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MODELS OF EXCHANGE RATE BEHAVIOR: APPLICATION TO THE YEN AND THE MARK

by

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I. Introduction

Since the industrial countries adopted floating exchange rate systems in early 1973, nominal and real exchange rates of the major industrial countries have greatly varied. Greater variability in the exchange rates have greatly affected the economies of industrial nations and the rest of the world. As a result, the behaviors of exchange rates of major currencies and the U.S. dollar in particular have become focal points of many international economic policy issues in the 1980's. In consequence, many detailed studies have addressed the behavior and determination of exchange rates. However, many theoretical models of exchange rate determination provide poor explanations of the actual behaviors of the exchange rates in the 1980's. The use of such models to analyze issues of economic policy involves some embarrassments and reflects an element of faith rather than economic logic.

As part of the effort to enhance our understanding of the actual movements of exchange rates under the floating exchange rate system, the purpose of this paper is to review the development of major exchange rate modeling in the past two decades and to build a better empirical model of exchange rate determination. This paper presents an empirical model of yen-dollar and mark-dollar exchange rates tested over the period from January 1976 to June 1990.

In section two, we will discuss major theories on exchange rate determination for industrial countries generated since the early 1970's to cast some light on exchange rate modeling. In section three, we discuss some of the empirical results of the theories of exchange rate determination applied to the yen-dollar and mark-dollar rates, and finally section four holds the conclusion of this paper.

2. Select Exchange Rate Theories

In the traditional approach, the exchange rate of a country is viewed as the relative price of goods and services between the country in question and the rest of the world. Thus the exchange rate is determined by the 'flow' equilibrium in the foreign exchange market. In the asset approach, the exchange rate is regarded as a relative price of assets. Thus the exchange rate is determined by the 'stock' equilibrium in the asset markets. The asset market approach can be divided into the monetary approach and the portfolio balance approach.

In this study, the flow model and the asset model is used to determine the exchange rate of a small open economy. The country in question is small relative to the rest of the world, so all the conditions of the foreign country, including prices, interest rates and outputs, are assumed to be predetermined. For analytical simplicity, we assume that economic agents have perfect foresight on all future events; perfect foresight assumption is consistent with the rational expectations hypothesis.

2.1 Balance of payments flow approach

The balance of payments is the net inflows of foreign exchange resulting from current and private capital transactions. Traditionally, the current account balance is assumed to depend negatively (positively) on domestic (foreign) real income and positively on the real exchange rate and net foreign assets. The real exchange rate is the nominal exchange rate multiplied by the ratio of foreign goods prices to domestic goods prices. It is assumed that foreigners do not invest in assets of the other country including money, so that capital account transactions are only done by domestic residents. The capital account balance is affected positively if the domestic interest rate is greater than the foreign interest rate. Hence, the flow equilibrium condition in the balance of payments is:

$$\text{(1) } C(\overset{(-)}{y}, \overset{(+)}{y^*}, \overset{(+)}{e + p^* - e}, \overset{(+)}{f}) + K(\overset{(+)}{i - i^*}, \overset{(+)}{f}) = 0$$

where C=the current account balance,

y=the logarithm of domestic real income, log (domestic income Y),

p=the logarithm of domestic prices, log (domestic prices P),

f=the logarithm of net foreign asset holdings, log (foreign assets holding F),

i=nominal interest rate at home,

* indicates foreign variables, e.g. y* is the logarithm of foreign real income.

Equation (1) is solved for e:

$$(2)\quad e=H(\overset{(+)}{y},\ \overset{(-)}{y^*},\ \overset{(+)}{p},\ \overset{(-)}{p^*},\ \overset{(-)}{i},\ \overset{(+)}{i^*},\ \overset{(-)}{f})$$

The exchange rate in the balance of payments flow equilibrium is related positively to domestic real income and prices and negatively to domestic interest rate and holdings of net foreign assets. It is also affected positively by foreign interest rates and negatively by foreign real income and prices. If the domestic and foreign produced goods are perfect substitutes in the consumer demand preferences, the price elasticity of goods is infinite. In this case, equation (2) indicates the exchange rate to be determined exclusively by the relative price of goods, namely $e=p-p^*$. In the case where domestic and foreign assets are perfect substitutes in the investor's portfolio preferences, the exchange rate is determined by the differential between domestic and foreign interest rates, that is to say $e=i-i^*$.

2.2 Asset approach

The asset approach regards the exchange rate as the relative price of two assets, domestic and foreign. Of the various asset approach models, we will discuss the flex-price monetary model (FPM), sticky-price monetary model (SPM), and portfolio balance model (PB). The differences among these models are apparent in the degree of flexibility of prices and substitutability of assets.[1]

1. For the discussions on the theories of exchange rate determination, see Dornbusch (1980, 1989), Frankel (1983) and Isard (1987).

We assume that the country trades only commodities with the rest of the world. If we assume perfect mobility of goods across countries and perfect substitutability of demand preference, the domestic price level is equal in equilibrium to the foreign price multiplied by the exchange rate, whereby purchasing power parity (PPP) holds. From the PPP condition, the exchange rate is determined by the relative price of goods:

(3) $e=p-p^*$

2.3 Flex-price monetary model (FPM)

The flex-price monetary model (FPM) is based on the assumption that prices are perfectly flexible, so that any disequilibrium in the goods market is instantaneously cleared by a change in price levels. Because of the complete flexibility in prices, the output (real income) is always at the full employment level determined by the supply condition of the economy. The model regards the exchange rate to be the relative price of two currencies. For the determination of the exchange rate, therefore, the FPM model depends on the supply of and demand for money.

The flex-price monetary model by Frenkel (1976) and Bilson (1978) is summarized by equations (3) and (4):

(3) $e=p-p^*$

(4) $m-p=\Phi y-\lambda i \qquad \Phi>0,\ \lambda>0$

where m is the logarithm of the nominal money stock supplied by the monetary authority, log (nominal money stock M). It is assumed in (4) that a higher real income causes the demand for real money balance to rise, whereas a higher domestic interest rate reduces the demand for real money balance.

The money supply affects the price level, which in turn determines the exchange rate. We substitute equation (4) into (3) to solve for e:

(5) $e=m-\Phi y+\lambda i-p^*$

An increase in domestic output or a decrease in the domestic interest rate creates an excess demand for the money balance. The excess money demand is satisfied by reducing domestic absorption, thereby causing prices to fall. Consequently, a rise in domestic real income or a decrease in the domestic interest rate appreciates the exchange rate. Variations in the nominal interest rate reflects both the real interest rate, r, and the rate of change in the prices, π. Thus, a rise in the nominal interest rate induced by a rise in the expected inflation depreciates the exchange rate.

In addition to the trade of goods, we introduce capital transactions across countries. We assume that the domestic and foreign assets are perfect substitutes, implying that domestic interest rate equals foreign interest rate plus the expected rate of depreciation; this equality is called uncovered interest rate parity (UIRP). In a world with only one commodity and one bond, the FPM model consists of three equations (3), (4), and (5):

(3) $e=p-p^*$

(4) $m-p=\Phi y-\lambda i$

(5) $\dot{e}=i-i^*$

where $\dot{e}=e_{t+1}-e_t$ for any t is the rate of expected depreciation from time t to t+1.

To examine the factor determining the exchange rate, we solve for e:

(6) $e=m-\Phi y+\lambda i^*+\lambda\dot{e}-p^*$

At the given expected exchange rate, e_{t+1}, initially, the exchange rate is:

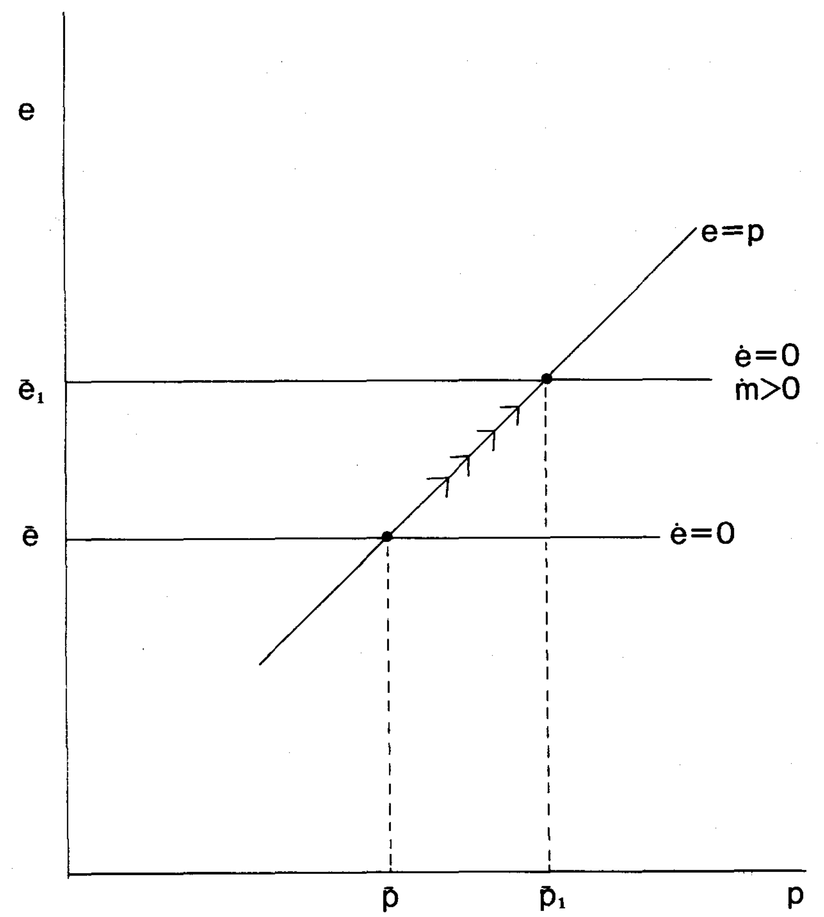
(7) $e=(1+\lambda)^{-1}(m-\Phi y+\lambda i^*-p^*)+\lambda e_{+1}$

At full equilibrium, $\dot{e}=0$ and hence $i=i^*$. The equilibrium price, *p*, and equilibrium exchange rate, $\bar{e}$, are:

$$(8)\quad \bar{p}=m-\Phi y+\lambda i^*$$
$$\bar{e}=\bar{p}-p^*=m-\Phi y+\lambda i^*-p^*$$

The subtraction of (8) from (6) yields $\dot{e}=-\lambda^{-1}(\bar{e}-e)$, which describes the time path toward the equilibrium exchange rate. The PPP condition implies that the rate of expected depreciation equals the expected inflation differential. Using the condition $\dot{e}=\pi-\pi^*$ and the dynamic path equation above, we obtain:[2]

Figure 1: Flex-Price Monetary Model



2. Real interest rate is regarded as being constant at the full employment level of output. Nominal interest rate reflects inflation expectation. If the nominal interest rate in (5) is substituted by the inflation expectation, the resulting equation is similar to (9).

$$(9)\quad e=m-\Phi y+\lambda i^*+\lambda\ (\pi-\pi^*).$$

The exchange rate is determined by the money supply, real income, foreign interest rate, foreign prices, and the inflation differential. When there are exogenously given shocks, the motion of the exchange rate towards the equilibrium value is indicated by an arrow in Figure 1. For instance, a one percent rise in the nominal money stock immediately increases the price level and the exchange rate by one percent, thereby maintaining a constant exchange rate.

2.4 Sticky-price monetary model (SPM)

The flex-price monetary model does not allow for changes in the real exchange rate and output in the short-run. In order to relax this property of the FPM model, Dornbusch (1976) introduces an additional assumption that the rate of inflation slowly responds to excess demand in the goods market. As a result, the domestic price moves slowly to an equilibrium level. Consequently, changes in money market conditions instantaneously affect the domestic interest rate, which determine the exchange rate. Therefore, the exchange rate is determined by the UIRP condition, $e=i^*+e_{t+1}-i$, implying that the capital account conditions influence the exchange rate.

A simplified version of the sticky-price monetary model by Dornbusch is:

$$(4)\quad m-p=\Phi y-\lambda i$$

$$(5)\quad \dot{e}=i-i^*$$

$$(9)\quad \dot{p}=\sigma[AD-y]=\sigma\{\delta(e+p^*-p)+x\},\ 0<\sigma<1$$

where AD is aggregate demand for goods, and x denotes exogenous components of aggregate demand such as real government expenditures, g, and foreign real income, $y;x=g+y^*$. The implicit assumption in (9) is that private total absorption equals the full employment level of output, and thus

$AD=y+\delta(e+p^*-p)+x$[3]

The operation of the sticky price monetary model (SPM) is as follows. The relationship between the expected rate of depreciation and money market conditions is obtained by substituting the money market equation (4) for i in the UIRP relation (5):

$$(10)\quad \dot{e}=\frac{1}{\lambda}(p+\Phi y-m)-i^*$$

Consequently, the SPM model is reduced to equations (9) and (10), which jointly determine the time path of e and p. In the long-run, $\dot{e}=0$ and $\dot{p}=0$, and

$$(11)\quad \bar{p}=m-\Phi y+\lambda i^*$$

$$(12)\quad \bar{e}=\bar{p}-p^*-\frac{1}{\lambda}x=m-\Phi y+\lambda i^*-\frac{1}{\lambda}x-p^*$$

The time path of domestic price and exchange rate is described by the following two differential equations:

$$(13)\quad \dot{p}=\sigma\delta\,[(e-\bar{e})-(p-\bar{p})]$$

$$(14)\quad \dot{e}=\frac{1}{\lambda}(p-\bar{p})$$

The above system has a unique convergent saddle path, since $-\sigma\delta/\lambda<0$ holds. The saddle path is:

3. Dornbusch assumes that the interest rate affects aggregate demand and thus inflation. We do not include the interest rate. But the results from our simplified version do not differ qualitatively from those of Dornbusch.

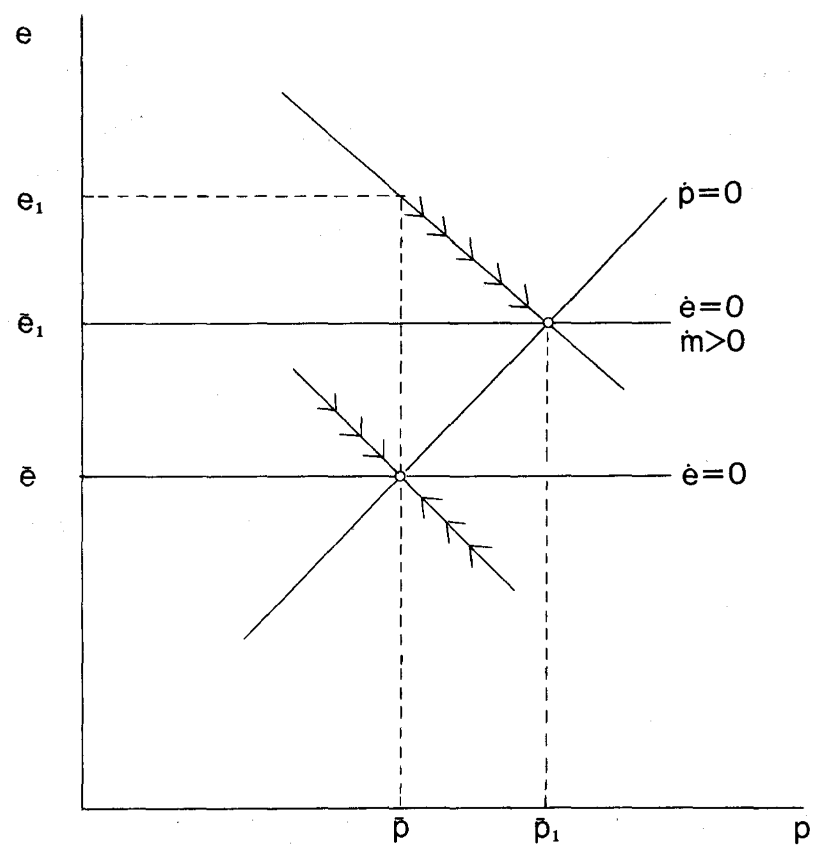
(15) $e=\bar{e}-(\lambda\theta)^{-1}(p-\bar{p})$.

The substitution of p and e by (11) and (12) yields the reduced form exchange rate equation:

(16) $e=(1+\frac{1}{\lambda\theta})\{m-\Phi y+\lambda i^*\}-\frac{1}{\lambda}x-p^*-\frac{1}{\lambda\theta}p$

In the SPM model, price is constant in the short-run, relatively speaking, and becomes perfectly flexible in the long-run. As a consequence, the exchange rate overly responds in the short-run to shocks generating a shift in the saddle

Figure 2: Sticky Price Monetary Model



path and moves gradually to equilibrium, as indicated by arrows of motion in Figure 2. From (16), it is obvious that de/dm>1 when p is fixed and de/dm=1 in the long-run. The short-run effect on the exchange rate of a rise in the money supply, for example, exceeds the long-run effect [see the distance $e_1 - e_1$]; this phenomenon is called "overshooting" in the exchange rate. The resulting excessive depreciation in the real exchange rate increases aggregate demand which pushes up domestic prices and interest rate. This causes the exchange rate to appreciate until the price and the exchange rate rise at the same rate as the rate of monetary expansion. As a result, the PPP condition holds in the long-run, and the interest rate moves back to the level which existed before the monetary injection. In an implicit form, the SPM model is:

$$(17)\quad e = H(\overset{(+)}{m}, \overset{(-)}{y}, \overset{(+)}{i^*}, \overset{(-)}{p}, \overset{(-)}{p^*}, \overset{(-)}{g}, \overset{(-)}{y^*})$$

The SPM model by Dornbusch does not factor in a role for the inflation rate differential and produces "overshooting." Frankel (1979) postulates that the expected rate of depreciation is affected not only by the deviation of the current exchange rate from the long-run exchange rate value but also by the differentials in expected inflation rates. Frankel's expectation scheme is:

$$(18)\quad \dot{e} = \theta(\bar{e} - e) + (\pi - \pi^*).$$

The replacement of Dornbusch's regressive expectation scheme $\dot{e} = \theta(\bar{e} - e)$ by (18) yields

$$(19)\quad e = \bar{e} - \frac{1}{\lambda\theta}(p - \bar{p}) + \frac{1}{\theta}(\pi - p^*)$$

$$= (1 + \frac{1}{\lambda\theta})\{m - \Phi y + \lambda i^*\} - \frac{1}{\lambda}x - \frac{1}{\lambda\theta}p - p^* - \frac{1}{\theta}(\pi - \pi^*)$$

We substitute p in (19) by the money market equation (4) and get:

$$(20)\quad e=m-\Phi y+\lambda i^{*}-\frac{1}{\lambda}x-\frac{1}{\theta}((i-\pi)-(i^{*}-\pi^{*}))-p^{*}$$

implicitly,

$$e=H\ (\overset{(+)}{m},\ \overset{(-)}{y},\ \overset{(-)}{p},\ \overset{(+)}{p},\ \overset{(+)}{i^*},\ \overset{(+)}{\pi},\ \overset{(-)}{\pi^*},\ \overset{(-)}{g},\ \overset{(-)}{y^*})$$

Considering the role of real interest rate differential, Frankel's version of the SPM model (SPMRID) is referred to as the real interest rate model.

Hooper and Morton (1982) argue that a change in the equilibrium exchange rate affects the expected rate of depreciation; however, this is not incorporated in the expectation scheme by Frankel. Furthermore, the long-run exchange rate is assumed to be associated with the net foreign assets.[4] Hence, the expectation scheme of Hooper and Morton is approximated by:

$$(21)\quad \dot{e}=\theta(\bar{e}-e)+(\pi-\pi^{*})-\theta_1(f-\bar{f})$$

where f and $\bar{f}$ are the logarithm of actual and equilibrium net foreign assets, log (foreign assets F), respectively. The substitution of Dornbursch's regressive expectation by (21) yields the SPM model of Hooper and Morton (SPMHM):

$$(22)\quad e=(1+\frac{1}{\lambda\theta})\ (m-\Phi y+\lambda i^{*})-\frac{1}{\lambda}x-\frac{1}{\lambda\theta}p-p^{*}+\frac{1}{\theta}(\Pi-\bar{\Pi})-\frac{\theta_1}{\theta}(f-\bar{f}),$$

implicitly, $e=H\ (\overset{(+)}{m},\ \overset{(-)}{y},\ \overset{(-)}{p},\ \overset{(-)}{p^*},\ \overset{(+)}{i^*},\ \overset{(+)}{\pi},\ \overset{(-)}{\pi^*},\ \overset{(-)}{f},\ \overset{(-)}{g},\ \overset{(-)}{y^*})$

4. Hooper and Morton include a change in the cumulative current account balance as a variable determining an unexpected change in the long-run equilibrium real exchange rate.

Frankel and Rodriguez (1982) and Driskell (1981) examined whether the overshooting in the exchange rate is a general phenomenon or a particular case associated with the characteristics of the SPM's specifications. They argued that the overshooting results largely from the high (perfect) substitutability in assets. To condense their arguments, we assume that the domestic and foreign assets are imperfect substitutes. The capital account equilibrium does not necessarily assure the balance of payments equilibrium. Therefore, the balance of payments equilibrium needs to be introduced as a substitute for the UIRP condition and is given by:

$$(23)\quad \delta(e+p^{*}-p)+\beta(i-i^{*}-e_{+1}+e)=0 \qquad 0\leqslant\delta\leqslant\infty,\ 0\leqslant\beta\leqslant\infty$$

Real incomes and the foreign asset position are ignored in (23). As $\beta\to\infty$, the UIRP condition holds. However, as $\beta\to 0$, the payments equilibrium depends exclusively on the current account conditions. In the short-run where e_{t+1} and p are predetermined, the effect of a rise in the money supply by decreasing the interest rate is:

$$(24)\quad \frac{de}{dm}=\frac{\partial e}{\partial i}\frac{\partial i}{\partial m}=\frac{\beta}{\lambda(\delta+\beta)}$$

The effect lies within the limit of zero to one. When the elasticity of trade flows with respect to a change in the real exchange rate which is infinite, i.e. $\delta=\infty$, no change in the exchange rate occurs. If the elasticity of the capital account with respect to a change in the interest rate differential is closer to zero, i.e. $\beta\to 0$, the initial exchange rate depreciation is closer to zero, Hence, it is possible that monetary expansion produces "undershooting" in the exchange rate.

To investigate the possibility of undershooting in the SPM model, we generalize the SPM model by extending the price equation (9) to include the holdings of net foreign assets as an additional explanatory variable and by introducing the balance of payments equilibrium condition[5]:

(4) $m-p=\Phi y+\lambda i$

(25) $\dot{p}=\sigma\{\delta_1 (e+p^*-p)-\delta_2 f+X\}$

(26) $\delta_1(e+p^*-p)-(\delta_2-1) f+x-\delta_3 g-b+e-\beta(\dot{e}+i^*-i)=0$

The imperfect capital outflows are assumed to take place in order to close the gap existing between the desired and actual holdings of foreign assets. The desired stock is determined on the basis of portfolio diversification [see equation (35) below]; b is the logarithm of domestic non-tradable bonds, log (domestic bond B); and x=g+y*. Given the value of net foreign assets $f=\bar{f}$, the long-run equilibrium values of domestic price and the exchange rate are:

(27) $$\bar{e}=\bar{p}-p^*-\frac{1}{\delta_1}x-\frac{\delta_2}{\delta_1}\bar{f}$$
$$=[\beta\ \{-p^*+m-\Phi y+\lambda i+((\delta_2-(\lambda/\beta))/\delta_2)\bar{f}\}$$
$$-\lambda(x-\delta_3 g-b)]\ (\beta-\lambda(1-\delta_1-\beta))^{-1}$$

(28) $$\bar{p}=[\beta\ (m-\Phi y+\lambda i^*)+\lambda\{(\delta_2-1-(\delta_1+\beta)\delta_2)f$$
$$-(x-\delta_3 g-b)\}]\ (\beta-\lambda(1-\delta_1-\beta))^{-1}$$

The dynamic path of p and e are:

(29) $\dot{p}=\sigma\delta_1\ ((e-\bar{e})-(p-\bar{p}))$

(30) $$\dot{e}=\frac{\beta-\lambda}{\beta}(p-\bar{p})+\frac{\delta_1+\beta}{\beta}(e-\bar{e})$$

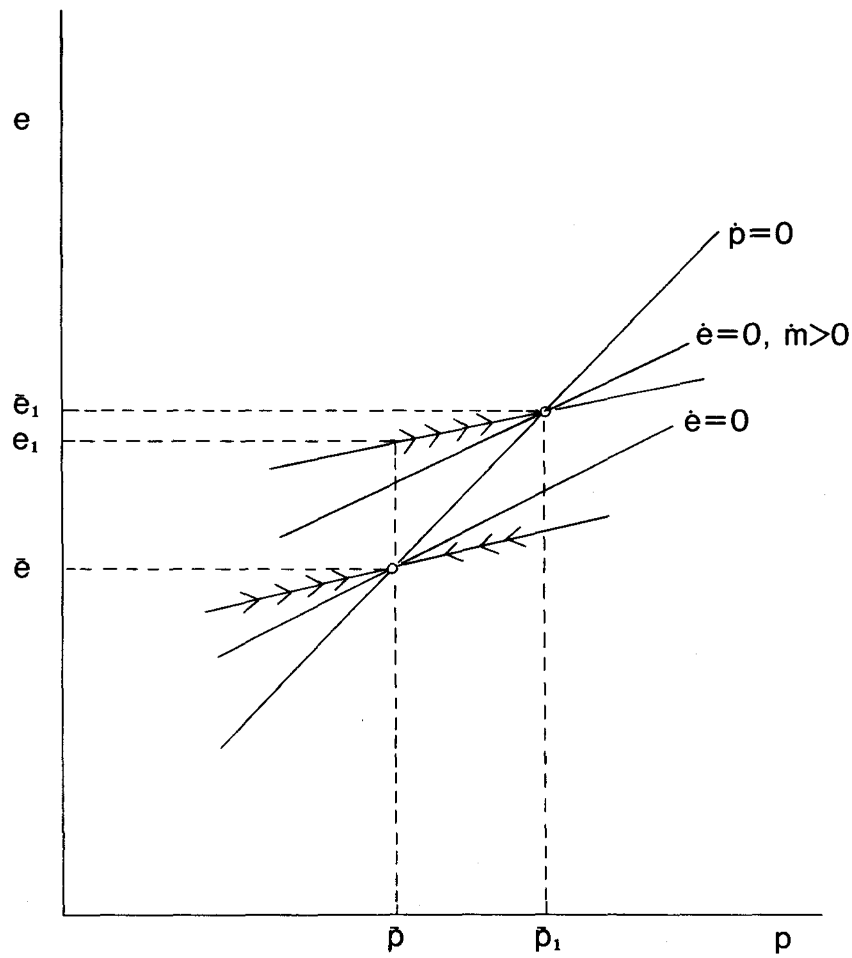
5. The stability of an open macroeconomic system requires that the effect on the current account of a rise in the foreign assets is negative, other things being equal. See Branson and Buiter (1983). This requirement implies that the effect on domestic absorption of a change in income and wealth resulting from a rise in net foreign assets is substantial.

If $\beta \rightarrow \infty$, these two equations are the same as (13) and (14) of Dornbusch's SPM model. The saddle path is:

$$(31)\quad e = e - \frac{\beta - 1}{\lambda(\beta\theta + \delta_1 + \beta)}(p - p)$$

Equation (30) indicates that the slope of $\dot{e}=0$ is negative when $\beta>1$ [Dornbusch's case], as shown in Figure 3. For the value of β smaller than one [low degree of asset substitutability], the slope is positive. In the case of low substitutability, therefore, the slope of the saddle path is positive, and a monetary

Figure 3: Sticky Price Monetary Model
(Low Substitutability Case)



expansion leads to undershooting in the exchange rate [see the distance $e_1 - e_1$ in Figure 3]. The magnitude of the undershooting is larger when the real exchange rate elasticity, δ_1, and interest rate elasticity of money demand, λ, are larger. Domestic price and the exchange rate move in the same direction.

The model for the low asset substitutability case is written as follows:

$$\text{(32)}\quad e = H\,(\overset{(+)}{m}, \overset{(-)}{y}, \overset{(+)}{i^*}, \overset{(+)}{p}, \overset{(-)}{p^*}, \overset{(-)}{f}, \overset{(+)}{b}, \overset{(-)}{g}, \overset{(-)}{y^*})$$

2.5 Portfolio balance model

In the monetary model discussed above, money is valued as a distinctive asset, whereas domestic and foreign non-money assets are treated as a single identical asset. The portfolio balance model recognizes the exchange rate as the relative price of assets (non-money assets) and takes an explicit account of the wealth-holder's diversification among the available different assets in determining the exchange rate.

Following Branson (1977), we assume that portfolios consist of three types of assets: money, bonds, and foreign assets. In the case of three assets, the portfolio balance model consists of the demand equations for the three assets and the identity that the sum of the values of the three assets held is equal to the value of wealth. Equilibrium takes place when the demand for each asset equals its supply. We postulate that the log of the share of an asset demanded to wealth is a linear function of the domestic interest rate, the foreign interest rate, and the expected rate of currency depreciation. The linear form of the wealth identity is replaced by the log form of the identity where the log of wealth is the average of the logarithmic values of the three assets weighted by their relative value shares.[6] After substituting the log of wealth in the three demand functions

6. The approximation holds from the fact that arithmetic average of the values of different assets is approximated by the geometric average.

by the weighted average of the log values of the three assets, the three asset demand equations are:

$$(33)\quad m=m_0-m_1i-m_2i^*-m_2e+b_{m0}b+f_{m0}e+f_{m0}f$$

$$(34)\quad b=b_0+b_1i-b_2i^*-b_2e+m_{b0}m+f_{b0}e+f_{b0}f$$

$$(35)\quad e+f=f_0-f_1i+f_2i^*+f_2e+m_{f0}m+b_{f0}b$$

where all the parameter values are positive.

When the values of m, b, f, i, i*, and e_{+1} are taken as predetermined, the exchange rate can be determined from equation (35), assuming that the exchange rate is the relative price of foreign assets:

$$(36)\quad e=(1+f2)^{-1}(f_0-f_1i+f_2i^*+f_2e_{+1}+m_{f0}m+b_{f0}b-f)$$

A rise in the domestic interest rate and supply of foreign assets tends to appreciate the exchange rate, whereas a rise in the foreign interest rate and the expected exchange rate tends to depreciate the exchange rate.

In the short-run, the portfolio balance model determines both the interest rate and the exchange rate, with the given values of m, b, f, i*, and e_{+1}. Equations (33) and (35) are utilized to determine the two variables i and e. The domestic interest rate is solved from the money market condition (33), and the resulting equation is substituted for i in the demand function for foreign assets (36). The reduced form of the exchange rate equation is:

$$(37)\quad e=K_0i^*+k_1m+k_2b-k_3f+k_4e_{t1}$$

where $k_0=(m_1f_2+f_1m_2)\ k_5>0$,

$k_1=(m_1m_{f0}+f_1)\ k_5>0$,

$k_2=(m_1b_{f0}-f_1b_{m0})\ k_5\gtrless 0$,

$k_3=(m_1+f_1f_{m0})\ k_5>0$,

$k_4=(m_1f_2+f_1m_2)\ k>0$,

$k_5=(f_1f_{m0}+m_1+m_1f_2+f_1m_2)^{-1}>0$.

Thus, the exchange rate is determined by the foreign interest rate, money stock, bonds, foreign assets, and the expected exchange rate. An increase in the supply of domestic bonds either depreciates or appreciates the exchange rate, depending largely upon the degree of substitutability between domestic and foreign bonds. To the extend that the expected future exchange rate e_{t1} is based on the information on expected relative prices, current account and government policies, the public perception of future monetary and fiscal policies will have an effect on the exchange rate determination in the current period.

The exchange rate changes arising with the given levels of the money stock, bonds, and foreign assets induce changes in the current account. The changes in the current account in turn feeds back into the asset market and the exchange rate. The evolution of the exchange rate over time involves the dynamic stock-flow interactions of changes in the exchange rate and the current account. Hence, the long-run equilibrium is established when the dynamic process is complete.

The substitutions of i in equations (34) and (35) by (33) yield equations for domestic bonds and foreign assets:

(38) $b=z_0-z_1i^*-z_1\dot{e}+z_2m+z_3(e+f),\ z_1>0,\ z_2\gtrless0,\ z_3>0$

(39) $e+f=v_0+v_1i^*+v_1\dot{e}+v_2m+v_3b,\ v_1>0,\ v_2>0,\ v_3\gtrless0$

Equations (38) and (39) solve for e+f, and in addition, we introduce the equation describing the current account behavior:

(40) $e+f=q_0+q_1i^*+q_1\dot{e}+q_2m, \qquad q_1>0,\ q_2>0$

(41) $\dot{f}=\delta_1(e+p^*-p)-\delta_2f+x-\delta_3g$

where direct effects are assumed to outweigh indirect effects in determining the signs of q_1 and q_2[7]. Equations (40) and (41) describe the behaviors of e

7. A high government spending reduces the current account balance by increasing domestic income or price. Since x includes g, the coefficient value of g in (44) is greater than 1.

and f over time. The long-run equilibrium for e and f are:

$$(42)\quad \bar{e}=p-p^{*}+\frac{\delta_2}{\delta_1}\bar{f}-\frac{x-\delta_3 g}{\delta_1}$$

$$=\frac{1}{\delta_1+\delta_2}\{-(x-\delta_3 g)+\delta_1(p-p^{*})+\delta_2(q_0+q_1 i^{*}+q_2 m)\}$$

$$(43)\quad \bar{f}=q_0+q_1 i^{*}+q_2 m-\bar{e}$$

$$=\frac{1}{\delta_1+\delta_2}\{(x-\delta_3 g)-\delta_1(p-p^{*})+\delta_1(q_0+q_1 i^{*}+q_2 m)\}$$

The dynamic paths obtained from (40) and (41) are:

$$(44)\quad \dot{e}=\frac{1}{q_1}((e-\bar{e})+(f-\bar{f}))$$

$$(45)\quad \dot{f}=\delta_1(e-\bar{e})-\delta_2(f-\bar{f})$$

Recalling that $x=g+y^{*}$, the exchange rate is determined by:

$$(46)\quad e=\bar{e}-\frac{1}{1+q_1\theta}(f-\bar{f})$$

$$=\frac{1}{(1+q_1\theta)(\delta_1+\delta_2)}\{q_1\theta(-y^{*}+\delta_1(p-p^{*}))-(\delta_1+\delta_2)f$$

$$+(\delta_1+d_2+\delta_2 q_2\theta)(q_0+q_1 i^{*}+q_2 m)-(1-\delta_2)q_1\theta g\}$$

The exchange rate of the portfolio balance model is:

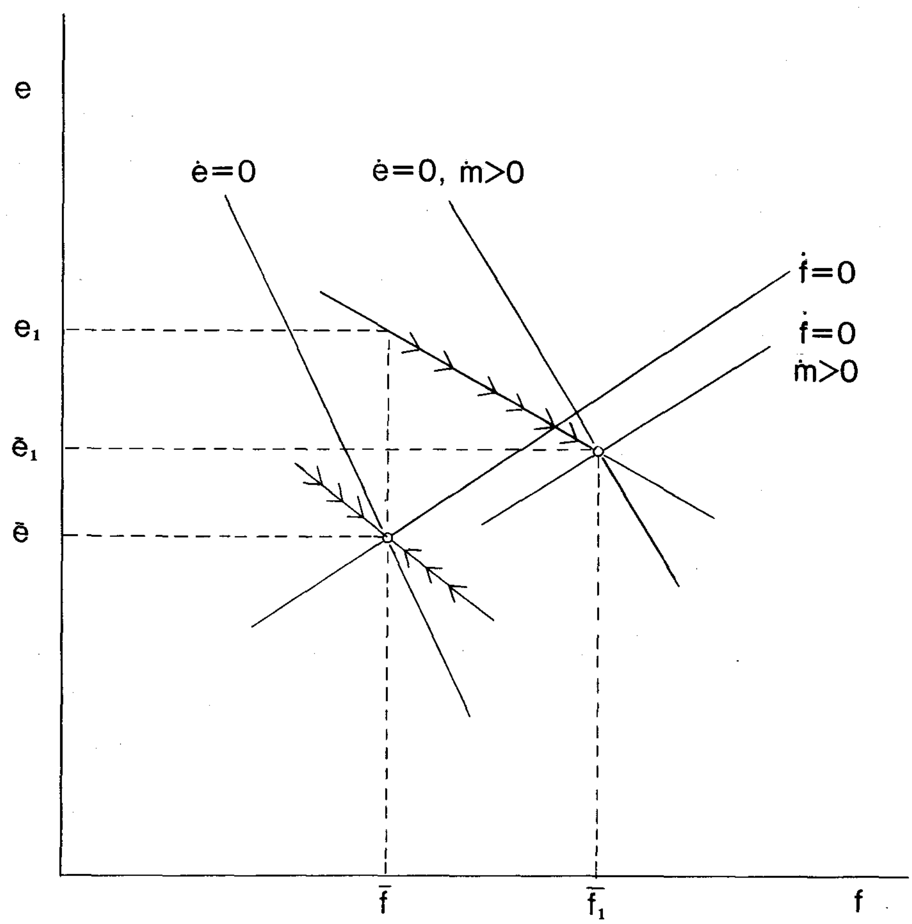
$$(47)\quad e=H(\overset{(+)}{p-p^{*}},\ \overset{(+)}{m},\ \overset{(+)}{i^{*}},\ \overset{(-)}{f},\ \overset{(-)}{g},\ \overset{(-)}{y^{*}})$$

since $(1-\delta_2)>0$.

As shown in Figure 4, a rise in the money stock causes the exchange rate to overshoot. The initial overshooting causes a surplus in the current account. The resulting rise in the foreign asset holdings leads the exchange rate to appreciate at a decreasing rate with the accumulation of foreign assets. At the same time, a rise in domestic prices due to monetary expansion generates additional appreciation of the real exchange rate. Since the increase in foreign asset holdings produce additional interest income, a zero balance in the current account in the long-run equilibrium requires the depreciation of the nominal exchange rate and the appreciation of the real exchange rate. Therefore, the PPP condition does not hold in the long-run.

When investment income from net foreign assets is used to purchase foreign goods, its effect on the current account is zero, and $\delta_2=0$ into (46) gives

Figure 4: Portfolio Balance Model



(48) $e=\frac{1}{1+q_1\theta}\{q_1\theta(-\frac{x-\delta_3 g}{\delta_1}+(p-p^*))-f+q_0+q_1 i^*+q_2 m\}$

We have presented the essence of select models determining the exchange rate. Although most of the models were originally developed in the context of two countries of equal size, our presentation of the models was based on that of a small open economy. Table 1 summarizes the coefficient signs on major determinants implied in the models. Because each of the models emphasizes the role of particular markets of the economy, these models appear to differ substantially. Surprisingly, however, the coefficient signs on the majority of the determinants of these models agree with each other.[8] The few differences arise with respect to domestic prices, domestic interest rate, and domestic real income. In the SPM model by Dornbusch and Frankel, the negative sign on domestic price holds only in the short-run and becomes zero in the long-run. Therefore, the coefficient sign of the domestic price variable is positive, implying that a rise in the domestic price leads to a currency depreciation. The sign of the domestic interest rate is positive for the FPM model because the nominal interest rate mainly reflects the expected inflation rate which is based on the rate of growth of the money stock. This reflects the fact that when monetary expansions are excessive over a long period interest rates are also likely to increase. In the case of a modest monetary growth, the liquidity effect of monetary growth is greater than its price expectation effect. Thus, the nominal interest rate represents real interest rate, and the coefficient sign of the domestic interest rate is expected to be negative, which is consistent with the positive sign on the foreign interest rate variable predicted in all the models we have included in Table 1. The coefficient sign of the domestic income variable in the monetary models is negative. This is attributed to the fact that real income represents the output supplied. A larger supply of goods relative to demand im-

8. For persuasive discussions on this point, see Gylfason and Helliwell (1983).

plies a current account surplus, which leads to currency appreciation. The positive sign on domestic real income is owing to the fact that real income is generated from aggregate demand for goods and services. Therefore, the sign of real income is not uniquely determined, as different supply and demand conditions can have a major impact on output and thus real income.

Table 1: Coefficient Signs of Exchange Rate Equations

	p	p*	i	i*	π	π*	y	y*	e_{t+1}	g	m	b	f
BOP Flow Model (2)	+	−	−	+			+	−					
OPP Basis (3)	+	−											
FPM (5)		−	+				−				+		
+UIRP (9)		−		+	+	−	−				+		
UIRP Basis			−	+					+				
SPM (17)	−	−		+			−	−		−	+		
SPMRID (20)	−	−		+	+	−	−	−		−	+		
SPMHM (22)	−	−		+	+	−	−	−		−	+		−
Portfolio Basis													
Foreign Assets (26)			−	+					+		+	+	−
Short-term (37)				+					+		+	?	−
Short- & long-run (47)	+	−		+				−		−	+		−

Figure in parentheses indicates equation number in the text.
p=domestic prices, p* =foreign prices, i=domestic nominal interest rate, i* =foreign nominal interest rate, π=domestic expected inflation, π* =foreign expected inflation, y=domestic real income, y* =foreign real income, e_{t+1}=expected exchange rate, g=real government expenditures, m=money stock, b=bonds, f=foreign assets.

3. Empirical Tests of the Models

A large number of empirical studies on exchange rate models have appeared since 1976. These studies are largely confined to variants of monetary and portfolio balance models, as a balance of payments flow model is perceived as possessing theoretical shortcomings. The portfolio balance model has been tested less frequently than the monetary models, perhaps due to the difficulty in obtaining proper data required for the portfolio balance model.

The models work well with data from the period 1973-1978. The coefficients of key explanatory variables are statistically significant and possess the expected signs. However, when the coverage of data is extended beyond 1978 to the late 1980's, the regressions of the models produce unexpected coefficient signs and insignificant coefficients for key explanatory variables. Meese and Rogoff (1983, 1984, 1988) compared the out-of-the-sample performance of reduced-form monetary models with the random walk model and concluded that monetary models did not perform any better than the random walk model. This conclusion is confirmed by studies of Backus (1984) and Boughton (1984), although Boughton reported that the portfolio balance model in general performed better in the case of the dollar-DM exchange rate. Doubts regarding the ability of theoretical models to explain the behavior of exchange rates is expressed clearly by Dornbusch (1989, p. 401): "After 20 or 30 years of exchange rate modeling, from the work of Meade and Mundell to the New Classical Economics, we are left with an uncomfortable recognition that our understanding of exchange rate movements is less than satisfactory."

Why have these theoretical models performed unsatisfactorily in recent years? Among the many possibilities, we present two reasons.[9] First, the equations employed for empirical studies are reduced-form equations. Reduced-form equations are easily subject to mis-specifications. Reduced-form coefficients vary

9. For more detailed discussions, see Isard (1987) and Dornbusch (1989).

substantially, especially when the underlying economic structures of countries vary. This is confirmed indirectly by the work of Schinasi and Swamy (1986), in which the equations estimated with varying coefficients for select monetary models performed better than those with fixed coefficients and the random walk models. Secondly, the interdependence among not only financial and capital sectors within a country, but also industrial and developing countries, has been growing at a rapid pace during the 1980's. The growing interdependence causes unexpected events in a country which in turn affects economic conditions of other countries in the world and thus exchange rates. News and political risks accompanied by the growing interdependence of nations are difficult to adequately capture in exchange rate modeling.

Earlier empirical studies found the presence of first-order serial correlations between residuals. This suggests that the change in the levels of an exchange rate is more significant than the actual levels of the exchange rate. In order to examine this hypothesis, unit root tests are performed on the basis of the following regression equations:[10]

(49) $\log(e(t))=a1\ \log(e(t-1))$

(50) $\log(e(t))=a0+a1\ \log(e(t-1))$

(51) $\log(e(t))=a0+a1\ \log(e(t-1))+a2\ t$

(52) $\log(e(t)p^*(t)/p(t))=a0+a1\ \log(e(t-1)p^*(t-1)/p(t-1))+a2\ t$

where e is the exchange rate, t is the time trend, p^* and p are the foreign and domestic price levels, respectively. Equations (49)-(52) are tested with monthly data from January 1976 to June 1990 on the yen-dollar and the mark-dollar exchange rates. As shown in Table 2, the results confirm statistically that $a0=0$, $a2=0$, and $a1=1$, indicating that the specification of an exchange rate equation in the difference form is preferable.

10. See Phillips (1987) for unit root tests.

Table 2: Unit Root Tests, 1976-1990

	a_0	a_1	a_2	R^2 (adj.)	DW
Yen-Dollar					
(2.1) Nominal (JAE)		0.99		0.98	1.36
		(2383)			
(2.2)	0.05	0.99		0.98	1.36
	(1.0)	(114)			
(2.3)	0.10	0.98	0.00	0.98	1.35
	(1.0)	(87)	(0.6)		
(2.4) Real (JAE.USCPI/JACPI)	0.09	0.98	0.00	0.97	1.40
	(1.0)	(70)	(0.0)		
Mark-Dollar					
(2.5) Nominal (WGE)		0.99		0.97	1.45
		(384)			
(2.6)	0.01	0.99		0.97	1.45
	(0.5)	(85)			
(2.7)	0.01	0.99	0.00	0.97	1.45
	(0.7)	(82)	(0.5)		
(2.8) Real (WGE.USCPI/WGCPI)	0.01	0.99	0.00	0.97	1.45
	(0.9)	(83)	(0.2)		

1. JAE=Yen dollar rate (yen per dollar), WGE=mark dollar rate (mark per dollar), USCPI=U.S. consumer price, JACPI=Japanese consumer price, WGCPI=West German consumer price.
2. R^2 (adj.)=coefficient of determination adjusted for degree freedom, DW=Durbin=Watson statistic figures in parentheses are t-statistic.

Before we begin our regression run, we test whether a change in the exchange rate follows the movement of relative prices, which are the underlying hypothesis of flexible price models, or whether it follows the movement of interest rate differentials, using the following difference equations:

(53) Δ 100 log(e)=a0+a1 Δ 100 log(p*/p)

(54) Δ 100 log(e)=a0+a2 Δ (i* − i)

(55) Δ 100 log(e)=a0+a3 Δ (i* − π* − i + π)

As presented in Table 3, the estimates of a2 and a3 for the Japanese yen and the Deutsche mark are significantly different from zero, while the estimated values of a1 do not differ significantly from zero. These simple tests suggest that changes in the exchange rates are greatly affected by changes in the interest rates.

Variations of the nominal exchange rate have been similar to variations of the real exchange rate since the adoption of the flexible exchange rate system, as shown in Table 4, which reports the co-variance of monthly percent changes in the logarithms of nominal and real exchange rates and national price levels from March 1973 to June 1990. The monthly percent changes in the logarithm

Table 3: Simple Tests

	a_0	a_1	a_2	a_3	R^2 (adj.)	DW
Yen-dollar	−0.48	0.42			0.01	1.36
(JAE)	(2.1)	(1.3)				
	−0.41		0.57		0.02	1.32
	(1.8)		(2.2)			
	−0.38			0.45	0.02	1.32
	(1.7)			(2.3)		
Mark-dollar	−0.25				0.00	1.45
(WGE)	(1.0)					
	−0.25		0.55		0.02	1.40
	(1.2)		(2.2)			
	−0.25			0.45	0.02	1.42
	(1.2)			(2.0)		

JARCM=Japanese call money rate, WGRS=German Interbank deposit rate, USRTB=U.S. Treasury bill rate, JAPHI=Japanese expected inflation, WGPHI=West German expected inflation, and USPHI=U.S. expected inflation.

Table 4: Exchange Rate Variability

	Yen-dollar		Mark-dollar	
	1973.3 −1990.6	1985.10 −1990.6	1973.3 −1990.6	1985.10 −1990.6
Variance of				
100 Δ log(e)	8.01	10.8	15.4	7.74
100 Δ log(ep*/p)	8.76	11.5	15.7	7.79
100 Δ log(p*/p)	0.65	0.34	0.13	0.07
Covariance of				
100 Δ log(e), 100 Δ log(p*/p)	0.05	0.18	0.05	−0.01

of the national price levels are small and less correlated to monthly percent changes in the nominal exchange rate. This is evidence of the slow adjustments in the exchange rates to changes in the price levels. As a result of the sluggish response, a change in the real exchange rate brings about approximately equal change in the nominal exchange rate. Thus, the specification for the real exchange rate determination is relevant to the specification for the nominal exchange rate behavior.

Now we utilize the variety of the monetary and portfolio balance model equations to explain the behavior of the yen-dollar and the mark-dollar exchange rates. The typical equations are as follows:

(56) $\Delta\ 100 \log(e) = a0 + a1\ \Delta \log(M1^*/M1) - a2\ \Delta \log(ip^*/ip) - a3\ \Delta\ (i - i^*)$

(57) $\Delta\ 100 \log(ep^*/p) = a0 - a1\ \Delta\ (i - i^* - \pi + \pi^*) + a2\ (USST/(p^* ip^*)) - a3\ FEI/FER(-1)$

(58) $\Delta\ 100 \log(ep^*/p) = a0 + a1\ \Delta\ (i - i^* - \pi + \pi^*) + a2\ \Delta\ (USST/p^*) - a3\ \Delta\ (M2^*/p^*) + a4\ \Delta\ (M2/p)$

where FEI and FER represent the amount of foreign exchange intervention during a unit period of time and foreign exchange reserves, respectively. USST is the net foreign assets of the United States, which is the accumulated sum of the U.S. trade balance; M1 and M2 are the narrowly and broadly defined money stock.

Equation (56) represents the monetary model, and (57) and (58) represent the portfolio balance model. The ratio of the U.S. foreign assets relative to U.S. income in (57) represents the risk associated with holding U.S. dollar-denominated assets. When the asset to income ratio is high, the risk is low, leading to a depreciation of foreign currency. The intervention data of monetary authorities are not available to the public, making it impossible to know the precise nature of official intervention. However, a proxy of the amount of intervention can be assumed to be the changes in official foreign exchange reserves after subtracting estimated interest earnings on the reserves during the period. Since Japan and West Germany have maintained a surplus on their current account balance, whereas the United States has a current account deficit, it is likely that the monetary authorities would wish to have the yen and the mark appreciate against the dollar. Therefore, exchange interventions are likely to occur to smooth foreign exchange operations and to prevent the depreciation of the yen and the mark.

Industrial production and consumer price indices are used in place of income and national prices, respectively. Two different measures of the money stock, M1 and M2, are alternatively used. With regards to interest rates, short-term rates and long-term rates are used, although short-term rates turn out to be more preferable. The proxy of expected inflation is the actual inflation one year ahead of the period of data. In the absence of monthly data on the U.S. current account balance, we used net foreign asset values which are the accumulated sum of the trade balance of the United States. Alternatively, we used, in place of U.S. net foreign assets, the accumulated sum of Japanese and German trade balance in domestic currency and U.S. dollars, with the bench-mark values in December 1971, which are sums of the trade balance from January 1950 to December 1971. The sources of the monthly data are from International Financial Statistics of the International Monetary Fund and the Federal Reserve Bulletin. Actual data used in regressions are given in Appendix 1.

The regression period is from January 1976 to June 1990. The estimation techniques used are ordinary least squares. Whenever past movements of an economic variable affect the present levels of an exchange rate, the time lag effects are captured through a polynomial lag distribution scheme. When regressions indicate the presence of serial autocorrelations between residuals, the equations were re-estimated with a first-order correction for autocorrelations between residuals. A variety of specifications (56)-(58) was tried, and the

Table 5: Monetary Model Specifications

	Yen-dollar		Mark-dollar	
	100 Δ log (JAE)		100 Δ log (WGE)	
Eqn. No.	(5.1)	(5.2)	(5.3)	(5.4)
Constant	−0.40	−0.39	−0.24	−0.24
	(1.8)	(1.7)	(1.1)	(1.1)
Δ log (USM1/FM1)	−6.05	−5.86	−6.90	−6.91
	(1.2)	(1.2)	(1.0)	(1.0)
Δ log (USIP/FIP)	0.11	0.14	4.24	4.22
	(0.2)	(0.3)	(0.4)	(0.4)
Δ (FR−USRTB)	−0.57		−0.55	
	(2.3)		(2.2)	
Δ (FR−USRTB−FPHI+USPHI)		−0.57		−0.56
		(2.3)		(2.2)
Δ (FPHI−USPHI)		−0.32		−0.53
		(0.8)		(0.9)
R^2 (adj.)	0.02	0.02	0.02	0.01
SEE	2.91	2.92	2.71	2.71
DW	1.3	1.3	1.3	1.3

FM1=foreign money stock M1, (F=JA, WG) i.e. JAM1, WGM1; FIP=foreign industrial production; FR=foreign short-term interest rate, JARCM, WGRS; FPHI=foreign expected inflation, JAPHI, WGPHI. SEE=standard error estiamte.

regressons are included in Appendix 2.

Table 5 reports the estimates of equation (56), which represents a monetary approach to determining the exchange rate. The variables of relative money stock, industrial production, and expected inflation have insignificant coefficients, even though the coefficients of the relative money stock and expected inflation variables have the theoretically expected signs. The interest rate variables in the equations of the yen-dollar as well as the mark exchange rate have significant coefficients. The results shows that interest rates are important determinants of the exchange rates.

Table 6 contains the estimates of equations (57) and (58) for the yen-dollar exchange rate. The coefficient estimates for all the determinants except for the real money stock of the United States are significant and possess the correct sign in the case of real yen exchange rate. The Durbin-Watson statistics reject the presence of significant serial correlations between the residuals at the five percent level of significance. Real interest rate differentials and U.S. foreign assets relative to U.S. income have a significant affect on the nominal yen-dollar exchange rate, although the relative money stock, which is assumed to determine the relative prices of goods, is found to be insignificant. Overall, our results show that the portfolio balance model can explain a substantial portion of the yen-dollar movements. The real interest rate differentials affected the exchange rate over a period of one year. Based on the coefficient estimates of the real interest rate variable, a one percentage point rise in the real interest rate of the United States leads to a depreciation of the yen by 0.2 percent in the short-run and approximately 2 percent in the long-run. When we evaluate at the mean value, 7585, of U.S. nominal income, USCPI.USIP, a one billion dollar rise in the U.S. trade balance is estimated to depreciate the yen against the U.S. dollar by 1.7 to 2.6 percent.[11] The effect of an improvement in the U.S. trade balance

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11. Slightly different estimates are reported in Fukao (1989). Real interest rate causes a 2.5-3.7 percent depreciation on average, whereas an improvement in the trade balance causes a 1.8-2.7 percent depreciation.

is conditioned by the size of U.S. nominal income. Thus, the effect of an equal rise in the U.S. trade balance is smaller in recent years, since U.S. income is currently higher than the mean value. The coeffiicient estimate, −25.3, of the exchange intervention implies that a one billion dollar-worth intervention tends

Table 6: Portfolio Balance Specifications for the Yen

	Real Yen			Nominal Yen	
	100 Δ log (JAE.USCPI/JACPI)			100 Δ log (JAE)	
Equation No.	(6.1)	(6.2)	(6.3)	(6.4)	(6.5)
Constant	0.71	0.96	0.75	0.48	0.72
	(2.0)	(2.5)	(1.7)	(1.4)	(1.9)
Δ (JARCM−USRTB−JAPHI+USPHI)	−1.9	−2.1	−2.1	−1.7	−2.0
	(3.4)	(3.5)	(3.3)	(3.2)	(3.3)
Δ (USST/(USCPI.USIP))	1361	2028		1327	1983
	(2.7)	(3.6)		(2.7)	(3.7)
Δ (USST/USCPI)			15.9		
			(2.6)		
Δ (USM2/USCPI)			−2.1		
			(1.4)		
Δ (JAM2/JACPI)			0.01		
			(2.3)		
JAFEI/JAFER (−1)	−25.3			−25.8	
	(6.5)			(7.0)	
Δ log (USM1/JAM1)				−1.57	−1.6
				(0.1)	(0.3)
R^2 (adj.)	0.32	0.14	0.14	0.33	0.13
SEE	2.5	2.8	2.8	2.4	2.7
DW	1.8	1.6	1.6	1.7	1.5

1. JAM2=Japanese money stock M2, USM2=U.S. money stock M2, JAFEI=foreign exchange intervention, JAFER=Japanese official foreign exchange reserves.
2. The coefficient of real interest rate differentials is the sum of current and past eleven month lag coefficients, estimated by PDL with 2nd degree ad far end constraint.

to appreciate the yen by about 0.8 percent, at the mean value of foreign exchange reserves. Although the effect is small, the intervention helps a great deal to explain the actual changes in the yen rate. This indicates that foreign exchange interventions facilitated the changes in the exchange rate.

Table 7 reports the estimates of equations (57) and (58) for the Deutsche mark. The results are, more or less, similar to what we obtained for the Japanese yen; namely, all the determinants, except for the real money stock and relative money stock, are significant. Again, the real interest rate differentials are found to be important.[12] A change in the real interest rate differentials has an effect over a period of one and a half years and has a greater effect than an equal change in the real interest rate differential on the yen exchange rate. A one percentage point rise in the U.S. interest rate depreciates the mark-dollar rate by about 0.3 percent in the short-run and 4.5 percent in the long-run. An increase of 10 billion dollars in the U.S. trade balance depreciates the mark by 2 to 2.3 percent, at the mean value of U.S. nominal income. While the effect of a rise in the U.S. trade balance on the German mark rate is similar to the effect on the Japanese yen, a rise in the real interest rate differential has a greater impact on the mark exchange rate than on the yen rate. The greater impact on the German mark rate may be attributed to the higher degree of capital mobility between the United States and Germany or the absence of capital controls. This implies that as capital controls decrease, interest rates become more important in the determination of exchange rates. Foreign exchange interventions affect the mark rate: a one billion dollar-worth intervention leads to about a 0.2 percent appreciation of the mark.

Finally, one questions how much the portfolio balance exchange rate model, consisting of equations (6.1) and (7.1), traces the actual movements of the yen and the mark rates. Alternatively, does the model perform better than the ran-

12. The importance of real interest rate differentials is reported by Marston (1989) and Stein (1989), whereas Meese and Rogoff (1988) cast some doubt on the relationship between real interest rates and exchange rates.

Table 7: Portfolio Balance Specifications for the Mark

	Real Mark			Nominal Mark	
	100 Δ log (WGE.USCPI/WGCPI)			100 Δ log (WGE)	
Equation No.	(7.1)	(7.2)	(7.3)	(7.4)	(7.5)
Constant	0.92	0.99	0.75	0.62	0.72
	(2.8)	(3.1)	(1.9)	(1.9)	(1.9)
Δ (WGRS−USRTB−WGPHI+USPHI)	−4.5	−4.8	−4.8	−4.7	−5.1
	(3.6)	(3.8)	(3.7)	(3.7)	(4.1)
Δ (USST/(USCPI.USIP))	1592	1761		1528	1682
	(3.3)	(3.6)		(3.2)	(3.4)
Δ (USST/USCPI)			10.0		
			(1.8)		
Δ (USM2/USCPI)			−2.1		
			(1.6)		
Δ (WGM2/WGCPI)			14.9		
			(0.9)		
WGFEI/WGFER (−1)	−5.1			−5.1	
	(2.9)			(3.0)	
Δ log (USM1/WGM1)				−12.9	−5.8
				(0.9)	(0.9)
R^2 (adj.)	0.22	0.18	0.18	0.21	0.18
SEE	2.4	2.5	2.5	2.4	2.4
DW	1.8	1.7	1.7	1.8	1.6

1. WGM2=West German money stock M2, WGFEI=foreign exchange intervention amount, WGFER=West German official foreign exchange reserves.
2. The coefficient of real interest rate differentials is the sum of current and past eleven month lag coefficients, estimated by PDL with 2nd degree and far end constriant.

dom walk model, equations (2.4) and (2.8) of Table 2? In order to compare the performance within the sample period, the portfolio balance model and the random walk model are dynamically simulated from January 1976 to June 1990 in addition to the simulation from January 1988 to June 1990. The root mean squared percentage errors obtained from the simulations are summarized in Table 8. Furthermore, the predicted yen and mark rates in June 1990 by the model simulation from January 1988 are 130 and 1.7, respectively. On the other hand, the predicted values for the yen and the mark by the random walk model are 132 and 1.56, respectively. On the basis of the root mean squared percentage errors and the predicted values, the portfolio balance exchange rate model is clearly better in predicting the mark rate than the random walk model. The model's performance in predicting the yen rate is no worse than the random walk model's performance. However, the model's predictive ability over a longer period is better than the random walk model. Since the forecasts by the random walk model depend on the initial condition and are monotonic, the forecasts would not capture long-term swings in the exchange rate cycle generated by stock-flow interactions; the accumulated current account surplus tends to keep the currency overvalued for a long period, until the accumulated foreign assets are offset by a flow of current account deficits. As a result, currency remains undervalued for a long period, until the accumulated deficits are eliminated by a flow of current account surpluses.

Table 8: Root-Mean Squared Percentage Errors

	1976.1 −1990.6	1988.1 −1990.6
Yen-Dollar		
Model	10.6	8.5
Random Walk	18.1	7.3
Mark-Dollar		
Model	8.6	3.6
Random Walk	17.9	11.7

4. Concluding Remarks

This paper discusses major theories developed on the behavior of flexible exchange rates during the past twenty years and tests a variety of monetary and portfolio balance models on the yen-dollar and mark-dollar exchange rates. Real interest rate differentials, net external assets to income ratio and official foreign exchange interventions have been major determinants of the actual movements of the yen and the mark rates since 1976. Furthermore, in-sample forecasting tests indicate that the estimated portfolio balance model does not perform any better or worse than the random walk model.

Because the external value of a currency is the price of assets, the exchange rate is affected by the past, present and future trends of economic factors including economic policies. In developing our empirical models, we did not fully incorporate forward-looking aspects of exchange rate determinations. Future studies should take the forward-looking mechanism into account to bring about a better understanding of the behavior of exchange rates.

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