Currency Substitution via Expected Exchange Rate and Domestic Money Demand: An Empirical Analysis for Japan

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ABSTRAK

Kajian ini menguji hipotesis kebolehganti matawang secara empirikal di atas permintaan matawang Jepun dengan menggunakan data bulanan dari Januari 1977 ke Disember 1989. Di bawah sistem kadar pertukaran boleh ubah, ejen ekonomi yang rasional akan membentuk portfolio matawang untuk tujuan permintaan urusniaga dan permintaan spekulasi. Penganggaran tak linear berbilang pembolehubah kebolehjadian maksimum Jepun dan persamaan kadar pertukaran dijangka: ada kemungkinan terdapat kebolehgantian matawang. Penemuan kajian ini mencadangkan bahawa (a) kadar pertukaran dijangka bagi matawang Jepun (Yen) dengan matawang Dollar Kanada menunjukkan kebolehgantian matawang berdasarkan permintaan spekulasi dan (b) kadar pertukaran dijangka matawang Jepun (Yen) dan Dollar Amerika menunjukkan kebolehgantian berdasarkan permintaan urusniaga.

ABSTRACT

In this paper the currency substitution hypothesis is tested empirically on the Japanese money demand, using monthly data from January 1977 to December 1989. Under a flexible exchange rate a rational economic agent forms currency portfolios for both transaction and speculative reasons for demanding money. The nonlinear multivariate maximum likelihood estimation was used to estimate jointly the Japanese money demand and the expected exchange rate equation; possible existence of current substitution is found. The empirical results indicate that (a) the expected exchange rate for the Japanese yen/Canadian dollar shows currency substitution due to speculative demand, and (b) the expected exchange rate of the yen/US dollar shows currency substitution due to transaction demand.

INTRODUCTION

For more than a decade, the growing integration of world capital markets has brought changes in the environment for monetary policy. The efficacy of monetary policy under a flexible exchange rate has been challenged by proponents of the currency substitution hypothesis [CSH] (see literature review by Bana and Handa 1987). The controversy evolves around the belief that if currencies are substitutable on the demand side, the expectation of future behaviour of exchange rates under uncertainty may make domestic money demand unstable and reduce the autonomy of monetary policy under a flexible exchange rate system (Miles 1978a, 1978b; McKinnon 1982; Chen and Tsaur 1983).

One of the main explanations for the CSH is that money demand is influenced through a combination of distinctive channels of currency substitution–transaction demand and speculative demand (King *et al.* 1980). Specifically, they suggest that with increasing integration of the goods and services market around the world, global traders have more opportunity to choose from a broader variety of substitutable goods and services with many denominations of currencies, i.e., currency

substitution in transaction demand [CSTD]. Foreign money demand is thus directly related to foreign goods and services demands which, in turn, depend on their relative price expectations.

Furthermore, as capital markets around the world have become increasingly integrated, risk-averse investors have had more opportunity to diversify their wealth among all available currencies, i.e. through currency substitution in speculative demand [CSSD]. Basically, traders attempting to optimize their currency portfolio balances will demand more of a foreign currency when its value is expected to appreciate. In particular, a currency that has a low correlation with their holdings is preferable, given the uncertainty associated with the set of exchange rate expectations.[1]

However, a usual analysis can show that the optimizing shifts in demand for currency stocks through these two different channels tend to offset each other with a given change in expected exchange rates. Therefore, an attempt to prove empirically the existence of these two demand channels, including each demand channel's direction and magnitude, is needed. The result would indirectly answer the question of the efficacy of domestic monetary policy in the new environment of world trade and capital liberalization.

In this paper, the Japanese money demand function is empirically estimated and analysed for the possible existence of substitution effects between the yen and US and Canadian dollars. Japan is selected for this study because it is an open economy with relatively large trading volume in world markets and a currency widely held among traders. The Canadian dollar is included in the analysis because it has a low correlation with the yen in their exchange rate movements; thus it could provide a channel of CSSD when traders prefer Canadian dollars to diversify their currency portfolios.

THEORY AND EVIDENCE

Previous Studies

Standard monetary theory which assumes that residents of a single country hold only

the national money has been criticized by Miles (1978a), noting that when economic agents hold both domestic and foreign currencies, the composition of these cash balance portfolios will vary with the relevant opportunity cost of holding real balances of the various types of currencies. Therefore, a change of monetary policy in a foreign country will change the relative costs of holding currencies and thus induce offsetting inflows or outflows of money. An excess supply of foreign currency flows to a domestic country by the distribution effect and changes in price levels that are not consistent with the traditional flexible exchange rate model. McKinnon (1982) argues that high substitutability among industrial countries' currencies destabilizes the demand for individual national currencies so that one cannot make much sense out of year-to-year changes in purely national monetary aggregates in explaining cycles in purely national rates of inflation. Therefore, the growth in the world supply is a better predictor of American inflation than the US money growth rate. Lapan and Enders (1983) conclude that in the absence of government control, if the private sector views the currencies as perfect substitutes for each other, then the exchange rate must be invariant over time and indeterminate. Calvo and Rodriguez (1977) incorporate currency substitution in their exchange rate determination model and explain exchange rate overshooting. In Daniel (1981), currency substitution is a channel for international transmission of monetary disturbances under flexible exchange rates in both the long and short term. In the short term, currency substitution can be responsible for overshooting the exchange rate and affects the national level of real wealth and consumption because of the unexpected change in money supply.

On the other hand, Thomas (1985) explains that the monetary service model is more likely than the portfolio balance model to explain the interactions of domestic and foreign money demand. This implies that the demand for alternative monies is from the real rather than the financial channel, and the transaction services that money produces

are the main reason for the money demand rather than its expected real return or risk when complete bond markets exist.

Both Hamberger (1977) and Britain (1981) support the currency substitution hypothesis by employing an alternative empirical procedure which examines the cross-correlations of the residuals from regressing a velocity variable on the time variable. Studies on this issue for developing countries include Ramirez-Rojas (1985) for Argentina, Mexico, and Uruguay, Fasano-Filho (1986) for Argentina, Marquez (1987) for Venezuela, and Arize (1991) for South Korea. All their findings support the evidence of CSH. To a varying degree, it is an important feature of these developing countries.

Bordo and Choudhri (1982) note that the differential cost of holding foreign instead of domestic money is the expected change in the exchange rate, but it does empirically exist in the Canadian money demand function. Darby *et al.* (1983) maintain the view that foreign bonds are generally more important substitutes for domestic money than foreign money. They include a foreign interest rate plus expected depreciation term in estimating the domestic money demand function and conclude that foreign-asset substitution for domestic money is not an important channel of economic transmission among countries. Batten and Hafer (1986) raise some empirical issues about choosing economic variables to explain the CSH and propose a testing framework that avoids the problems associated with previous works. By employing the distributed lag model and the GNP deflator as the dependent variable, they found that adding the rest of the world money growth to the explanatory power of domestic money growth alone did not offer more explanation to US inflation.

The evidence indicates that the role of currency substitution in domestic money demand is mixed at best in both empirical and theoretical studies. Most empirical studies, however, do not explicitly differentiate the two different channel-of-substitution effects and have contributed much to the debate about the existence and the significance of the effects.

Empirical Model

Under the rational expectation assumption, an economic agent could optimally expect a future exchange rate one period ahead of the realized exchange rate, using all available relevant information (Mishkin 1983). The forecasting equation that can be used to generate the anticipation of the growth rate of a basket of current spot exchange rates expressed in domestic currency per unit of foreign currency, S_t, is.

$$S_t = Z_{t-1} \cdot \alpha' + u_t \qquad (1)$$

where

Z_{t-1} = a vector of regressors available at time t-1 to forecast S_t (variables like interest rate, money supply, and trade balance, etc. known at t-1, t-2, t-3,..., t-n),

α' = a vector of coefficients to be estimated,

u_t = an error term which is assumed to be uncorrelated with any information available at t-1 (which includes any variable in Z_{t-1} or u_{t-1} for all i > 1).

An optimal forecast for S_t then simply involves taking expectations of equation (1) conditional on information available at t-1 as

$$E[S_t] = Z_{t-1} \cdot \alpha' \qquad (2)$$

where E[.] is an expectation operator.

The hypothesis for CSTD and CSSD suggests that the domestic money demand is a function not only of domestic factors like income and the interest rate, but also of international influences through future expectations of exchange rates. Therefore, the money demand equation can be specified as

$$m_t = m_t + E[S_t] \gamma' + e_t \qquad (3)$$

where

m_t = the growth rate of real money demand,

m_t = an equilibrium money demand based only on the domestic fac-

tors, i.e. the interest rate and income variables (however, in this study the interest rate variable was not selected as an independent variable to estimate Japanese money demand function),

$\gamma' =$ vector of coefficients for forecasted (expected) exchange rates as independent variables, i.e. the expected exchange rates for yen/C\$ and yen/US\$ from previous two equations,

$e_t =$ a serially uncorrelated disturbance-term.

The CSTD hypothesis proposes that the parameter γ' is positive and that the expected depreciation of the exchange rate will induce the substitution of foreign goods and services for domestic ones in the world market and force both domestic and foreign traders to demand more of domestic than foreign currency. On the other hand, the CSSD hypothesis suggests a negative parameter; the expected depreciation of exchange rates reduces domestic money demand for the utility-maximizing currency traders. These substitution effects will create a problem of monetary dependency if the coefficients are significantly different from zero, although the substitution effects tend to offset each other.

Since equations(1) and (3) share information by using common variables in the system, it is likely that the disturbances from the two are correlated. The technique of joint nonlinear estimation of (1) and (3) will be used for the efficient estimation of parameters.[2]

To test the hypotheses of CSTD and CSSD, a constrained system of equations restricting the parameters for the expected exchange rates to zero is estimated. Then, a likelihood ratio test is performed to compare the constrained and unconstrained systems. The likelihood ratio is computed as

$$LR = 2(Lu\text{-}Lc)$$ which is distributed as chi-square with q degrees of freedom,

where

$Lu =$ log likelihood value of unconstrained system,

$Lc =$ log likelihood value of constrained system,

$q =$ number of coefficients being restricted.

Furthermore, the Aaike Information Criterion (AIC) (Amemiya 1980) is used to select the lag length of relevant variable in the exchange rate and money demand equations.[3]

Data

From Citibase, the monthly data for the money supply, the short-term interest rate, and the industrial production and consumer price indices are collected for Japan, USA and Canada from January 1977 to December 1989 (total 156 months). In addition, the monthly data for the exchange rates and import and export volume *vis-à-vis* USA are collected for Japan and Canada. The Canadian exchange rates are then converted into a series expressed as the number of Japanese yen per Canadian dollar. The real industrial production is used for the real income measure as a proxy. For the stationarity of each of these data, the first difference of interest rate and the first difference of growth rate for exchange rate, real income, money supply, import, and export are used. The tests of stationarity for these series using regressions of each of these series against time trend and the square of time trend show no evidence of the rejections against stationarity. Note that, in this study, no attempt is made to test whether systems of equations are cointegrated since *expected* values of exchange rates are used rather than *actual* exchange rates in the Japanese money demand function (equation 3).

EMPIRICAL RESULTS

Table 1 shows the contemporaneous correlation coefficients of five major currencies on their growth rates of the spot exchange rate per US dollar. It also shows the average merchandise trading volume of these countries with USA. The lowest correlation between the Canadian dollar and Japanese yen suggests that the yen per Canadian dollar exchange rate would be a good candidate to

TABLE 1
Correlation matrix of five major currencies*
(January 1977 - December 1989)

	£	C$	FR	GM	¥
£	1.00				
C$	0.25	1.00			
FR	0.66	0.23	1.00		
GM	0.69	0.19	0.94	1.00	
¥	0.56	0.09	0.68	0.66	1.00

* Growth rates of spot exchange rate (each currency per US dollar)

£ : British pound
C$: Canadian dollar
FR : French franc
GM : German mark
¥ : Japanese yen

Average Monthly Volume and Growth Rate of Merchandise Trade with USA**
(Million US dollars, January 1977 - December 1989)

	UK	Canada	France	Germany	Japan
Exports to USA:	1,067	4,691	633	1,393	4,442
	(0.9%)	(0.8%)	(1.0%)	(0.9%)	(1.1%)
Imports from USA:	1,011	3,740	576	848	1,987
	(0.9%)	(0.7%)	(0.8%)	(0.7%)	(0.9%)

** Average growth rates in parenthesis

test the CSSD hypothesis on the Japan money demand function. Although it is not shown in the table, these two countries have lowest correlation coefficient of monthly growth rate of trade volume with USA. On the other hand, the highest growth rate and the relatively large volume of trade between USA and Japan suggest a high degree of CSTD between yen and the US dollar.

For these reasons, the unconstrained system of two different exchange rates (¥/C$ and ¥/US$) and Japanese money demand equations were estimated with the nonlinear maximum likelihood estimation technique. However, the final specifications of each equation were first determined by the AIC technique for their appropriate variables and lag lengths and reported in Table 2; the equation is repeatedly estimated with various lag lengths, and then the appropriate order of lag length is determined by selecting the order with the lowest AIC value. Some usual tests are run for robustness of these specifications. Since each equation contains lagged dependent variables, Breusch and Pagan's (1980) Lagrange multiplier test was applied to analyse the possibility of serial correlations of a higher order.[4] No evidence of significant serial correlations was found in error terms up to the 6th lag at the 5% significance level. For the test of heteroscedasticity, Breusch and Pagan's (1979) chi-square test method was used, and no significant evidence of violations of homoscedasticity at the 5% significance level was found.[5] Based on the homoscedastic error terms, it was possible to perform Chow tests for the exchange rate equations by dividing the samples into two equally sized sub-groups because each equation is estimated first with the OLS procedure before substituting in the system of equations. The resulting F-statistics show that the stability of the parameters was not rejected at 5% significance level for all equations.

TABLE 2

Joint estimation for exchange rates and Japanese money demand equations
(maximum likelihood estimation from January 1980 to December 1989)

A. The Unconstrained System

$$\yen/C\$: S_{C,t} \overset{6}{\underset{I=1}{=}} \alpha0 + \sum_{I=1}^{2} \alpha1_i \cdot S_{C,t-I} \overset{6}{\underset{I=1}{}} + \sum \alpha2_i \cdot \overset{2}{I_{j,t-I}} + \sum \alpha3_i \cdot M_{j,t-I} + \sum \alpha4_i \cdot X_{J,t-I} + u_t$$

Initial AIC = -4.336   Final AIC = -4.419

$$\yen/U\$: S_{U,t} \overset{7}{\underset{I=1}{=}} \beta0 + \sum_{I=1}^{3} \beta1_i \cdot S_{C,t-I} \overset{2}{} + \sum \beta2_i \cdot I_{j,t-I} + \sum \beta3_i \cdot X_{j,t-I} + v_t$$

Initial AIC = -4.175   Final AIC = -4.222

$$Md: m_{J,t} \overset{10}{\underset{I=1}{=}} \gamma^0 + \sum_{I=1}^{2} \gamma1_i \cdot m_{J,t-I} + \sum \gamma2_i \cdot y_{t-I} + \gamma^3 \cdot E[S_{C,t}] + \gamma4 \cdot E[S_{U,t}] + e_t$$

Initial AIC = -3.964   Final AIC = -3.967
(excluding expected exchange rates)

$S_{K,t}$: Exchange rate as K currency per one unit of Japanese yen at time t,
$I_{K,t}$: Short-term interest rate for the country K at time t,
$M_{K,t}$: Nominal money supply for the country K at time t,
$m_{K,t}$: Real money demand for country K at time t,
$X_{K,t}$: Volume of exports to USA for country K at time t,
$Y_{K,t}$: Real income measure of country K at time t.
(All variables except interest rate are the first differences of growth rate of these variables).

B. Parameter Estimation

$\yen$/C\$: Coefficient	Sum	t-statistics	F-statistic*
$\alpha0$	-0.0005	-0.2257	
$\alpha1$	-2.4398	-7.7301	19.2105
$\alpha2$	-0.0248	-3.6345	6.6962
$\alpha3$	-0.0428	-0.3535	0.6241
$\alpha4$	-0.0229	-0.8943	5.4687
R^2 = 0.38			
$\yen$/U\$: $\beta0$	-0.0007	-0.2754	
$\beta1$	-2.7150	-7.9466	16.9492
$\beta2$	-0.0284	-3.8437	5.1582
$\beta3$	-0.0035	-0.1297	3.7949
R^2 = 0.37			
Md: $\gamma0$	0.0009	0.3423	
$\gamma1$	-3.7994	-5.2829	7.6319
$\gamma2$	0.2975	1.1735	2.5867
$\gamma3$	-0.9061	-2.4617	
$\gamma4$	0.7468	2.0808	
R^2 = 0.41			

* Joint hypotheses test when all individual coefficients for lags are restricted to zero.

C. The log likelihood test for constrained and unconstrained models
    Log likelihood Ratio = 2 (906.24 - 903.159) = 6.162 (restricting $\gamma3$ and $\gamma4$ to zeros for the constrained
    model), which is larger than chi-square with q degrees of freedom (number of restricted coefficients); we
    cannot reject the null hypothesis that the restrictions do not apply.

The estimated parameters of the unconstrained system are presented in part B of Table 2; both exchange rate equations have significant negative effects of Japanese interest rate on the exchange rate in the long term.[6] When the Japanese interest rate increases, both the ¥/C\$ and ¥/US\$ exchange rates decrease, implying the appreciation of the yen *vis-à-vis* the Canadian and US dollars. This result follows the balance of payments approach to exchange rate determination where a rising domestic interest rate should lower the exchange rate either by attracting capital from abroad or by reducing domestic expenditure for imports (and thereby improve the trade balance). Although the sum coefficients are not significant, the Japanese export variables have significant F-statistics for all lags of zero. Investigating individual coefficients of the export variable shows partial support of the fact that an increase in Japanese exports causes the appreciation of the yen in the short term. Based on these observations, both CSTD and CSSD can be expected in the Japanese money demand function. Note that interest rate variable was omitted in the Japanese money demand equation because of a technical reason (the AIC value of the equation is higher if it is included); no attempt is made here to explain why it does not have any effect on the Japanese money demand.

In fact, the coefficients of the expected exchange rates in the Japanese money demand equation show negative and positive signs in their parameters for ¥/C\$ and ¥/US\$ exchange rates, respectively (see Table 2, part B). The significant and negative coefficient for the ¥/C\$ rate (γ^3 = -0.9061) can be interpreted as the expected depreciation of the yen inducing currency traders to reduce their holdings of Japanese money in an attempt to avoid the associated capital loss, while the expected appreciation of the yen encourages them to demand more Japanese money. This result, combined with the negative effect of the Japanese interest rate or exchange rate, is consistent with the CSSD hypothesis that a change in either interest rate or exchange rate expectation exerts an influence on the composition of

optimal money holdings for a currency trader and provides corresponding capital flows which affect the domestic money holdings.

On the other hand, the coefficient for the ¥/US\$ rate (γ^4 = 0.7468) has a significantly positive sign in the money demand equation. This result combined with the negative effect of the Japanese interest rate on the exchange rate shows that CSTD dominates CSSD in the Japanese money demand with respect to the ¥/US\$ exchange rate, given the fact that USA is Japan's largest trading partner, and the growth rate of trading volume is the highest among the major US trading partners. Therefore, when the yen is expected to depreciate, US importers demand more Japanese goods, and thus demand more yen balance to finance the increased trade.

A constrained system of equations (with the restrictions of the parameters for the expected exchange rates at zero in the money demand equation) is also estimated (see Table 2, part C). The log likelihood ratio test on these constrained and unconstrained systems shows the rejection of the null hypothesis that the constrained system is present at the 5% significance level. This result and the offsetting influences of different foreign exchange rates on money demand may provide a possible explanation for the conflicting results of previous studies on the significance of currency substitution effects in other countries. However, by differentiating the two different channels of substitution effects using the ¥/C\$ and ¥/US\$ exchange rates, the results identify the direction and magnitude of the currency substitution effect of the two different channels. Without including these two channels of substitution, the domestic money demand function may mot be stable over time as shown in the log likelihood test.

CONCLUSION

This paper analyses the Japanese money demand function and tests the currency substitution hypothesis (CSH) in which the expected exchange rates for yen per Canadian dollar (¥/C\$) and yen per US dollar (¥/US\$) affect the Japanese money demand in

two different ways, depending on the magnitude of two different channels of substitutions: the currency substitution in transaction demand and the currency substitution in speculative demand for money. The rationale for including these two exchange rates in the Japanese money demand arises from the following: (1) this approach may reconcile the previous controversies over the significance of the CSH between the portfolio and money-service approaches of money demand; (2) the transaction demand could be the dominant channel with ¥/US$ because of the high trade volume between USA and Japan; and finally (3) speculative demand could be the dominant channel with ¥/C$ because of their low correlation in the exchange rate changes.

The results of maximum likelihood estimations on the system of equations show that the current expectation of ¥/C$ has a significant negative effect on the Japanese money demand, implying currency substitution in the speculative demand for money. On the contrary, the currency expectation of ¥/US$ shows a significant positive effect on the Japanese money demand function, implying currency substitution in the transaction demand for money. The offsetting effects of these two different substitutions could be the reason for the previous controversies over the existence and significance of currency substitution effects. By identifying these two different channels explicitly, the Japanese money demand function is found to be dependent on foreign exchange rate expectations, thus providing support for the CSH, at least in the period analysed here. However, although these expected exchange rates are significant in determining equilibrium money demand for Japan, the effects tend to offset each other and the net effect of foreign exchange rates may be negligible.

In comparison with previous studies, tests based on combined rather than separate channels of currency of substitution show some doubt about the existence of the CSH, but in this paper findings confirm the existence of the CSH with the opposite signs for the coefficients of expected exchange rate variables in the money demand equations

and give more information that may explain the previous controversy over the existence and significance of currency substitution effect. An individual country's monetary authority must now recognize that its policy can affect foreign exchange rates differently depending *on what money demand channel* is dominant in that currency. In essence, the rapidly integrating capital market seems to diminish an individual country's ability to conduct the monetary policy, e.g. the disaster in Mexico's emerging capital market in 1994; hence a coordinating monetary policies or a newly designed exchange rate system may be needed.

Footnotes

1.   The portfolio optimization decision here assumes the constant covariances of returns on all other assets and considers only the behaviour of the exchange rate returns of one currency *vis-à-vis* other currencies.

2.   The estimation procedures can be described step by step as follows: (1) Estimate exchange rate equations with OLS. (2) Get fitted values (expected values) of Yen/C$ and Yen/US$ exchange rates. (3) Use these values as independent variables in the memory demand equation and estimate the three equations (two exchange rate and one money demand equations) jointly with maximum likelihood method. (4) Use coefficients estimated from the procedure (3). (5) Again re-estimate the three equations jointly, and get estimated coefficients to get fitted values of exchange rates. (6) Re-estimate the three equations jointly with newly estimated values of exchange rates to replace the old independent variables in the money demand equation. (7) Continue these procedures until the highest possible R^2 value for the joint estimation is obtained.

3.   In the forecasting of exchange rates, the Granger (1969) causality concept was used for a specification of the model. A variable Z is said to Granger-cause another variable S if S can be predicted better from the past values of S alone. The forecasting equation of S should include lagged values of S to eliminate any serial correlation in the residuals. If Z Granger-causes S, then it should also be used in an optimal forecast of S. To get the relevant variables Z and their optimum lag length, AICs are calculated up to the 10th lag of both domestic and foreign variables including the first differences of interest rate, first difference of the real growth rate of income, the first difference of the growth rate of nominal money supply, and the first differences of the growth rate of trade volume figures. The variable and its lag with minimum AIC are selected.

4. Breusch and Pagan's Lagrange multiplier test for assumption of no serial correlations of higher order in error terms was performed as follows. First, the residual were obtained from OLS estimation, then a series of regressions with current residual as dependent variable was run with lags of different order, p, of residual and independent variables of original equation as regressors. The resulting R^2 of each regression multiplied by its number of observations, NR^2, is distributed as chi-square with p degrees of freedom when the null hypothesis of no p^{th} order serial correlation is true.

5. Breusch and Pagan's (1979) test for heteroscedasticty can be performed as follows. Assume error terms are normally distributed. First, get the residuals (ε) and variance($\sigma2$) from original equation. Then make a new series, $g^t = (\varepsilon^2/\sigma^2)$, and run another regression with g as a dependent variable. It can be shown that half the difference between the total sum of squares and the residual sum of square from the second regression is distributed asymptotically as chi-square distribution with k degrees of freedom when the null hypothesis of homoscedasticity is true.

6. The sum coefficients of Japanese interest rate changes have significant long-term negative effects on the exchange rates, and the negative coefficients are consistent for all lags considered in the equations.

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