
- \tau^2 \left(\alpha+\beta \delta \theta\right) \left[2 \left(-\alpha+\beta \delta \theta\right)\Pi_0 + \beta\right]
$$

$$
- \frac{\left(\alpha+\beta \delta \theta\right)2\Pi_0(1-\Pi_0)\Pi_0^2}{\left(1+\Pi_0\right)^2} \frac{\eta \Pi_0}{\eta \Pi_0} \cdot \frac{\eta}{\eta \Pi_0} \cdot \frac{2}{\eta \Pi_0} \cdot \sigma_{\epsilon}^2
$$

$$
= \frac{1}{\{-\alpha+\beta(1-\delta \theta)\}^2 \left(1+\Pi_0\right)^2} \left\{2\tau \left[\left(-\alpha+\beta \delta \theta\right)\Pi_0 + \beta\right]^2 + \frac{\Pi_0^2(1-\Pi_0)(\alpha+\beta \delta \theta)^2}{1+\Pi_0}\right\}
$$

$$
+ 2\tau^2 \left(\alpha+\beta \delta \theta\right)^2 \left\{ \frac{\Pi_0^2+2\Pi_0}{\left(1+\Pi_0\right)^2} - \frac{\beta}{\alpha+\beta \delta \theta} \right\} \frac{\eta \Pi_0}{\eta \Pi_0} \cdot \frac{\eta}{\eta \Pi_0} \cdot \frac{2}{\eta \Pi_0} \cdot \sigma_{\epsilon}^2
$$

(H.3)
Appendix I

Asymptotic Variance of Forward Exchange Rate

Substituting Eq. (5.7) and Eq. (5.17) in the text into covered interest parity ($f_t = e_t + R_t$), we obtain:

$$f_t = e_t - \tau e_t$$

$$\frac{\tau(1-\Pi_0)(\alpha+\beta\delta\theta)}{-\alpha+\beta(1-\delta\theta)} \left\{ \varepsilon_t + \Pi_0 \varepsilon_{t-1} + \Pi_0^2 \varepsilon_{t-2} + \cdots \right\}$$

$$- \frac{(1-\Pi_0)}{-\alpha+\beta(1-\delta\theta)} \left\{ \mu_t + \Pi_0 \mu_{t-1} + \Pi_0^2 \mu_{t-2} + \cdots \right\}$$

$$= \frac{(1-\Pi_0)}{-\alpha+\beta(1-\delta\theta)} \left\{ \tau(\alpha+\beta\delta\theta) \left\{ \varepsilon_t + \Pi_0 \varepsilon_{t-1} + \Pi_0^2 \varepsilon_{t-2} + \cdots \right\}$$

By assuming zero mean and known constant variance of the disturbance term, the asymptotic variance of forward rate can be obtained as following:

$$\text{Asy Var}(f_t) = \frac{(1-\Pi_0)^2}{\left(-\alpha+\beta(1-\delta\theta)\right)^2} \cdot \frac{1}{1-\Pi_0^2} \left\{ \tau^2(\alpha+\beta\delta\theta)^2 \sigma^2_\varepsilon + \sigma^2_\mu \right\}$$

$$= \frac{1}{\left(-\alpha+\beta(1-\delta\theta)\right)^2} \cdot \frac{1-\Pi_0}{1+\Pi_0} \left\{ \tau^2(\alpha+\beta\delta\theta)^2 \sigma^2_\varepsilon + \sigma^2_\mu \right\}$$

(I.2)
When $\sigma_v^2 = 0$, \[ \frac{d(\text{Asy Var}(f_v))}{d\tau} = \frac{1}{(-\alpha + \beta(1-\delta \theta))^2} \cdot \frac{(1+\Pi_0)\left(-\frac{\partial \Pi_0}{\partial \eta}\right) - (1-\Pi_0)\left(-\frac{\partial \Pi_0}{\partial \eta}\right)}{(1+\Pi_0)^2} \cdot \frac{\partial \eta}{\partial \tau} \cdot \sigma_\mu^2 > 0 \] (I.3)

When $\sigma_\mu^2 = 0$, \[ \frac{d(\text{Asy Var}(f_v))}{d\tau} = \frac{1}{(-\alpha + \beta(1-\delta \theta))^2} \cdot \frac{1-\Pi_0}{1+\Pi_0} \cdot \frac{2\tau(\alpha + \beta \delta \theta)^2}{\sigma_v^2} \cdot \frac{\partial \Pi_0}{\partial \eta} \cdot \frac{\partial \eta}{\partial \tau} \cdot \sigma_\varepsilon^2 > 0 \] (I.4)
Appendix J

Forward Forecast Error and Squared Prediction Error

Updating Eq. (E.13) by one period and subtracting Eq. (I.1) from it, we obtain:

\[ e_{t+1} - f_t = \pi_0 e_t + \frac{\pi \{- (\alpha + \beta \delta \theta) \pi_0 + \beta \}}{-\alpha + \beta (1-\delta \theta)} \varepsilon_{t+1} - \pi \varepsilon_t \]

\[ = \frac{(1-\pi_0)}{-\alpha + \beta (1-\delta \theta)} \mu_{t+1} - (e_t - \tau \varepsilon_t) \]

\[ = (\pi_0-1)e_t - \tau (\pi_0-1) \varepsilon_t + \frac{\tau \{- (\alpha + \beta \delta \theta) \pi_0 + \beta \}}{-\alpha + \beta (1-\delta \theta)} \varepsilon_{t+1} \]

\[ = \frac{(1-\pi_0)}{-\alpha + \beta (1-\delta \theta)} \mu_{t+1} \]

The above equation can be rewritten as the following:

\[ e_{t+1} - f_t = -(1-\pi_0)(e_t - \tau \varepsilon_t) + \frac{\tau \{- (\alpha + \beta \delta \theta) \pi_0 + \beta \}}{-\alpha + \beta (1-\delta \theta)} \varepsilon_{t+1} \]

\[ = \frac{(1-\pi_0)}{-\alpha + \beta (1-\delta \theta)} \mu_{t+1} \]

Using Eq. (I.2), we obtain:

\[ \text{Asy Var}(e_{t+1} - f_t) = \frac{(1-\pi_0)^2}{-\alpha + \beta (1-\delta \theta)^2} \cdot \frac{(1-\pi_0)^2}{1-\pi_0^2} \cdot \frac{\tau^2 \{ (\alpha + \beta \delta \theta)^2 \sigma_e^2 + \sigma_\mu^2 \}}{1-\pi_0^2} \]

\[ + \frac{\tau^2 \{- (\alpha + \beta \delta \theta) \pi_0 + \beta \}^2}{-\alpha + \beta (1-\delta \theta)^2} \sigma_e^2 + \frac{(1-\pi_0)^2}{-\alpha + \beta (1-\delta \theta)^2} \sigma_\mu^2 \]

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Differentiating Eq. (J.3) with respect to $\tau$, we obtain:

When $\sigma^2_\varepsilon = 0$, \[
\frac{d}{d\tau} \text{Asy Var}(e_{t+1-f_t})
\]
\[\begin{align*}
&= \frac{-2}{\{-\alpha+\beta(1-\delta\theta)\}^2} \cdot \frac{(1-\Pi_0)(3+\Pi_0)}{(1+\Pi_0)^2} \cdot \frac{\partial \Pi_0}{\partial \eta} \cdot \frac{\partial \eta}{\partial \tau} \cdot \sigma^2_\mu > 0 \quad (J.4)
\end{align*}\]

When $\sigma^2_\mu = 0$, \[
\frac{d}{d\tau} \text{Asy Var}(e_{t+1-f_t})
\]
\[\begin{align*}
&= \frac{2\tau}{\{-\alpha+\beta(1-\delta\theta)\}^2} \left[ (\alpha+\beta\delta\theta)^2 \frac{(1-\Pi_0)^3}{1+\Pi_0} + \frac{2(1-\Pi_0)^2(2+\Pi_0)}{(1+\Pi_0)^2} \right] \cdot \frac{\partial \Pi_0}{\partial \eta} \cdot \frac{\partial \eta}{\partial \tau} \cdot \sigma^2_\varepsilon \\
&\quad + \frac{\tau^2}{\{-\alpha+\beta(1-\delta\theta)\}^2} \left[ (\alpha+\beta\delta\theta)^2 \frac{-2(1-\Pi_0)^2(2+\Pi_0)}{(1+\Pi_0)^2} \right] \\
&\quad - 2(\alpha+\beta\delta\theta)(-\alpha+\beta\delta\theta)\Pi_0+\beta) \cdot \frac{\partial \Pi_0}{\partial \eta} \cdot \frac{\partial \eta}{\partial \tau} \cdot \sigma^2_\varepsilon \\
&\quad = \frac{2\tau}{\{-\alpha+\beta(1-\delta\theta)\}^2} \left[ (\alpha+\beta\delta\theta)^2 \frac{(1-\Pi_0)^3}{1+\Pi_0} + \frac{2(1+\Pi_0)^2}{(1+\Pi_0)^2} \right] \cdot \frac{\partial \Pi_0}{\partial \eta} \cdot \frac{\partial \eta}{\partial \tau} \cdot \sigma^2_\varepsilon \\
&\quad - \frac{2\tau^2(\alpha+\beta\delta\theta)^2}{\{-\alpha+\beta(1-\delta\theta)\}^2} \left[ \frac{4-(1+\Pi_0)^2}{(1+\Pi_0)^2} + \frac{\beta}{\alpha+\beta\delta\theta} \cdot (1-1) \right] \cdot \frac{\partial \Pi_0}{\partial \eta} \cdot \frac{\partial \eta}{\partial \tau} \cdot \sigma^2_\varepsilon \\
&\quad = (J.5)
\end{align*}\]
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