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AN EMPIRICAL EVALUATION OF THE MONETARY APPROACH TO EXCHANGE RATE DETERMINATION

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I. INTRODUCTION

A number of authors have presented successful estimates of the simple monetary model using data from the early experience with floating-rate regime. When applied to an observation period extended beyond the late 1970s, however, the monetary model has been shown to lose its explanatory power substantially.[1] In this paper, we purport to check for the robustness of previous authors' finding as to the strong performance of the monetary model both from the perspective of general econometric problems surrounding conventional estimation method and from the perspective of alternative theoretical hypotheses.

The paper is organized as follows. In Section II, we provide a brief review of leading exchange rate models developed along the line of monetary approach. Various econometric problems that arise in estimating the reduced-form equations are also discussed. Section III performs empirical tests of the models reviewed along with a specification error test. Conclusions and some comments are provided in Section VI.

II. THEORETICAL MODELS[2]

In this section we briefly examine a number of models that are representative of the monetary approach to exchange rate determination. Our starting point is with the flexible-price monetray model (Bilson 1978, Frenkel 1976), which is a direct outgrowth of the purchasing power parity view of exchange rates. The estimation equation is:

(1) $s = a_0 + a_1 m' + a_2 y' + a_3 R'$,

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[1] See Dornbusch(1980), Driskill and Sheffrin(1981), Ahking(1989), and Kohsaka(1984).

[2] See Lee(1989) for full details of derivation for each model.

where, it is required that $a_1=1$, $a_2<0$, $a_3>0$. It has long been recognized in the literature that the use of a single equation approach, in either money demand studies or exchange-rate modelling, may be inappropriate since it constrains many of the elasticities to be the same across countries, and more importantly, it fails to consider the endogeneity of the explanatory variables.[3] To begin with, note in equation (1) that the income and the interest rate variables have identical effects on the dependent variable but in the opposite directions. As pointed out formally in Haynes and Stone(1981), this kind of subtractive restriction may produce an estimator which does not fall in the range of values of the unrestricted coefficients and may even reverse the sign. If that is the case, then we are bound to make Type I or Type II errors.[4] It may therefore be necessary to use the unrestricted alternative:

$$(2)\ s = a_0 + a_1 m + a_1^* m^* + a_2 y + a_2^* y^* + a_3 R + a_3^* R^*$$

where it is required that $a_1=1$, $a_1^*=-1$, $a_2<0$, $a_2^*>0$, $a_3>0$, $a_3^*<0$. Notice also that in the above estimating equations, we have an interest rate as one of the explanatory variables. Inclusion of interest rates, or the forward premium(as in Bilson(1978)), may cause simultaneous equation bias due to potential feedback from exchange rates to interest rates. In addition, the stock of money may not be exogenous policy-controlled variable as assumed in most exchange-rate models in the sense that its movements can be explained by other variables in the system in which the monetary authorities have stronger interest.[5] This is more likely to be the case in the short run. An alternative procedure often pursued is to specify a reaction function for the intervention activities of the monetary authorities into the money demand as in Papell(1984).[6] In the presence of simultaneous feedback between the dependent and independent variables, ordinary single equation estimation will not produce consistent estimators. On the other hand, system estimation can ensure consistent and efficient estimators as well as enabling a test of cross-equations coefficient restrictions.[7] A recent ex-

[3] See, for instance, Hodrick(1978).

[4] Even if the assumption of equal parameters is true, Hakkio(1983) argues that conventional single-equation estimation procedures may be inappropriate unless we further assume certain conditions about the relationship between the error structures of money demand equations and the PPP relationship.

[5] Since money supplies are imposed with unit coefficients, moving them over to the left-hand side will ensure consistent estimation of the remaining variables, if endogeneity of the money supply is indeed the problem. See Frankel(1981).

[6] See also Branson & Buiter(1983).

[7] In general practice, instrumental variables are usually used for the variables that may be endogenous in order to ensure consistent esimation.

ample of system estimation approach is Ahking(1989). In estimating models with explicit assumption of rational expectations, in particular, simultaneous equation method is usually employed as in Woo(1985), and Hoffman and Schlagenhauf(1983).

In order to avoid the possible endogeneity problem with the interest rate differential, we can replace it with the uncovered interest parity condition. As in Frankel(1979), we then assume that expectations are rational, income growth is stagnant, and the velocity is constant. Then from a simple quantity theory of money, the expected inflation rate is equal to the rationally expected monetary growth rule. Assume monetary growth follows a random walk with no drift such that $\Delta m = \Delta m(-1) + \nu$, where Δ is the difference operator. Then it follows that the rationally expected future relative monetary growth rule is simply the current relative monetary growth rate, which we will represent by $\pi - \pi^*$. Therefore, we obtain another estimation equation :

$$(3)\ s = b_0 + b_1 m' + b_2 y' + b_3 \pi',$$

where it is required that $b_1 = 1$, $b_2 < 0$, $b_3 > 0$. A close variant of this model was originally tested by Frenkel(1976) for the German hyperinflation years 1920-1923. We can also convert equation (3) in an unconstrained form in our estimation to avoid possible sign reversal problem.

A drawback of the Frenkel-Bilson type model is the assumption that PPP holds continuously, which is widely rejected by the empirical data for various countries. As shown in Frenkel(1981), for example, real exchange rates are not constant and nominal exchange rates fluctuate more than price levels.[8] One modification is to assume some goods-price sluggishness, creating the possibility of temporary deviations of relative prices from PPP. Dornbusch(1976) and Frankel(1979) have developed a class of model where short-run PPP assumption is replaced by sluggish price adjustment in the goods market while PPP is maintained in the long run. In his widely influential seminal work, Dornbusch formalized a monetary model with sticky price of home goods to demonstrate that the exchange rate may overshoot in the short run in response to a permanent change in the money supply. The equation for estimation is:

$$(4)\ s = a_0 + a_1 m' + a_2 y' + a_3 p',$$

where the value of a_1 exceeds unity, implying short-run overshooting, and the coefficients of m' and p' sum to unity, i.e., $a_1 + a_3 = 1$, implying neutrality of

[8] It seems that this has been established as a stylized fact regarding the behavior of exchange rates. See also Kimbrough, Mussa(1976), and Saidi and Swoboda(1983).

money. It is also required that $a_2<0$, $a_3<0$. The degree of overshooting depends upon the interest elasticity of money demand and the regressive price adjustment coefficient. In the case where the interest rates are known to be truly exogenous. Then we can obtain another estimation equation through a few simple steps:

$$(5)\ s=\tilde{a}_0+\tilde{a}_1 m'+\tilde{a}_2 y'+\tilde{a}_3 R',$$ [9]

where it is required that the exchange rate is homogeneous of degree 1 with respect to the relative money supply, i.e., $\tilde{a}_1=1$, and $\tilde{a}_2<0$, $\tilde{a}_3<0$. The sign of interest rate coefficient is the only difference between (5) and (1). Note that the interest rate differential is required to be negative contrary to the prediction of the Frenkel-Bilson model. In the case where goods prices are sticky, a relatively low domestic nominal interest rates will cause an incipient capital outflow causing the currency to depreciate, or overshoot the long-run equilibrium, until there is sufficient expectation of future appreciation to offset the low interest rate. The degree of overshooting is again inversely related to the value of the price adjustment coefficient.

We can easily show that lagged specification of the Dornbusch model in estimation equation form is:

$$(6)\ s=b_0+b_1 s(-1)+b_2 m'+b_3 m(-1)'+b_4 p(-1)'+b_5 y'+b_6 y(-1)',$$

where the coefficients are required to satisfy:

$$\sum_{i=1}^{4} b_i=1,\quad b_1<0,\ b_2>1,\ b_3<0$$
$$b_4<0,\ b_5<0,\ b_6<0.$$

Notice that the assumption of long-run PPP corresponds to the constraint that the coefficients of $s(-1)$, m', $m(-1)'$ and $p(-1)'$ add up to one.

Frankel(1979) extends the Dornbusch model by incorporating secular inflation rates. The corresponding estimation equation is

$$(7)\ s=c_0+c_1 m'+c_2 y'+c_3 R'+c_4 \pi',$$

where it is required that $c_1=1$, $c_2<0$, $c_3<0$, $c_4>|c_3|>0$. This formulation may be regarded as a nonnested test for the previous models including the

[9] This is the equation considered as the Dornbusch model in Frankel(1979). He then compares this model with his own which has inflation differential as one additional term.

Dornbusch model [equation (4)]. If estimated value of c_4 is not significantly different from zero, then the Dornbusch hypothesis cannot be rejected. Secondly, equations (1) and (3) are special cases of equation (7). Bilson's equation (1) obtains when $c_4=0$, and Frenkel's equation(3) obtains when $c_3=0$.

Again, an econometric problem in estimating equations (5) and (7) is that the interest rate differential R' may be endogenous in the system. In order to remedy this problem, we can substitute the monetary equilibrium condition for R' in equation (7). The resulting estimation equation is

$$(8)\ s=j_0+j_1m'+j_2y'+j_3p'+j_4\pi',$$

where it is required that $j_1>1$ implying short-run overshooting, $j_1+j_3=1$, indicating zero-degree homogeneity of the system with respect to changes in money supply (i.e., PPP holds in the long run), and $j_2<0$, $j_3<0$, $j_4>0$.

One of the assumptions of the models we have considered so far was that assets are perfect substitutes across borders. Now we can relax this perfect substitutability assumption and introduce the interaction between demand for internationally traded assets and trade flows. The resulting model, called the stock-flow model, is based upon the idea that the exchange rate is also influenced by the current account which reflects trade flows through the financial markets. One widely cited model along this line is the one developed by Driskill(1981). His model, however, is often criticized since the demand for foreign assets is specified as being independent of income and wealth.[10] Drawing on these criticisms, we can extend the model by including a wealth term in the asset demand function.[11] In addition, we specify the money supply process as a random walk around a long-term trend following Frankel(1979). The estimation equation that we obtain is:

$$(9)\ s=a_0+a_1s(-1)+a_2m'+a_3m(-1)'+a_4p(-1)'+a_5y'+a_6y(-1)' \\ +a_7W'+a_8W(-1)'+a_9\pi'+a_{10}\pi(-1)'.$$

Notice in equation (9) we have four additional arguments, i.e., contemporane-ous and lagged values of wealth and inflationary expectation terms compared to Driskill's original model. The coefficient constraint is $a_1+a_2+a_3+a_4=1$, which can be easily tested using the Likelihood Ratio Method. A priori expectation dictates that $a_2>0$, $a_4>0$, $a_7>0$, $a_9>0$ and all other coefficients have uncertain signs.

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[10] See Backus(1984) for other points.

[11] This is also done in Lafrance & Racette(1985). The reduced-form equation that he obtains is slightly different from ours due to a simpler specification of the price adjustment mechanism.

Hooper and Morton(1982) extends the Dornbusch-Frenkel model allowing for changes in the long-run equilibrium real exchange rates. These changes are assumed to be related to movements in the current account, both through changes in expectations about the long-run equilibrium exchange rate and through changes in risk premium.[12] The estimation equation of the model is:

$$(10)\ s = a_0 + a_1\overline{m}' + a_2 y' + a_3 R' + a_4 \pi' + a_5 CA,$$

where CA represents cumulative current account. The coefficient constraints are: $a_1 = 1$, $a_2 < 0$, $a_3 < 0$, $a_4 > |a_3| > 0$, and $a_5 < 0$. Note that this formulation may be viewed as a general form in which both the flexible-price and sticky-price models are special cases.

III. ESTIMATION RESULTS

The models we have reviewed thus far are empirically evaluated in the context of the yen-dollar rate in this section. The data are quarterly data for the period 1973:Q2-1988:Q1. Monthly data were also used but only a small portion of the results will be reported for our purpose. The beginning period of our sample approximately corresponds to the beginning of the floating rate regime in both countries.

1. Medium-term Yen and the Flexible-Price Monetary Model

1.1 Confirming the Short-Lived Success of the Model.

To begin with, let's look at the estimation results of our reference model, or, the flexible-price monetary model, firstly on the basis of quarterly data. Both restricted [equation (1)] and unrestricted [equation (2)] forms of the model are estimated against various periods starting from 1973:Q2 through 1988:Q1. We begin from the first subperiod (1973:Q2-1976:Q4) and then extend it by adding one year at the end of the sample each time. Reported in Table 1 and Table 2 are estimation results of the unrestricted version being conscious of the sign reversal problem emphasized by Haynes and Stone.[13] In fact, the estimated equation is slightly different than equation (1). Following the suggestion of Frankel(1980), we moved the money supply variables to the

[12] See Dornbusch & Fisher(1980) for an early emphasis on the relationship between current account and the behavior of exchange rates, and Haas and Alexander(1979) for a model that integrates the role of capital flows.

[13] Notable differences were not detected between the estimation results of unrestricted and restricted versions.

[**Table 1**] Estimation of the flexible-price monetary model

	〈Equation (1)〉					
subperiods	(73:Q2-76:Q4)		(73:Q2-77:Q4)		(73:Q2-78:Q4)	
equations	(1.1)	(1.2)	(1.3)	(1.4)	(1.5)	(1.6)
techniques	OLS	ML	OLS	ML	OLS	ML
c	0.032	0.084	-0.512	-0.430	-1.589	-1.473
	(0.027)	(0.072)	(-0.569)	(-0.496)	(-1.283)	(-1.066)
y	-0.557	-0.557	**-0.702**	**-0.701**	**-0.967**	**-0.926**
	(-1.757)	(-1.775)	(-2.574)	(-2.663)	(-2.502)	(-2.268)
y^*	0.725	0.713	**1.011**	**0.993**	**1.564**	**1.489**
	(1.431)	(1.410)	(2.500)	(2.519)	(2.996)	(2.700)
R	4.494	4.383	**5.858**	**5.645**	**8.060**	**8.355**
	(1.915)	(1.877)	(3.531)	(3.553)	(3.477)	(3.237)
R^*	-11.282	-11.041	**-17.227**	**-17.021**	**-30.022**	**-28.719**
	(-1.382)	(-1.336)	(-3.540)	(-3.540)	(-7.178)	(-6.208)
T	**-0.017**	**-0.017**	**-0.021**	**-0.021**	**-0.028**	**-0.028**
	(-3.250)	(-3.208)	(-6.611)	(-6.686)	(-9.536)	(-8.670)
$S.E.$	0.027	0.027	0.025	0.025	0.039	0.039
R^2	0.831	0.833	0.938	0.943	0.964	0.903
DW	1.993	1.960	1.915	1.823	1.625	1.831
ρ		-0.035		-0.851		0.197
		(-0.108)		(-0.287)		(0.814)

Notes: 1) Numbers in parentheses are t-ratios. $S.E.$ is the standard error of the regression, R^2 is coefficient of determination, DW is Durbin-Watson statistic and is the first-order autocorrelation coefficient. ML is the Maximum Likelihood Iterative technique. T is the time trend variable.

2) y, y^* are total industrial production(1980=100), R is money market rate and R^* is 3-month treasury bill rate.

3) Bolded figures represent the coefficient being significant at 5% level.

4) See Appendix for sources of data.

left-hand side so that possible endogeniety of money supply process could be subsumed into the dependent variable. Although significant improvement was not obtained, we choose to report the results without the money supply variables.

As can be seen in Table 1, for the subperiod (1973:Q1-1976:Q4), the fit is very good with a low value of $S.E.$ although the t-values of the structural coefficients are slightly below the critical value of 2.262. This may be due to the sample size being too small. For the subperiods (1973:Q1-1977:Q4), and (1973:Q1-1978:Q4), we observe that all the coefficients, including those of the time trend variable, are of correct sign and significant at 5% and the fit is quite

[Table 2] Estimation of the flexible-price monetary model

	〈Equation (1)〉					
subperiods	(73:Q2-79:Q4)		(73:Q2-88:Q1)		(79:Q1-88:Q1)	
equations	(2.1)	(2.2)	(2.3)	(2.4)	(2.5)	(2.6)
techniques	OLS	ML	OLS	ML	OLS	ML
c	1.539	0.632	2.718	0.619	-3.099	1.746
	(0.680)	(0.255)	(1.747)	(0.354)	(-0.895)	(0.504)
y	0.746	0.330	**1.636**	-0.211	**3.648**	0.245
	(-1.757)	(0.563)	(3.700)	(0.479)	(2.979)	(0.312)
y^*	-0.921	-0.332	**-2.084**	-0.211	**-2.871**	-0.591
	(-1.153)	(-0.454)	(-4.370)	(-0.454)	(-3.983)	(-0.903)
R	**9.135**	7.488	**7.167**	4.739	-1.466	5.648
	(2.082)	(1.501)	(3.652)	(1.447)	(-0.215)	(1.119)
R^*	-12.999	-3.470	**-7.821**	-1.834	1.782	1.589
	(-2.011)	(-0.499)	(-2.991)	(-0.586)	(0.377)	(0.410)
T	**-0.011**	**-0.014**	-0.006	**-0.009**	-0.014	-0.002
	(-3.061)	(-2.714)	(-1.950)	(-2.010)	(-1.552)	(-0.177)
$S.E.$	0.076	0.059	0.121	0.057	0.127	0.061
R^2	0.882	0.685	0.603	0.283	0.436	0.105
DW	0.853	1.327	0.443	1.542	0.445	1.704
ρ		**0.740**		**0.932**		**0.939**
		(5.513)		(22.635)		(19.581)

Note: 1) See the notes in table 1.

good. Notice that the properties of the estimates remain largely the same regardless of whether the model is estimated by the method of OLS or GLS(Generalized Least Squares). This kind of results are indeed what brought the monetary model a glorious debut. Turning to Table 2, however, we see a completely different picture. Estimation result for the next subperiod (1973:Q2-1979:Q4), for instance, reveals a striking contrast to the result of earlier periods. The fit deteriorates remarkably and all the structural coefficient estimators are insignificant except for that of the Japanese interest rate. Furthermore, the income variables have the wrong sign. Subsequent sample periods such as (1973:Q2-1980:Q4), (1973:Q2-1981:Q4),... etc., give similarly poor estimation results(not reported here) with very low Durbin-Watson statistics even with Maximum Likelihood (ML) Iterative corrections. This is consistent with the findings of previous authors as noted in Section I.

Why this sharp contrast? Why is it that the simple monetary model loses its effectiveness sharply when it covers sample periods after late 1970s?[14] We can

[14] We conducted a Chow test for a structural change between the selected subperiods (1973:Q2-

only suspect at this point that some structural changes in either or both countries are responsible for its short-lived success.[15)]

1.2 Is the Above Result Robust?

It is important to note that one can argue with the robustness of the early success of simple monetary model either from the perspective of general econometric problems surrounding single-equation estimation method or from the perspective of alternative theoretical hypotheses. Therefore, it seems sensible to check for the robustness of the above result from a broader perspective.

To that end, we proceed as follows. We first estimate an alternative formulation of the flexible-price model in the subsection below. Estimation of the model with the monthly data is reported in subsection (d) along with some insights on monthly versus quarterly horizons from the perspective of the nature of the monetary approach. A simultaneous equation system is set up in subsection (e) and estimated with the Full Information Maximum Likelihood Method (FIML).

Overall the results suggest that the strong performance of the flexible-price monetary model with quarterly yen-dollar rate until late 1978 is to a large extent a reality. This view is further supported by much less favorable estimation results of various other models that will be reported in subsequent sections.

1.3 Estimating Alternative Formulation of the Model.

Estimation results for equation (3) are presented in Table 3. In estimating equation (3), we used three proxies for the expected inflation rates, i.e., average *WPI* and *CPI* inflation rates over the preceding 12 months and the long-term government bond interest rates. It turns out that *WPI* and *CPI* inflation rates are inappropriate proxies for the expected inflation rates for the chosen sample period. Only the relative bond interest rates are significant but the t-statistics for both the relative money supply and relative income are not high enough to be significant. We experimented with several instruments using Fair's method but were not successful in improving the estimates. Overall the estimation results are not very much supportive of the model. This suggests that equation (1) is a superior specification in terms of the properties of the estimates at least for the data period involved.

1978:Q4) and (1979:Q1-1981:Q1). The null hypothesis of no structural change is rejected at $\alpha = 0.01$ with $F = 5.73$.

[15] It is shown in Lee(1989) that relative money demand in its simple specification reveals a point of discontinuity in the second quarter of 1978.

[Table 3] Estimation of the flexible-price monetary model

	⟨Equation (3)⟩,		subperiods 73:Q2-78:Q4			
equations	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)	(3.6)
techniques	OLS	ML	OLS	ML	OLS	ML
c	-4.042	**7.108**	-3.062	**5.755**	**9.705**	**8.578**
	(-1.173)	(2.608)	(-0.965)	(2.121)	(3.180)	(3.176)
m'	**1.961**	-0.293	**1.752**	-0.021	-0.868	-0.623
	(2.807)	(-0.529)	(2.720)	(-0.037)	(-1.391)	(-1.129)
y'	-1.297	-0.051	-0.632	-0.140	-0.759	-0.740
	(-1.656)	(-0.110)	(-0.756)	(-0.287)	(-1.639)	(-1.635)
π_1'	0.013	0.051				
	(0.316)	(1.623)				
π_2'			0.080	0.046		
			(1.565)	(1.052)		
π_3'					**40.566**	**31.013**
					(5.908)	(4.189)
$S.E.$	0.085	0.045	0.080	0.047	0.050	0.040
$\bar{R}^2$	0.610	0.982	0.655	0.983	0.866	0.993
DW	0.682	1.085	0.627	1.300	0.867	1.771
ρ		**0.941**		**0.928**		**0.718**
		(18.277)		(14.898)		(4.499)

Notes: 1) See the notes in Table 1.

2) π_1' and π_2' are relative average WPI and CPI inflation rates for the preceding 12 months, respectively. π_3' denotes the relative long-term bond interest rate used as a proxy for the inflationary expectations.

1.4 Monthly versus Quarterly Horizons

Would the flexible-price monetary model reveal the same pattern of explanatory power on the monthly data for the corresponding sample periods? Our hope that the model may produce somewhat comparable results at least for the periods of the 70s was completely dashed. Estimation results on the monthly data were very poor for any periods selected including the entire sample period. For the subperiod (1973:4-1978:12), for example, the estimated equation is:

$$(12)\quad s = \underset{(4.363)}{6.713} + \underset{(0.212)}{0.040}m' + \underset{(0.400)}{0.067}y - \underset{(-1.289)}{0.362}y^*$$

$$+ 3.824R + 8.531R^* - 0.004T.$$
$$(0.510) \quad (1.075) \quad (-1.741)$$

$$R^2 = 0.970 \qquad DW = 1.181 \qquad S.E. = 0.$$

None of the structural coefficients are significant and the *DW* statistic is very low even with Corc corrections. We also tested all the variants of monetary models considered in this paper on the monthly data numerous times but the results were in general very poor. The residuals invariably reveal severe serial correlation that is difficult to purge even with corrective techniques. After all, we must realize it should not be surprising that the monthly fluctuations of the yen-dollar rate are not accommodated very well by any of the models that subscribe to the monetary approach. Monetary models are basically a long-run description of the determinants of the exchange rate. The assumption of PPP, for example, is recognized to be invalid for the short-run. Free mobility of capital, implicitly assumed in monetary models, also requires a long-run horizon of time. It must also be noted that one month is too short a time to absorb government exchange market interventions. Greater influences may be played by external interferences over monthly horizons than by the market fundamentals.

1.5 Simultaneous Estimation Approach

In order to see how the flexible-price model withstands a more stringent test, we construct a simultaneous equation system as below. First, the money demand equations are restated as:

$$(13)\ m - p = \alpha + \beta_1 y + \beta_2 R + \mu$$

$$(14)\ m^* - p^* = \alpha^* + \beta_1^* y + \beta_2^* R^* + \mu^*$$

where μ and μ^* are disturbance terms. Assume that the error terms follow an AR(1) process such that

$$(15)\ \mu = \rho \mu_{-1} + \Psi$$

$$(16)\ \mu^* = \rho \mu_1^* + \Psi^*$$

where μ and μ^* are stochastic error terms. Also assume that the deviations from PPP follow an AR(1) process such that

$$(17)\ s - p' = \theta [s_{-1} - p_{-1}'] + \nu$$

where ν is also a stochastic error term. Then the system, which we call Model I, consists of the following three equations.

$$(18)\ m - p = \alpha(1-\rho) + \beta_1 y + \beta_2 R - \beta_1 \rho y_{-1} - \beta_2 \rho R_{-1} + \rho(m_{-1} - p_{-1}) + \Psi$$

$$(19)\ m^* - p^* = \alpha^*(1-\rho^*) + \beta_1^* y^* + \beta_2^* R^* - \beta_1^* \rho^* y_{-1}^* - \beta_2^* \rho^* R_{-1}^* + \rho(m_{-1}^* - p_{-1}^*) + \Psi^*$$

$$(20)\ s = \theta s_{-1} + p' - \theta p_{-1}' + \nu$$

where $E\begin{bmatrix} \Psi \\ \Psi^* \\ \nu \end{bmatrix} [\Psi\ \Psi^*\ \nu] = \Omega = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{bmatrix}$

We can easily show that the implied reduced-form exchange-rate equation from the above system has an error term that is correlated with Ψ and Ψ^*. Therefore, an Ordinary Least Squares(OLS) regression will yield inconsistent estimators unless further assumptions are made to constrain appropriately the error terms. Hakkio(1983) noted that the following set of assumptions, which we denote with H_0, must be imposed to ensure consistency of the OLS estimators:

$$(21)\ H_0^A : \alpha = \alpha^* \quad \beta_1 = \beta_1^* \quad \beta_2 = \beta_2^* \quad \rho = \rho^*.$$

Let's call the system with these restrictions Model II. Although OLS estimation is now consistent, the standard errors are incorrect.

To further ensure correctness of the standard errors, an additional assumption of equal autoregressive parameters must be made such that H becomes:

$$(22)\ H_0^B : \alpha = \alpha^* \quad \beta_1 = \beta_1^* \quad \beta_2 = \beta_2^* \quad \rho = \rho^* = \theta.$$

We call the above system Model III. Note that estimating a standard monetary equation of (2) by a conventional method, say, Corc is appropriate only under conditions such as (22).

In simple flexible-price monetary model, it is typically assumed that PPP holds identically in addition to the set of coefficient restrictions such as in (22). Our Model IV then consists of:

$$(23)\ H_0^C : \alpha = \alpha^* \quad \beta_1 = \beta_1^* \quad \beta_2 = \beta_2^* \\ \rho = \rho^* \quad \theta = 0 \quad \sigma_{3i} = \sigma_{i3} \quad (i = 1, 2, 3).$$

We estimated both the unrestricted and restricted models using the FIML procedure in version 4.0 of TSP. Gauss Method was used for the iteration technique. Starting values for Model I were taken from OLS estimators of equation (7) and a regression of $(s - p')$ on $(s_{-1} - p'_{-1})$. Starting values for Models II to IV were taken from the final estimates from Models I to III, respectively. The results are presented in Table 4 for the period (73:Q2 − 78:Q4). The first column gives estimates of the unrestricted model(Model I). The income elasticities of the demand for money are insignificant at 5 % level for both countries. Domestic(Japanese) elasticity is not even correctly signed. However, interest rate variables are of the correct sign and significant for both countries. The

[**Table 4**] Full Information Maximum Likelihood Estimation of the flexible-price monetary model

	Subperiod 78:Q2-78:Q4			
	Model I	Model II	Model III	Model IV
α	7.261	**4.933**	**8.734**	-118.443
	(0.237)	(5.838)	(2.350)	(-1.577)
β_1	-0.058	0.241	0.226	0.070
	(-0.160)	(1.311)	(1.236)	(0.363)
β_2	**-0.180**	**-0.136**	**-0.128**	-25.530
	(-4.930)	(-5.329)	(-3.819)	(-2.140)
α^*	0.048	-0.224	-3.453	-105.136
	(0.049)	(-0.252)	(-0.899)	(-2.200)
β_1^*	0.214			
	(1.173)			
β_2^*	**-0.101**			
	(-2.244)			
ρ	**0.994**	0.898	0.998	
	(7.354)	(24.142)	(640.008)	
ρ^*	**0.859**			
	(18.945)			
θ	**0.998**	**0.998**		
	(549.351)	(624.267)		
lnL	159.430	157.638	154.395	

Notes: 1) See the notes in Table 1.
2) lnL denotes log of the likelihood function.
3) For the income variable, our second industrial production series was used that has 1977 as the base year.

[Table 5] Likelihood Ratio Tests

	H_0^A	H_0^B	H_0^C
$2(lnL_u - lnL_r)$	3.584	10.07	719.474
5 % critical value	7.815	9.488	11.071
1% critical value	11.345	13.277	15.086

Notes: 1) See the notes in Table 1.
2) lnL_u is the unrestricted likelihood value and lnL_r is the restricted likelihood value. It is known that $\lambda = 2(lnL_u - lnL_r)$ follow a χ^2 distribution with k(number of restrictions) degrees of freedom.

autoregressive parameters in both money demand equations as well as deviations from PPP are significant and very close to unity suggesting they may have unit roots. The estimates of the remaining three restricted models show similar result. Although correctly signed, the income elasticities of money demand are always insignificant, while the interest rate coefficients are always significant with the expected sign.

Turning to the validity of coeffcient restrictions, we cannot reject either H_0^A or H_0^B at 1% level, as can be seen from Table 5. This suggests that the use of single-equation estimation method is warranted as far as the chosen sample period is concerned. In addition, linear subtractive constraint may be imposed on the explanatory variables without worrying about sign reversal problem. However, a more inclusive hypothesis H is rejected for the sample period involved implying the assumption that PPP holds instantaneously is false.

Taken as a whole, our evidence suggests that OLS estimates of the reduced-form equation are reliable although their properties deteriorate somewhat under FIML estimation for the sample period considered.

2. Estimation Results of the Sticky-price Monetary Models

We divide the entire period into three subsamples. The first subperiod(A; 73:Q2 − 78:Q4) is chosen so that we can compare the estimation results with the performance of the flexible-price model(Equation (1)). Having possible discontinuity in mind around the latter part of 1970s, the next subsample(B; 79:Q1 − 88:Q1) begins from the first quarter of 79 through the end of the entire period. All models are also estimated for the entire sample period(C; 73:Q2 − 88:Q1).

2.1 On the Hypothesis of Random Walk

To begin with, we perform a simple test on the assumptions implicit in "sticky-price models" about the stochastic processes governing the exogenous variables. As noted previously the forcing variables m' and y' are assumed to follow a random walk. A series is said to follow a random walk if its changes are serially uncorrelated such that each successive change in the series is drawn independently from a probability distribution with zero mean. Consider the following equation:

$$(24)\ x = a + \sum_{1}^{N} b_i x_{-1} + \varepsilon,$$

where $x=X-X_{-1}$. The null hypothesis of random walk can be tested by an F -test which determine whether the b's are jointly equal to zero for $i=1,\ldots\ldots, N$. Incorporating a long-term trend(upward or downward) in the series X, random walk with drift is expressed as

$$(25)\ X = X_{-1} + d + \varepsilon,$$

where if $d>0$ the process will tend to move upward and vice versa. Table 6 presents results of OLS regressions on the exogenous variables m' and y' in difference form for the period (A). As for m', we can not doubt that m' follows a random walk. In addition, it appears to follow a random walk around a long-term upward trend. However, the assumption that the monetary growth rate follows a random walk is not supported. In the case of y', however, we can not accept the hypothesis of random walk since influence of lagged changes in y' is obvious. Similar results were obtained for the periods (B) and (C) but not reported.

[Table 6] Tests of random-walk hypothesis

(6.1) $\Delta m' = 0.011 + 0.176 \Delta m'_{-1}$.	$DW=2.019$
(2.250) (0.176)	$F=0.673$
(6.2) $\Delta m' = 0.010 + 0.144\ \Delta m'_{-1} + 0.104\ \Delta m'_{-2}$.	$DW=2.036$
(1.795) (0.640) (0.552)	$F=0.478$
(6.3) $\Delta y' = -0.001 + 0.343\ \Delta y'_{-1}$.	$DW=1.517$
(-0.334) (1.670)	$F=2.790$
(6.4) $\Delta y' = -0.002 + 0.559\ \Delta y'_{-1} - 0.618\ \Delta y'_{-2}$.	$DW=1.891$
(-0.539) (3.186) (-3.554)	$F=8.485$

Note: 1) See the notes in Table 1.

2.2 On the Hypothesis of Short-Run Overshooting

Table 7 presents the estimates of equation (4), the Dornbusch(1976) model. For period (A), the *DW* statistic warrants OLS estimation. The fit is quite good and the standard error of the regression is relatively low. All coefficients except for domestic money supply and foreign income are significant at 5% level. For the next sample period (B), only the price levels are significant and the *DW* statistic is extremely low. ML correction for serial correlation yields no better results. Notice that the sign requirements are satisfied but the

[**Table 7**] Estimation of the sticky-price monetary model

	〈Equation (4)〉					
subperiods	(73:Q2-78:Q4)		(79:Q1-88:Q1)		(73:Q2-88:Q1)	
equations	(7.1)	(7.2)	(7.3)	(7.4)	(7.5)	(7.6)
techniques	OLS	ML	OLS	ML	OLS	ML
c	**35.589**	**39.734**	24.133	−3.287	**26.754**	1.864
	(2.787)	(3.133)	(1.659)	(−0.386)	(4.303)	(0.364)
m	−0.465	−0.509	−0.318	0.385	**−0.896**	0.011
	(−0.607)	(−0.684)	(−0.433)	(1.175)	(−3.019)	(0.043)
m^*	**−3.068**	**−3.504**	−2.258	−0.055	**−2.076**	−0.006
	(−2.286)	(−2.646)	(−1.925)	(−0.073)	(−2.922)	(−0.011)
y	**−1.385**	**−1.533**	−0.174	0.219	**0.729**	0.231
	(−2.188)	(−2.619)	(−0.136)	(0.328)	(2.131)	(0.635)
y^*	0.802	0.920	−0.336	−0.324	**−0.980**	−0.251
	(1.365)	(1.730)	(−0.418)	(−0.771)	(−2.515)	(−0.808)
p	**1.105**	**1.087**	**3.081**	**1.429**	**1.437**	**0.905**
	(3.751)	(3.957)	(3.105)	(2.761)	(4.266)	(3.115)
p^*	**−2.600**	**−2.879**	**−3.013**	−0.235	**−1.294**	0.029
	(−3.595)	(−4.337)	(−2.519)	(−0.285)	(−3.541)	(0.061)
T	**0.081**	**0.094**	−0.068	−0.016	**−0.054**	−0.019
	(2.392)	(2.829)	(−1.875)	(−0.698)	(3.129)	(−1.254)
S.E.	0.044	0.043	0.096	0.051	0.084	0.047
R^2	0.929	0.988	0.814	0.977	0.866	0.966
DW	2.150	2.174	0.570	1.625	0.585	1.393
ρ		−0.215		**0.902**		**0.918**
		(−0.882)		(13.800)		(19.585)

Notes: 1) See the notes in Table 1.

2) The price levels are represented by *WPI*'s(1980=100).

coefficients of m' and p' do not sum to unity. They add up to -5.028 rejecting the hypothesis of neutral money. How about the hypothesis of overshooting? The coefficient of m' is -3.533 far different from the required value of unity.

For the entire sample period (C), interestingly enough, all the coefficients are significant. However, the *DW* statistic is only 0.585 indicating severe positive serial correlation. After ML estimation only one variable, the domestic price level, remains significant and the *DW* statistic is still very low.

As can be seen in Table 8, estimates form the lagged version of the

[Table 8] Estimation of the lagged sticky-price monetary model

	⟨Equation (6)⟩					
subperiods	(73:Q2-78:Q4)		(79:Q1-88:Q1)		(73:Q2-88:Q1)	
equations	(8.1)	(8.2)	(8.3)	(8.4)	(8.5)	(8.6)
techniques	OLS	ML	OLS	ML	OLS	ML
c	-2.567	-2.489	-1.611	-1.822	-0.813	-0.556
	(-1.325)	(-1.592)	(-0.729)	(-0.858)	(-1.541)	(-0.824)
$s(-1)'$	**0.791**	**0.881**	**-1.081**	**1.093**	**0.990**	**0.921**
	(5.180)	(6.646)	(13.428)	(14.289)	(13.696)	(10.458)
m'	-0.175	-0.135	0.324	-0.361	0.256	0.163
	(-0.369)	(-0.306)	(1.101)	(1.217)	(1.001)	(0.749)
$m(-1)'$	0.937	0.781	-0.082	-0.090	-0.063	0.055
	(1.780)	(1.538)	(-0.225)	(-0.249)	(-0.263)	(0.266)
y'	-0.079	-0.160	0.165	0.117	0.113	0.081
	(-0.154)	(-0.351)	(0.337)	(0.243)	(0.325)	(0.241)
$y(-1)'$	-0.070	0.064	0.262	0.268	0.205	0.266
	(-0.137)	(0.143)	(0.593)	(0.613)	(0.604)	(0.790)
$p(-1)'$	0.131	**-0.013**	**-1.606**	**-1.598**	-0.353	-0.309
	(0.412)	(-2.396)	(-3.260)	(-3.396)	(-1.521)	(-1.164)
T	**-0.014**	**-0.013**	-0.012	-0.011	**-0.004**	**-0.004**
	(-2.351)	(-2.397)	(-1.738)	(-1.733)	(-2.510)	(-2.193)
$S.E.$	0.037	0.036	0.044	0.044	0.050	0.048
R^2	0.949	0.995	0.961	0.969	0.953	0.970
DW	2.133	1.915	2.112	2.027	1.447	1.943
ρ		-0.287		-0.073		**0.326**
		(-1.064)		(-0 401)		(2.457)

Notes: 1) See the notes in Table 1.

2) Price level is proxied by *WPI* index for both countries.

Dornbusch model merely confirm the strong influence of last period's spot rate on current value. The coefficient of the lagged endogenous variable is just about the only one that is significant for all three sample periods. The fits are strong but most of the structural variables remain insignificant across samples. None of the coefficient constraints are satisfied and the hypothesis of overshooting is again rejected.

The estimates of Frankel's model, equations (7) and (8), are presented in Table 9. The expected inflation rates are proxied by long-term bond interest rates. Alternative proxies, such as *WPI* and *CPI* inflation rates,or monetary growth rates over the preceding 12 months were also tried but no distinctive differences could be found. For the subperiod (A), all the coefficients are significant but the *DW* statistic is 1.471 much lower than the critical value of 2.15. They become insignificant, however, when the ML is applied except for the

[Table 9] Estimation of the sticky-price monetary model

	subperiod 73:Q2-78:Q4					
	⟨Equation (7)⟩,			⟨Equation (8)⟩		
equations	(9.1)	(9.2)	(9.3)	(9.4)	(9.5)	(9.6)
techniques	OLS	ML	FAIR	OLS	ML	FAIR
c	**13.606**	**7.713**	**23.490**	**9.014**	**8.325**	**20.517**
	(4.099)	(2.522)	(2.716)	(2.937)	(3.275)	(1.117)
m'	**-1.670**	-0.441	-3.699	-0.735	-0.580	-3.088
	(-2.457)	(-0.704)	(-2.090)	(-1.174)	(-1.118)	(-0.823)
y'	**-1.034**	-0.702	-1.233	-0.828	-0.800	-0.100
	(-2.345)	(-1.528)	(-1.298)	(-1.796)	(-1.850)	(-0.077)
p'				0.437	0.672	0.478
				(1.199)	(1.694)	(0.622)
R'	**-8.658**	2.871	**-16.468**			
	(-2.156)	(0.545)	(-2.219)			
π'	**63.262**	22.082	**97.749**	**32.409**	18.207	57.656
	(5.165)	(1.530)	(3.967)	(3.373)	(1.838)	(1.727)
T	**-0.023**	-0.001	0.053	0.009	0.001	0.048
	(-2.232)	(-0.108)	(1.995)	(0.957)	(0.146)	(0.838)
$S.E.$	0.045	0.041	0.056	0.049	0.038	0.065
R^2	0.914	0.994		0.899	0.995	
DW	1.471	1.718	1.967	0.828	1.864	1.711
ρ		**0.788**	0.015			0.371
		(5.791)	(0.064)			(1.682)

Notes: 1) See the notes in Table 1.
2) Price variable is *WPI* index.
3) For Fair's method, instrumental variable is the relative *CPI* inflation rate.

constant term. Notice the value of coefficient for m' is -0.441 although the coefficient of R' has the expected sign. The hypothesis of overshooting thus cannot be accepted. We also tried Fair's method which is designed to ensure consistency in the presence of endogenous variables on the right-hand side while correcting for serial correlation. The value of coefficients are raised but two of them, relative money supply and relative income become insignificant. Substituting the relative price level for interest rate differential worsens the results substantially.

For the next subperiod (B), however, the relative price level becomes significant regardless of the methods used(not shown). The relative expected inflation differential is also significant except for the ML estimation. The entire sample when estimated by OLS makes all the structural coefficients significant but the *DW* statistic is very low(not shown). ML does not improve the results at all and Fair's method fails too. The relative price level is significant for all methods used. Overall we are left with one obvious conclusion that the hypothesis of overshooting, or the sticky-price monetary models are not supported by the yen-dollar rate for any subsamples chosen.

3. Estimation Results for Models with Current Account Effect

3.1 Effect of Wealth

A generalized version of the stock-flow model developed above is estimated for the three subperiods. As can be seen from Table 10, relative real wealth and relative inflationary expectations emerge as significant for the period (A). It is somewhat disappointing to observe that they lose significance for the periods (B) and (C). Overall the estimates suggest that our model does not outperform the flexible-price model for the period (A). For a more recent period (B), or the entire period (C), the model fits very poorly as did other models considered so far.

Table 11 gives estimates of the Hooper-Morton model. Contrary to our expectations, the wealth variable as proxied by the cumulative current account fails to emerge as significant for any of the three sample periods. The wealth term is represented by the U.S. cumulative current account balances. We also tried the Japanese cumulative, and the relative cumulative current account balances but the results were worse.

3.2 Nested Hypothesis Testing

When a model is modified such that additional explanatory variables are added on the right-hand side, it can be viewed as a superior specification if the fit improves and the new variables enter as significant. Without conducting sep-

[Table 10] Estimation of the generalized stock-flow model

	⟨Equation (9)⟩					
subperiods	(73:Q2-78:Q4)		(79:Q1-88:Q1)		(73:Q2-88:Q1)	
equations	(12.1)	(12.2)	(12.3)	(12.4)	(12.5)	(12.6)
techniques	OLS	ML	OLS	ML	OLS	ML
c	1.132	0.894	**-4.386**	**-4.488**	**-2.446**	-1.833
	(1.010)	(1.513)	(-2.354)	(-2.564)	(-3.039)	(-1.950)
$s(-1)$	**0.790**	**0.900**	**0.991**	**1.022**	**0.968**	**0.905**
	(6.409)	(12.287)	(9.413)	(10.252)	(13.344)	(10.300)
m'	-0.277	-0.196	0.487	0.518	0.430	0.347
	(-0.277)	(-0.739)	(1.825)	(1.879)	(1.739)	(1.601)
$m'(-1)$	0.373	0.183	0.283	0.274	0.303	0.319
	(0.992)	(0.652)	(0.887)	(0.835)	(1.137)	(1.404)
$p'(-1)$	0.182	0.253	-0.647	-0.758	**-0.670**	-0.491
	(0.517)	(1.295)	(-1.377)	(-1.686)	(-2.229)	(-1.417)
y'	0.517	0.480	-0.703	-0.667	0.126	0.005
	(1.071)	(1.590)	(-1.419)	(-1.379)	(0.350)	(0.013)
$y'(-1)$	-0.515	**0.695**	0.514	0.532	0.681	**0.763**
	(1.122)	(2.592)	(0.935)	(0.978)	(1.823)	(2.055)
W'	0.223	**0.282**	0.374	0.437	-0.087	-0.012
	(1.791)	(3.172)	(1.118)	(1.252)	(-0.705)	(-0.104)
$W'(-1)$	**-0.335**	**-0.344**	-0.276	-0.380	-0.176	-0.236
	(-3.199)	(-4.436)	(-0.632)	(-0.850)	(-1.397)	(-1.998)
π'	0.052	**-0.077**	3.582	2.672	-1.659	1.435
	(-1.368)	(-3.246)	(0.527)	(0.401)	(-0.330)	(0.286)
$\pi'(-1)$	0.064	**0.091**	-7.553	-6.594	-4.812	-8.815
	(1.444)	(3.173)	(-1.304)	(-1.171)	(-0.961)	(-1.738)
$S.E.$	0.030	0.023	0.046	0.045	0.048	0.046
R^2	0.973	0.999	0.963	0.974	0.959	0.974
Durbin-h		-3.954		-0.750		1.896
ρ		**-0.772**		-0.098		**0.334**
		(-4.041)		(-0.509)		(2.476)

Notes: 1) See the notes in Table 1.

2) W' is relative real financial wealth. Each country's real financial wealth is computed by summing government debt outstanding and the accumulation of past current account surplus, deflated by CPI index.

3) Durbin-h statistics are computed as $\rho[n/(1-n \cdot \text{var}(s(-1)))]^{1/2}$

[Table 11] Estimation of the Hooper-Morton model

	⟨Equation (10)⟩					
subperiods	(73:Q2-78:Q4)		(79:Q1-88:Q1)		(73:Q2-88:Q1)	
equations	(13.1)	(13.2)	(13.3)	(13.4)	(13.5)	(13.6)
techniques	OLS	ML	OLS	ML	OLS	ML
c	**6.757**	**8.873**	-3.048	2.873	**3.849**	**4.312**
	(5.799)	(5.973)	(-1.222)	(1.708)	(2.595)	(3.258)
m'	-0.261	**-0.665**	**1.652**	0.480	0.333	0.224
	(-1.121)	(-2.278)	(3.403)	(1.450)	(1.132)	(0.854)
y'	-0.987	-0.515	1.151	0.407	0.257	0.069
	(-1.940)	(-1.196)	(1.216)	(0.730)	(0.529)	(0.181)
R'	-3.508	3.011	11.731	-0.803	**12.017**	0.117
	(-0.881)	(0.716)	(1.496)	(-0.230)	(2.781)	(0.045)
π'	**35.752**	14.012	-23.142	4.484	-6.567	6.632
	(3.249)	(1.330)	(-1.785)	(0.641)	(-0.801)	(1.156)
CA	0.025	0.068	0.033	0.043	**0.141**	0.062
	(0.593)	(1.776)	(0.650)	(0.641)	(4.425)	(1.645)
$S.E.$	0.051	0.037	0.129	0.060	0.126	0.054
R^2	0.891	0.995	0.644	0.941	0.690	0.912
DW	0.864	1.733	0.468	1.155	0.661	1.151
ρ		**0.813**		**0.956**		**0.965**
		(6.607)		(24.345)		(28.468)

Notes: 1) See the notes in Table 1.
2) CA is cumulative current account balance for the U.S.. detrended by the long-term average growth rate of GNP.
3) The coefficients of CA are multiplied by 103.

arate estimations, we can make some inferences regarding the effects of additional variables from the estimation results reported so far. For the subsample A, inclusion of nether the inflationary expectations nor the cumulative current account balances improves the fit. These additional variables enter as insignificant not only for the period (A) but for the periods (B) and (C) as well.

4. Specification Error Test

We have seen that the benchmark monetary model(equation (1) or (3)) performs as well as any other models for the sample period (A) in terms of signs and significance of coefficient estimates. However, the robustness of its strong performance must be analyzed in a more formal way. It has been a standard practice in evaluating competing models to conduct at least two tests, i.e., some form of specification test and predictive performance test. In this section, we intend to do specification error test using the evidence provided by non-nested alternative hypotheses. Among the many tests available in the literature, we choose to use the procedures developed by Davidson and MacKinnon(1981). They simplified the procedures proposed by Pesaran and Deaton(1978) into an empirically more tractable form.

Suppose we wish to test the truth of a reduced-form, possibly nonlinear regression model

$$(26)\ H_0 : y = f(X, \beta) + \mu$$

where y is the dependent variable, X is a vector of exogenous variables, β is a $(k \times 1)$ column vector of parameters to be estimated, and μ is a stochastic error term assumed to be $NID(0, \sigma_\mu^2)$. Suppose an alternative non-nested, or separate hypothesis suggested by economic theory is

$$(27)\ H_1 : y = g(Z, \gamma) + \nu,$$

where Z is a vector of exogenous variables, and γ is a $(\ell \times 1)$ vector of parameters to be estimated, and is $NID(0, \sigma_\nu^2)$ if H_1 is true. The term "non-nested" in this context means the truth of one model implies the falsity of the other model and vice versa. Combining (26) and (27), we construct an artificial compound model

$$(28)\ H_C : y = (1 - \alpha) f(X, \beta) + \alpha g(Z, \gamma) + \eta,$$

which collapses to H_0 if $\alpha = 0$ and to H_1 if $\alpha = 1$. Since we can estimate α, β, and γ jointly, we must modify equation (28). Davidson and MacKinnon(1981) show that under H_0, $\hat{g}$ is asymptotically nonstochastic so that g can be validly replaced by $\hat{g}$. Thus we rewrite (28) as

$$(29)\ H_C : y = (1 - \alpha) f(X, \beta) + \alpha \hat{g} + \eta, \text{ where } \hat{g} = g(Z, \hat{\gamma}).$$

They also prove that statistic is asymptotically $N(0,1)$. The test then consists of simply running a regression on equation (29) and using a usual t-test to see whether α is zero. If α is not significantly different from zero, then we can not reject H_0.

If H_0 is nonlinear, then equation (29) is also nonlinear and a unique value of α may not be obtained by estimating (29) in some cases. To overcome this problem, we can simply linearize equation (29) around the point $(\alpha = 0, \beta = \hat{\beta})$, obtaining

$$(30)\ y - \hat{f} = \hat{F}(\beta - \hat{\beta}) + \alpha(\hat{g} - \hat{f}) + \eta,$$

where is the matrix of derivatives of $f(\beta)$ evaluated at $\beta = \hat{\beta}$. We can easily see that equations (29) and (30) yield identical estimates of α and its standard error if H_0 is true since in that case $\hat{F} = X$ and $\hat{f} = X\hat{\beta}$.

What if we wish to test the true H_0 against several alternative hypotheses? To test H_0 against m alternative models $g_j(Z_j, \gamma_j)$, we can simply estimate

$$(31)\ y - \hat{f} = \hat{F}(\beta - \hat{\beta}) + \sum_{j=1}^{m} \alpha_j(\hat{g}_i - \hat{f}) + \eta,$$

and then perform a likelihood ratio test of the restriction that all the α_j's are zero. Table 12 presents test-statistics for the 8 models we have estimated in the chapter. If the model under test (H_0) is true, then the test-statistics are distributed asymptotically as $N(0,1)$. Therefore, large numbers are indicative of specification errors. The sample period is (73:Q2−78:Q2) during which it was found that a simple specification of money demand remained stable as we will show in the next chapter. It can be read from the table that the flexible-price equation, in particular, the second version (3), is a superior specification to the sticky-price equations (4) and (6). Equation (3) rejects (4) and (6) and they in turn are rejected by (3). Furthermore, equation (10) which has the flexible-price equations nested in itself rejects all four of the sticky-price models. All these observations along with our previous finding that sticky-price models fit poorly lead us to believe that flexible-price model is closer to the true model than the sticky-price models.

[Table 12] Nonnested pairwise specification test

	(1)	(3)	(4)	(6)	(7)	(8)	(9)	(10)
(1)	-	4.90	2.42	1.16	*	3.33	7.41	*
(2)	1.62	-	-1.15	2.02	*	*	8.57	*
(4)	4.53	6.47	-	4.06	7.16	*	15.50	19.72
(6)	1.49	5.89	2.99	-	4.67	3.77	8.15	13.74
(7)	+	+	1.25	0.65	-	-0.24	5.28	8.55
(8)	1.41	+	+	1.76	4.91	-	7.84	12.95
(9)	-0.01	3.39	4.37	-0.31	3.10	2.85	-	8.12
(10)	+	+	-1.40	1.22	0.79	-0.21	4.16	-

Notes: 1) See the notes in Table 1.
2) An asterisk(*) indicates that H_0 is nested in H_1, a plus (+) that H_1 is nested in H_0.
3) (1),(3) are flexible-price models, (4), (6), (7), (8) are the sticky-price models, (9) is a general stock-flow model and (10) is Hooper-Morton model

IV. CONCLUSIONS

Our empirical investigations of the yen-dollar rate produce a number of interesting results which can be summarized as follows.

First, the simple flexible-price monetary model gives a good description of the quarterly yen-dollar movement for the period covering up to 1978 and then it breaks down completely for a period covering beyond 1978. This is in line with the finding of previous authors.

Second, the strong performance of the flexible-price model for the period (73:Q2-78:Q4) seems to be robust in the sense that all other competing models give poorer fit with small Durbin-Watson statistics and our Log Likelihood Ratio test justifies OLS estimation as well as the usual coeffcient restrictions. This view is reinforced by the nonnested specification test which unambiguosly rejects variants of the sticky-price model in favor of flexible-price specifications. Our FIML estimation, however, diminishes success of 'the Chicago model' slightly by rendering the income coefficients insignificant.

Third, sticky-price models are a complete failure for any subperiods estimated. No evidence could be identified that supports the hypothesis of overshooting. This result is confirmed resoundingly by the specification test.

Fourth, among the three subperiods A, B,and C, all models showed a tendency to fit better for the period (A). This may be because money demand remained more stable relative to the other two periods.

Lastly, evidence is weak that the current account affected the yen-dollar rate.

APPENDIX

DATA SOURCES AND DEFINITIONS

The data set consists of both monthly and quarterly data collected from various sources. Most of the series are seasonally adjusted unless otherwise indicated. The selected period covers from as early as January 1971 to as recent as January of 1989 for most of the monthly series. The sources and their abbreviations are as follows.

- IFS : International Financial Statistics, International Monetary Fund.
- FRB : Federal Reserve Bulletin, U.S. Federal Reserve Board.
- SCB : Survey of Current Business, U.S. Department of Commerce.
- TB : Treasury Bulletin, U.S. Department of Treasury.
- NTG: Nihon Tokei Geppo(Monthly Statistics of Japan), Management and Coordination Agency, Japan
- NKS : Nihon Keizai Shihyo(Japanese Economic Indicators), Economic Planning Agency of the Government, Japan.

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