International Journal of Business and Economics, 2006, Vol. 5, No. 2, 129-145

The Monetary Model of the Dollar-Yen Exchange Rate Determination: A Cointegration Approach

M. Faizul Islam*
Department of Management Studies, Southeastern University, U.S.A.

Mohammad S. Hasan
Faculty of Organisation and Management, Sheffield Hallam University, U.K.

Abstract

This paper validates the monetary model in the determination of the dollar-yen exchange rate by applying cointegration methodology. Estimation results indicate a stationary relationship between the dollar-yen exchange rate and monetary models, with long-term causality flowing from monetary variables to the dollar-yen exchange rate. The forecasting performance of the monetary model based on the error-correction model outperforms random walk models.

Key words: cointegration; error-correction model; exchange rate; monetary model; random walk model

JEL classification: F31; F41

1. Introduction

Since the abandonment of the fixed exchange rate in the early 1970s, there has been a gradual decline in the nominal value of the US dollar vis-à-vis the Japanese yen. After bottoming in the mid 1990s, the dollar gained some strength against the yen. During the same period, the US had very large trade deficits with Japan. In 1974, the nominal exchange rate was ¥270 per US$1.00 and America's current account deficit with Japan was $32 billion. By 2002, the exchange rate fell to ¥120 per US$1.00 and the current account deficit rose to $250 billion. That is, a continued depreciation of the dollar was accompanied by burgeoning trade deficits. Understanding the dollar-yen relationship has been a topic of interest among academicians, policy makers, and businessmen.

The purpose of this paper is to empirically re-assess the relationship between the dollar-yen exchange rate and a vector of explanatory variables in the monetary

Received October 8, 2004, revised November 23, 2005, accepted September 20, 2006.
*Correspondence to: Department of Management Studies, Southeastern University, 501 I Street S.W., Washington D.C., 20024, USA. Telephone: (202) 478-8200; Fax: (202) 488-8093. E-mail: mislam49@seu.edu.

model of exchange rates in an attempt to explore whether the behaviour of this exchange rate lends support to the monetary model. The approach in this paper has significant differences from previous research, both temporally and methodologically. First, the data used in the paper are more recent and cover a wider span of time, from the first quarter of 1974 to the first quarter of 2003, to yield efficient parameter estimates. Second, it is well known in the literature that the residual-based cointegration test of Engle and Granger (1987) has low power when detecting an otherwise dormant long-run relationship and therefore is criticized in view of its inference-making limitations (see Luintel and Khan, 1999). Moosa (1994) and McDonald and Taylor (1991) argued that many of the studies done during the late 1980s and early 1990s using cointegration tests of the monetary model failed to reject the null hypothesis of no cointegraton because of an inappropriate testing method, such as the Engle-Granger method. Therefore, using the Johansen and Juselius (1990) maximum likelihood method of cointegration, this paper seeks to derive a relatively more robust cointegration result. Third, our study differs in the choice of variables determining the dollar-yen exchange rate, the frequency of the data, and the introduction of short-run dynamics to examine causal relations between the monetary variables. More specifically: (1) previous studies used monthly data, whereas we use quarterly data; (2) most previous studies used the industrial production index as a proxy of real income, whereas this study uses real gross domestic product; (3) unlike earlier studies, this study uses the Gensaki interest rate to represent the Japanese short-term interest rate; (4) to study the short-run dynamics, a vector error-correction model is estimated, the results of which assist examination of temporal causality among the monetary variables.

The rest of the paper is organized as follows. The literature is reviewed in Section 2. Section 3 presents the theoretical model and empirical methodology. Section 4 presents and discusses empirical results. Section 5 concludes the paper.

2. Literature Review

Since the seminal contribution of Frenkel and Johnson (1976) the 'Monetary Approach of Exchange Rates' has remained an important research issue both temporally and spatially in the area of international finance and monetary management. The monetary approach to exchange rates hypothesizes that the nominal exchange rate is determined solely by contemporaneous excess supplies of money in the two trading countries. Countries that follow a relatively expansionary monetary policy experience a depreciation of their currencies, while countries that follow relatively restrictive monetary policies observe an appreciation of their currencies. The theory therefore predicts a proportional relationship between exchange rates and relative supplies of monies between trading nations over long periods of time. The doctrine has important significance and implications at the theoretical, empirical, and policy levels. For example, the monetary approach constitutes a theoretical cornerstone of the open economy quantity theory as proposed by Lucas (1982). At a policy level this has implications in the implementation of structural adjustment programs sponsored by the World Bank and International Monetary Fund and exchange rate misalignment in a monetary union such as the European Monetary Union. Given the wide-ranging implications, it is not surprising that the monetary model of exchange rates is one of the most widely tested propositions in economics.

A large body of literature has accumulated over the past thirty years concerning the empirical validity of the monetary model. Earlier studies during the late 1970s and the early 1980s employed traditional regression analysis and found mixed evidence. For example, empirical studies covering the interwar period and the flexible exchange rate period during most of the 1970s were largely supportive of the monetary model (see Frankel, 1976; Bilson, 1978; Dornbusch, 1979). In contrast, Dornbusch (1980), Rasula and Wilford (1980), Haynes and Stone (1981), Meese and Rogoff (1983), Frankel (1984), Backus (1984), and Boughton (1988) covered the period of floating exchange rates beyond the late 1970s and found that evidence did not support the monetary model. Meese and Rogoff (1983) demonstrated that the monetary model failed to outperform a random walk model in out-of-sample prediction. The constraints imposed on relative monies, incomes, and interest rates, as well as the assumptions of purchasing power parity, exogeneity of money supply and uncovered interest rate parity, and the statistical problems as found in Driskill and Sheffrin (1981), have been cited as reasons for the poor performance of the monetary model.

The development of the cointegration and error-correction statistical technique coupled with the notion of equilibrium has generated renewed interest in empirical investigation of the validity of the monetary model of exchange rates. Studies using unit root and cointegration methodology again found mixed evidence. For example, most early studies using the Engle and Granger (1987) two-step cointegration methodology found no evidence of a long-run relationship between exchange rates and the set of monetary variables as envisioned in a standard monetary model (see Meese, 1986; Baillie and Selover, 1987; Boothe and Glassman, 1987; Kearney and MacDonald, 1990; McNown and Wallace, 1989). Furthermore, this body of work suggests that the residual series corresponding to a simplified version of the monetary model is an I(1) process, and the estimated coefficients are very often different from prior values in terms of magnitudes and signs. Earlier studies are alleged to be plagued by the weak power of the Engle-Granger cointegration test, short time spans, and small sample sizes during this period.

In contrast, in later studies MacDonald and Taylor (1991, 1992, 1994), using the multivariate method of Johansen and Juselius (1990), showed that a long-run version of the monetary model explained the stylized facts of recent float in the sense that the residuals are I(0) and the point estimates are close to their a priori values. Studies of MacDonald and Taylor (1991) however indicate that, with few exceptions in the case of the German mark-US dollar exchange rate, most of the popular monetary restrictions were rejected in the cases of dollar-yen and sterling-dollar exchange rates. Following the lead of MacDonald and Taylor, a number of researchers seem to have resuscitated the monetary model (see Moosa, 1994;

Choudhry and Lawler, 1997; Husted and MacDonald, 1998; Francis et al., 2001; Moersch and Nautz, 2001; Goren, 2002). Choudhury and Lawler (1997) applied the Johansen contegration technique to examine the monetary model for the Canadian dollar-US dollar exchange rate during the period of the Canadian float from 1950 to 1962. They identified one cointegrating vector whose coefficients conformed broadly to the restrictions of the monetary model. The error-correction model identified a short-run tendency for the exchange rate to adjust about 8% per month to revert to the equilibrium value of the estimated long-run model. Applying cointegration techniques for developing countries, McNown and Wallace (1994) found support for the monetary model for Chile and Argentina, as did Miyakoshi (2000) for South Korea.

Some of the more recent studies employed relatively more sophisticated techniques, such as the panel unit root test, multivariate unit root test in the presence of I(2) and I(1) components, and cointegration test in the presence of a structural break and found evidence supportive of the monetary model of exchange rates (see Husted and MacDonald, 1998; Diamandis et al., 1998). Husted and MacDonald (1998) estimated the monetary exchange rate model using four different panel data sets of 21 OECD countries: an international dollar-based data set, a European sample against both the US dollar and the German mark, and an international data set based on Japanese yen. They found evidence of significant long-run relationships for all the panel combinations with many of the monetary coefficients being correctly signed and of plausible magnitudes. Diamandis et al. (1998) re-examined the long-run validity of the monetary model of exchange rates using monthly data for three key US dollar bilateral exchange partners (namely, Germany, the UK, and Japan) from January 1976 through May 1994. They employed the testing procedure suggested by Paruolo (1996) to examine the presence of I(2) and I(1) components in the multivariate context. They argued that the unrestricted monetary model is a valid framework for explaining the long-run movements of exchange rates. Furthermore, they found no evidence of instability in the estimated coefficients by applying the Hansen-Johansen (1993) parameter stability test in a recursive framework.

Given the theoretical and operational significance of the issue and the mixed empirical evidence, we empirically investigate the validity of the monetary model for the bilateral exchange rate between the US dollar and Japanese yen over an extended time period. Over this time span, there is a high chance that the dollar-yen exchange rates might have several kinked time trends. Therefore, we employ the Gregory and Hansen (1996) cointegration test with a regime shift at an unknown date.

3. Theoretical Model and Empirical Methodology

(A) Theoretical Model

The most basic variant of the monetary approach includes two key building blocks, the quantity theory of money and purchasing power parity. To empirically approximate the theoretically identified factors in the estimable model, following Moosa (1994) and Francis et al. (2001), we start with the following three equations:

$$e_t = p_t - p_t^f \quad (1)$$

$$p_t = m_t - \omega(y_t) + \lambda(i_t) \quad (2)$$

$$p_t^f = m_t^f - \omega^f(y_t^f) + \lambda^f(i_t^f), \quad (3)$$

where e is the spot exchange rate (units of domestic currency per unit of foreign currency), m and m^f are exogenously given domestic and foreign money supplies, y and y^f are domestic and foreign real income, and i and i^f are domestic and foreign short-term nominal interest rates. Equation (1) signifies a purchasing power parity relationship to link the exchange rate with the price levels (p_t and p_t^f). Equations (2) and (3) are the money demand functions of the home country and foreign country, respectively. Substituting equations (2) and (3) in equation (1) yields:

$$e_t = m_t - m_t^f - \omega(y_t) + \omega^f(y_t^f) + \lambda(i_t) - \lambda^f(i_t^f). \quad (4)$$

Since the monetary model of exchange rates hypothesizes a proportional relationship between relative monies and the exchange rate, it is assumed that coefficients attached to monetary variables are unity with opposite signs. Previous research imposed additional theoretical restrictions of equal and opposite coefficients attached to the relative income and interest rate terms. For instance, the domestic interest rate has a positive influence, while the foreign interest rate has a negative influence on the exchange rate. This is primarily because interest rates reflect the inflation premium in this model, where a rise in expected inflation leads agents to substitute domestic currency with domestic and foreign bonds, resulting in depreciation of the domestic currency (see MacDonald and Taylor, 1994, p. 278). Given this condition coupled with the assumption of exogeniety of the money supply, the restricted version of the monetary model can be expressed as follows:

$$e_t = (m_t - m_t^f) - \alpha(y_t - y_t^f) + \beta(i_t - i_t^f), \quad (5)$$

where $\alpha = \omega = -\omega^f$ and $\beta = \lambda = -\lambda^f$. Equation (5) is usually referred to as the flexible price monetary approach. Here, the nominal exchange rate determination of the monetary approach emphasizes the relative money supplies and perfect price flexibility.

The actual exchange rate movements in equation (4) may be decomposed into changes in the long-run equilibrium exchange rate and disequilibrium adjustment of the current spot rate towards this long-run value. The source and form of these disequilibrium dynamics is as follows. The expected lags in the demand for money, possible money market disequilibrium, and gradual output adjustment all contribute towards deviations of the exchange rate from its long-run value and provide sources of adjustment dynamics additional to sticky prices (see Choudhry and Lawler, 1997).

In this context, cointegration and error-correction methodology is viewed as an appropriate technique for exchange rate modeling to represent the notion of long-run equilibrium with an error-correction mechanism to rectify the disequilibrium in the short-run.

Introducing a stochastic error term and re-writing equation (4) in a form suitable for estimation yields:

$$e_t = \psi_1 m_t + \psi_2 m_t^f + \psi_3 y_t + \psi_4 y_t^f + \psi_5 i_t + \psi_6 i_t + u_t \,. \tag{6}$$

The relationship represented in equation (6) is the basis of the long-term equilibrium exchange rate determination using the cointegration methodology. For the validation of the monetary model of the exchange rate, it is assumed that $\psi_1, \psi_4, \psi_5 > 0$ and $\psi_2, \psi_3, \psi_6 < 0$. The monetary restriction is signified by $\psi_1 = -\psi_2$. Using the notation of Johansen and Juselius (1992, p. 227), we implement direct tests on the coefficients entering the cointegrating vector of the general form $H_0 : \beta = H\phi$. In particular, the following are testable hypotheses of the monetary model:

H_1: $\psi_1 = 1$
H_2: $\psi_2 = -1$
H_3: $\psi_1 = \psi_2$
H_4: $\psi_3 = \psi_4$
H_5: $\psi_5 = \psi_6$.

(B) Empirical Methodology

The monetary model of the dollar-yen exchange rate determination is examined empirically based on cointegration methodology. The cointegration and vector error-correction (VEC) modeling technique is now well known and widely used in applied econometrics. For detailed methodological exposition, see Engle and Granger (1991), Hargreaves (1994), or nearly any econometrics textbook. This technique seeks to explore whether a set of interrelated variables share a common trend such that the stochastic trend in one variable is related to the stochastic trend in some other variable(s). The Johansen and Juselius (1990) system approach is employed to test for cointegration among variables. The Johansen maximum likelihood approach sets up the non-stationary time series as the vector autoregressive process of order k in re-parameterized form:

$$\Delta Y_t = \mu + \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \ldots + \Gamma_{k-1} \Delta Y_{t-k+1} + \Pi Y_{t-k} + U_t \,, \tag{7}$$

where $y(t) = \{e(t), m(t), m^f(t), y(t), y^f(t), i(t), i^f(t)\}$ is a 7×1 vector of the first-order integrated variables of exchange rate, money stock, real income, and interest rate, respectively (the superscript f signifies the foreign counterpart); μ is a 7×1 vector of constant terms to capture the time series trend characteristics; Γ_i is a $7 \times k$

coefficient matrix; and U_t is a vector of normally and independently distributed error terms. The rank of the long-run multiplier matrix, Π, determines the number of cointegrating vectors, which could at most be equal to $m_y = 7$, and the rank deficiency of Π is represented as $\text{Rank}(\Pi_y) = r < m_y$. The Johansen method provides two likelihood ratio tests, the trace test and the maximum eigenvalue test, to determine the number of co-integrating vectors, and Osterwald-Lenum (1992) furnishes the appropriate critical values. If Π is rank deficient such that $0 < r < 7$, then it can be decomposed as $\Pi = \alpha\beta'$, where the $\alpha_{(7\times r)}$ matrix contains the adjustment coefficients towards a long-run equilibrium and the $\beta_{(7\times r)}$ matrix contains the co-integrating vectors. The formulation and estimation of the short-run error-correction model and the detection of Granger causality is discussed in the next section.

4. Empirical Results

(A) Cointegration Tests and Results

In the empirical model (6), Japan is regarded as the home country and the US is viewed as the foreign country. The money stock variable used for the US and Japan is seasonally adjusted M1. Real income is represented by real gross domestic product (GDP). We use the GDP measure of output for various reasons. Theoretical models suggest income as the candidate variable in the specification of the monetary model. However, data on income and output measures such as GDP are available at the quarterly frequency. The monetary model appears to be a valid long-run model of the exchange rate. Furthermore, the impact and adjustment lags of various macro relations, such as the money-income, money-price, and money-exchange rate relationships, are too long for weekly or even monthly observations to reflect the actual correlation between these macroeconomic variables. The noise effects associated with weekly or even monthly observations tend to average out with quarterly data, which better approximate these relationships. Moreover, there is a change in the sectoral contribution of GDP in the sense that the US economy is moving more towards the service sector and away from manufacturing. All these considerations lead us to choose the GDP measure of output in the selection of data series. The nominal exchange rate is expressed as the Japanese yen per US dollar. The theoretical underpinning of the interest rate variable embedded in the determination of the monetary model of exchange rates is one of a short-term rate. In this context, the short-term interest rate for the US is represented by the 3-month Treasury bill rate. To maintain consistency in terms of the time period, the short-term Japanese interest rate is represented by the 3-month Gensaki interest rate as its counterpart (see Jeong, 2000; Ohno, 1989). All these data except the 3-month Gensaki interest rate were obtained from the International Financial Statistics tape. Data for the 3-month Gensaki interest rate were obtained from various issues of *Financial and Economic Statistics Monthly* of the Bank of Japan. All data are applied in logarithmic form.

As a first step, the data are checked for stationarity using the augmented Dickey-Fuller (ADF) unit root test on each variable. The results of the ADF tests indicate that each variable is non-stationary in level but not in first difference form. To conserve space, results of unit root tests are not reported here; they are available upon request from the authors.

Next, the data series are checked using the Gregory and Hansen (1996) cointegration test with a regime shift at an unknown date. Gregory and Hansen (1996) contended that if a model is cointegrated with a one-time regime shift in the cointegrating vector, the standard ADF test may not reject the null hypothesis of no cointegration and the researcher will falsely conclude that there is no long-run relationship. They suggested a modified residual-based test for cointegration in cases where the intercept and/or slope coefficients have a single break at an unknown date. The structural breakpoint (τ) is endogenously determined from the sample based on the information of the smallest t statistic. Since Gregory and Hansen (1996) provided asymptotic critical values for a cointegrated system up to four variables, we estimated the restricted version of the monetarist model (equation (5)). The lags selected for various cases of structural break are based on the Akaike information criterion (AIC). The results are reported in Table 1, which presents a modified ADF test after allowances are made for the level (L), trend (L/T), and regime (L/S) shifts. The modified ADF (ADF*) statistics fail to reject the null hypothesis of no cointegration for all cases of structural break. The conventional ADF statistics computed with a constant and trend are −3.134 and −3.112, respectively, which again fail to reject no cointegration. Since both the conventional ADF and ADF* tests produce similar results of no cointegration, it is appropriate to infer that there is no structural break in our sample. Our results accord well with Diamandis et al. (1998), who found no evidence of parameter instability in the case of the dollar-yen exchange rate. Overall, the result of no long-run relationship is consistent with the findings of earlier residual-based tests of cointegration.

Table 1. Testing for Regime Shifts in the Monetary Model

Model	ADF*	Breakpoint
L	−1.927	1986:Q4
L/T	−3.237	1981:Q1
L/S	−1.835	1986:Q3

Notes: L, L/T, and L/S denote level shift, level shift with trend, and regime shift, respectively. 5% critical values for the level, trend, and full-break shift models are −5.28, −5.57, and −6.00, respectively.

The data series are further checked using the Johansen and Juselius (1990) maximum likelihood procedure to test for cointegration since this method allows for the detection of non-dominant long-run relationships that the residual-based test might fail to identify. Johansen's vector autoregressive model is specified with an intercept and deterministic trend, as there appears to be a linear trend in all the non-stationary series. Use of the AIC suggests a lag length of 2 for the vector autoregressive model for the estimated period.

The results of Johansen's eigenvalue and trace tests are presented in Table 2A. The results indicate that there exists at least one cointegrating relationship between nominal exchange rate and relative real incomes, money supplies, and interest rates since the calculated test statistics exceed the 5% critical values for testing the existence of a zero cointegrating vector. A unique cointegrating vector between nominal exchange rate and right hand variables in equation (6) suggests a single stochastic shared trend. The identified cointegrating vector could be interpreted as a typical long-run relationship. The existence of such a stationary long-run relationship between nominal exchange rate and right hand variables in equation (6) lends support to the monetary approach as an explanation of equilibrium exchange rate behaviour over the sample period. Given that there are $n-r$ common trends within the system, we can conclude that there exist 6 common trends within the vector. The estimated cointegrating vector is reported below after normalizing on the exchange rate variable. The zero restrictions on the elements of the cointegrating vector are tested with the help of likelihood ratio tests. The χ^2 statistics 15.45 (p-value < 0.0001), 7.0486 (0.008), 22.84 (< 0.0001), and 29.48 (< 0.0001) indicate that the variables m, y, i, and i^f enter significantly in the cointegrating vector normalised on the exchange rate. The results also suggest that all coefficients, except foreign money supply and foreign income, have the correct sign and are significantly different from zero. Since all variables are specified in logarithms, the normalised equation comprises the implied long-run elasticities.

Table 2A. Johansen Tests for Cointegrating Relationships

		Test Statistics		5% Critical Values	
H_0	H_1	Max Eigenvalue	Trace	Max Eigenvalue	Trace
$r=0$	$r>0$	60.97*	162.06*	49.32	147.27
$r=1$	$r>2$	32.79	101.08	43.61	115.85
$r=2$	$r>3$	26.06	68.29	37.86	87.17
$r=3$	$r>4$	21.15	42.23	31.79	63.00
$r=4$	$r>5$	9.35	21.08	25.42	42.34
$r=5$	$r>6$	8.48	11.72	19.22	25.77
$r=6$	$r>7$	3.24	3.24	12.39	12.39

Estimated cointegrating vector (standard errors) normalised on e, m, m^f, y, y^f, i, i^f, *trend*: −[1.00, 4.3065 (2.0077), 0.48826 (0.58731), −5.3051 (3.5005), −0.93037 (1.7221), 0.51309 (0.22073), −0.48567 (0.17871), 0.0025504 (0.020448)].

Chi-square critical values (*p*-values): $\chi^2_{m(1)}$ = 15.45 (< 0.0001), $\chi^2_{m^f(1)}$ = 0.594 (0.441), $\chi^2_{y(1)}$ = 7.04 (0.008), $\chi^2_{y^f(1)}$ = 0.348 (0.555), $\chi^2_{i(1)}$ = 22.84 (< 0.0001), $\chi^2_{i^f(1)}$ = 29.48 (< 0.0001).

Notes: r indicates the number of cointegrating relationships. * indicates rejection of the null hypothesis of no cointegration at the 5% critical level. The chi-square statistics $\chi^2_{m(1)}$, $\chi^2_{m^f(1)}$, $\chi^2_{y(1)}$, $\chi^2_{y^f(1)}$, $\chi^2_{i(1)}$, and $\chi^2_{i^f(1)}$ test the restrictions that domestic money, foreign money, domestic income, foreign income, domestic interest rate, and foreign interest rate variables in the cointegrating vector individually are statistically significant.

Table 2B presents the restriction tests of the monetary model based on chi-square tests. Overall, the results of monetary restrictions implied by the monetary model are rather mixed. For example, the null hypotheses of unit coefficient restrictions on the foreign money supply (H_2) and the two interest rates (H_5) are accepted. On the other hand, the chi-square tests reject the remaining null hypotheses: the unit coefficient restriction of the domestic money supply term implied by the monetary approach (H_1); the identical (in absolute terms) coefficients of the two money supplies (H_3); and the two income levels (H_4). MacDonald and Taylor (1994) rationalized this seemingly mixed evidence by contending that the relationship between the exchange rate and monetary variables may not be as simple and direct as the basic flexible-price monetary approach suggests.

Table 2B. Restriction Tests of the Monetary Model

Null Hypothesis	Monetary Restrictions (Chi-Square)
H_1: $m = -1$	22.4*
H_2: $m^f = 1$	0.73
H_3: $m = -m^f$	11.26*
H_4: $y = -y^f$	5.75*
H_5: $i = -i^f$	0.06

Notes: * implies rejection of the null hypothesis at the 5% level.

The cointegration results have several implications. First, consistent with theory, the finding indicates that the monetary model provides a useful representation of the long-run behaviour of the bilateral dollar-yen exchange rates. Second, the evidence of cointegration also rules out the possibilities of spurious correlation and Granger non-causality between the exchange rate, relative money supplies, incomes, and interest rates.

(B) Test Results for Granger Causality

Following the Granger representation theorem, the above unit root and cointegration test results also imply that the dynamic modeling of variables embedded in the monetary model of the exchange rate has a valid error-correction representation with a cointegrating constraint embedded in them. The following VEC representation of the monetary model of the exchange rate is specified with a 2-period lag using the AIC criterion (see Choudhry, 2003):

$$\Delta Y_t = C + \sum_{i=1}^{2} \Gamma_i \Delta Y_{t-i} + \hat{\beta} u_{t-1} + \upsilon_t \ , \quad (8)$$

where $u_{t-1} = \alpha Y_{t-1}$ and $\hat{\beta}' = (1, -\hat{\beta}_1, -\hat{\beta}_2, -\hat{\beta}_3, -\hat{\beta}_4, -\hat{\beta}_5, -\hat{\beta}_6, -\hat{\beta}_7)$. The second term in model (8) represents the short-term dynamic interaction between exchange rates and monetary variables. The disequilibrium adjustment of each variable towards its long-run equilibrium value is represented by the lagged error-correction term u_{t-1}.

Table 3. Parameter Estimates of the Error-Correction Model*

Dependent Variable	e	m	m^f	y	y^f	i	i^f
Constant	5.933	−2.029	1.687	−0.601	0.251	−47.418	−3.210
	(−2.192)[b]	(−1.822)[c]	(3.440)[a]	(−1.018)	(0.614)	(−2.394)[a]	(−0.573)
Trend	0.00002	−0.00007	−0.00006	−0.0001	−0.0003	−0.002	−0.001
	(0.099)	(−1.014)	(−1.859)[c]	(−2.166)[b]	(−1.151)	(−1.181)	(−1.914)[a]
u_{t-1}	−0.065	−0.022	0.018	−0.007	0.003	−0.518	−0.035
	(−2.193)[b]	(−1.845)[c]	(3.418)[a]	(−1.041)	(0.597)	(−2.393)[a]	(−0.577)
Δe_{t-1}	0.287	0.005	−0.030	−0.031	−0.007	0.757	−0.240
	(2.809)[a]	(0.124)	(−1.624)[c]	(−1.383)	(−0.473)	(1.011)	(−1.132)
Δe_{t-2}	−0.159	−0.088	−0.021	−0.010	−0.027	1.183	−0.323
	(−1.459)	(−1.977)[b]	(−1.062)	(−0.423)	(−1.661)[c]	(1.487)	(−1.435)
Δm_{t-1}	0.090	−0.168	−0.069	−0.003	−0.058	−3.198	−0.156
	(0.396)	(−1.804)[c]	(−1.687)[c]	(−0.057)	(−1.685)[c]	(−1.929)[b]	(−0.333)
Δm_{t-2}	−0.016	0.026	0.005	0.010	0.013	−0.062	0.075
	(−0.073)	(0.285)	(0.131)	(0.207)	(0.392)	(−0.038)	(0.162)
Δm^f_{t-1}	0.161	−0.492	0.099	−0.032	−0.099	7.682	0.488
	(0.279)	(−2.067)[b]	(0.944)	(−0.250)	(−1.143)	(1.814)[c]	(0.407)
Δm^f_{t-2}	0.127	0.271	0.201	−0.123	−0.030	−0.138	−1.372
	(−0.236)	(1.226)	(2.067)[b]	(−1.045)	(−0.364)	(−0.035)	(−1.232)
Δy_{t-1}	−0.055	−0.156	0.050	−0.052	−0.004	4.685	−1.067
	(−0.108)	(−0.750)	(0.547)	(−0.474)	(−0.058)	(1.263)	(−1.016)
Δy_{t-2}	0.017	0.114	0.064	0.138	0.032	4.159	−0.653
	(0.035)	(0.563)	(0.720)	(1.277)	(0.429)	(1.151)	(−0.638)
Δy^f_{t-1}	−0.172	0.391	−0.062	0.073	0.320	2.869	1.771
	(−0.248)	(1.372)	(−0.495)	(0.482)	(3.059)[a]	(0.567)	(1.236)
Δy^f_{t-2}	−0.190	0.075	−0.073	0.107	0.158	0.665	2.147
	(−0.273)	(0.264)	(−0.580)	(0.703)	(1.511)	(0.131)	(1.494)
Δi_{t-1}	0.030	0.006	−0.004	0.005	−0.004	0.189	0.090
	(1.803)[c]	(0.859)	(−1.369)	(1.487)	(−1.421)	(1.537)	(2.560)[a]
Δi_{t-2}	0.009	−0.019	−0.001	0.001	−0.0009	0.039	−0.031
	(0.498)	(−2.444)[a]	(−0.197)	(−0.295)	(−0.318)	(−0.278)	(−0.784)
Δi^f_{t-1}	−0.073	−0.081	−0.041	0.003	0.006	0.616	0.328
	(−1.296)	(−3.514)[a]	(−3.992)[a]	(0.234)	(0.668)	(1.493)	(2.812)[a]
Δi^f_{t-2}	0.023	−0.018	0.013	−0.012	−0.024	0.247	−0.273
	(0.418)	(−0.791)	(1.297)	(−0.982)	(−2.829)[a]	(0.609)	(−2.381)[a]
R^2	0.089	0.307	0.557	0.023	0.141	0.195	0.223
DW	1.922	2.083	2.059	1.915	2.040	1.956	1.832
SE	0.051	0.021	0.009	0.011	0.007	0.375	0.106

Notes: Figures in parentheses are *t* ratios. [a], [b], and [c] imply significance at 1%, 5%, and 10% levels, respectively. DW and SE are the Durbin-Watson statistic and standard error of regression, respectively.

In model (8), the null hypothesis of non-causality from domestic money stock to the exchange rate is rejected if either the group of coefficients on the money stock variable (m) in the exchange rate equation is statistically significant or the coefficient of the lagged error-correction term is negative and statistically significant. The joint significance is tested with the aid of an F statistic while the significance of the error-correction term is evaluated with a t statistic. The VEC model is estimated by ordinary least squares and results are reported in Table 3.

Table 4 summarises the Granger causal relationship among the variables based on the VEC model. It is evident that the lagged error-correction term is negative and statistically significant in the exchange rate equation, which suggests that real incomes, money supplies, and interest rates exert independent influences on the exchange rate. The significance of the lagged error-correction term implies a long-term causality from all variables in the monetary model towards the exchange rate. The size of the coefficient of the error term (−0.065) shows that 6.5% of the adjustment towards the long-run equilibrium takes place per quarter. In addition to the long-run causality, the one-period lagged difference of the exchange rate and Japanese interest rate (i) is significant, implying the existence of short-term causality from these two variables to the left hand exchange rate variable. Among the remaining six equations, the error-correction term is negative and significant in the case of the Japanese money supply (m) and interest rate (i). In the case of the US money supply equation, the US one-period lagged difference interest rate and Japanese money supply have a short-term causal relationship. In the Japanese money supply equation, the two-period lagged difference exchange rate, the one-period lagged difference of the US money supply and interest rate, and the two-period lagged difference of the Japanese interest rate have a short-term causal relationship. The lagged error-correction term is negative and statistically significant in the Japanese interest rate equation, which suggests that the exchange rate (e), real income (y), money supplies (m), and the US interest rate (i^f) exert independent influences on the Japanese interest rate. The F statistic in Table 4 indicates that the US interest rate induces a movement in the US money supply; the US and Japanese interest rates induce a movement in the Japanese money supply; the US interest rate induces a movement in the US real income (y^f); and the US real income and Japanese interest rate induce a movement in the US interest rate.

Finally, we test for the adequacy of the estimated model by assessing its out-of-sample forecasting performance. The ECM model is estimated from the first quarter of 1974 through the last quarter of 2000. The estimated equation is then used to forecast the exchange rate for four forecasting horizons, i.e., one, two, three, and four quarters ahead over the period from the first quarter of 2001 to the last quarter of 2002. The forecasts are fully dynamic in that the estimated values of the level of the exchange rate are incorporated back into the model. This procedure is pursued for all remaining observations and root mean square error (RMSE) statistics are estimated over the four forecasting horizons. As a comparison, forecasts are also made with two alternative models—a simple random walk and a simple random walk with drift. The results are reported in Table 5. In all cases, the estimated error-correction model clearly outperforms the random walk models across the forecasting horizons.

Table 4. Temporal Causality Results based on VECM

Independent Variable	u_{t-1}	e	m	m^f	y	y^f	i	i^f
e	−0.0649	4.4358	0.0949	0.0564	0.0071	0.0963	1.6317	0.8685
	(−2.1927)	(0.0143)	(0.9095)	(0.9452)	(0.9929)	(0.9082)	(0.2009)	(0.4228)
m	−0.0224	1.9943	1.8887	2.4400	0.4745	1.1205	3.9467	6.8992
	(−1.8484)	(0.1417)	(0.1568)	(0.0925)	(0.6236)	(0.3303)	(0.0225)	(0.0016)
m^f	0.0183	2.2555	1.5341	3.1511	0.3706	0.3915	0.9376	8.3529
	(3.4180)	(0.1103)	(0.2208)	(0.0472)	(0.6913)	(0.6771)	(0.3951)	(0.0044)
y	−0.0067	1.1800	0.0326	0.6704	1.0043	0.4847	1.2931	0.4926
	(−1.0405)	(0.3116)	(0.9679)	(0.5139)	(0.3700)	(0.6173)	(0.2791)	(0.6125)
y^f	0.0026	1.6903	1.7327	0.8437	0.0958	7.5360	1.0128	4.0067
	(0.5964)	(0.1898)	(0.1822)	(0.4333)	(0.9087)	(0.0009)	(0.3670)	(0.0213)
i	−0.5182	1.9357	1.8988	1.7002	1.3124	0.2000	1.3623	1.4216
	(−2.3930)	(0.1499)	(0.1553)	(0.1880)	(0.2739)	(0.8191)	(0.2609)	(0.2463)
i^f	−0.0354	2.0066	0.0827	0.7586	0.6466	2.5174	4.1298	5.9947
	(−0.5777)	(0.1400)	(0.9207)	(0.4711)	(0.5261)	(0.0859)	(0.0190)	(0.0035)

Notes: u_{t-1} signifies the lagged error-correction term; corresponding t statistics are in parentheses. Marginal significance levels are in parentheses for other variables.

Table 5. RMSE Statistics for Three Models for All Forecasting Horizons

Models\Forecast horizon	Quarter 1	Quarter 2	Quarter 3	Quarter 4
ECM monetary model	0.040	0.037	0.038	0.038
Random walk with drift	0.049	0.051	0.056	0.055
Random walk	0.047	0.052	0.058	0.056

5. Conclusion

In this paper we reappraise the empirical validity of the monetary model of the exchange rate using cointegration and vector error-correction modeling techniques in an attempt to discern the relationships in the US dollar-Japanese yen exchange rate from first quarter 1974 through first quarter 2003. Our period of study encompasses a longer period than previous research to reflect use of the monetary model as a long-run model of exchange rates. This period has coincidentally and characteristically witnessed continued depreciation of the dollar against the yen accompanied by burgeoning US trade deficits. Therefore, our results have implications to approximate the behaviour of the bilateral dollar-yen exchange rate movements in light of market fundamentals as incorporated in the monetary model.

Starting with simple and transparent flexible price and money demand functions, we derive an unrestricted version of the monetary model that subsumes relative money supplies, incomes, and interest rates of domestic and foreign countries as the proximate determinates of the exchange rate. Using the maximum likelihood procedure of Johansen and Juselius (1990), we identify a unique cointegrating vector that indicates a stationary long-run relationship between bilateral dollar-yen exchange rates and proximate determinants of the monetary model. There is also some evidence in favour of the monetary model based on restriction tests, namely, the unit coefficient restriction on the US money supply and the identical coefficient of the US and the Japanese interest rates. The VEC model indicates that about 6.5% of the dynamic adjustment took place every quarter for the exchange rate to revert to its long-term equilibrium value. The VEC model further corroborates a long-run causality running from the relative money supplies, incomes, and interest rates to the bilateral exchange rate. In addition, there is a short-term causality which is running from the one-period lagged difference exchange rate and the Japanese interest rate to the exchange rate variable. Finally, we evaluate the predictive performance of the unrestricted monetarist model which has shown that the forecasting performance of the monetary approach based on the error-correction model outperforms the random walk models at every forecast horizon. Overall, our results broadly confirm the empirical validity of the monetary model as a long-run explanation of the nominal dollar-yen exchange rate. Notwithstanding the dismal performance of the monetary model of exchange rate determination during the 1980s and early 1990s, our results are consistent with MacDonald and Taylor (1991), Moosa (1994), Choudhry and Lawler (1997), Francis et al. (2001), and others. Thus, our reappraisal not only constitutes a wider acceptance of the monetary model of exchange rate determination, it also contributes to a general reinforcement of the adequacy of the model in explaining the behaviour of the dollar-yen exchange rate relationship.

References

Akaike, H., (1969), "Fitting Autoregression for Prediction," *Annals of the Institute of Statistical Mathematics*, 21, 243-247.

Backus, D., (1984), "Empirical Models of the Exchange Rate: Separating the Wheat from the Chaff," *Canadian Journal of Economics*, 17, 824-846.

Baillie, R. T. and D. D. Selover, (1987), "Cointegration and Models of Exchange Rate Determination," *International Journal of Forecasting*, 3, 43-51.

Bilson, J. F. O., (1978) "Rational Expectations and the Exchange Rate," in *The Economics of Exchange Rates*, J. Frenkel and H. G. Johnson eds., Reading, Massachusetts: Addison Wesley.

Boothe, P. and D. Glassman, (1987), "Off the Mark: Lessons for Exchange Rate Modeling," *Oxford Economic Papers*, 39, 443-457.

Boughton, J., (1988), “The Monetary Approach to Exchange Rates: What Now Remains?” *Princeton Studies in International Finance*, No. 171, Princeton, New Jersey: Princeton University Press.

Choudhry, T., (2003), “Stock Market Volatility and the US Consumer Expenditures,” *Journal of Macroeconomics*, 25(3), 367-385.

Choudhry, T. and P. Lawler, (1997), “The Monetary Model of Exchange Rates: Evidence from the Canadian Float of the 1950s,” *Journal of Macroeconomics*, 19(2), 349-362.

Diamandis, P. F., D. A. Georgoutsos and G. P. Kouretas, (1998), “The Monetary Approach to the Exchange Rate: Long-Run Relationships, Identification and Temporal Stability,” *Journal of Macroeconomics*, 20(4), 741-766.

Dornbusch, R., (1979), “Monetary Policy under Exchange Rate Flexibility,” in *Managed Exchange-Rate Flexibility: The Recent Experience*, Federal Reserve Bank of Boston Conference Series, No. 20, Boston: Federal Reserve Bank of Boston.

Dornbusch, R., (1980), “Exchange Rate Economics: Where Do We Stand?” *Brookings Papers on Economic Activity*, 2, 143-185.

Driskill, R. A. and S. M. Sheffrin, (1981), “On the Mark: Comment,” *American Economic Review*, 71(5), 1068-1074.

Engle, R. F. and C. W. J. Granger, (1987), “Co-Integration and Error Correction: Representation, Estimation, and Testing,” *Econometrica*, 55(2), 251-276.

Engle, R. F. and C. W. J. Granger, (1991), *Long-Run Economic Relationships: Readings in Cointegration*, Oxford: Oxford University Press.

Francis, B., I. Hasan and J. R. Lothian, (2001), “The Monetary Approach to Exchange Rates and the Behaviour of the Canadian Dollar over the Long Run,” *Applied Financial Economics*, 11(5), 475-481.

Frenkel, J. A., (1976), “A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence,” *Scandinavian Journal of Economics*, 78, 200-224.

Frenkel, J. A. and H. G. Johnson, (1976), *The Monetary Approach to the Balance of Payments*, London: Allen and Unwin.

Frenkel, J. A., (1984), “Tests of Monetary and Portfolio Balance Models of Exchange Rate Determination” in *Exchange Rate Theory and Practice*, J. F.O. Bilson and R. C. Marston eds., Chicago: University of Chicago Press.

Gregory, A. W. and B. E. Hansen, (1996), “Residual-Based Tests for Cointegration in Models with Regime Shifts,” *Journal of Econometrics*, 70, 99-126.

Groen, J. J. J., (2002), “Cointegration and the Monetary Exchange Rate Model Revisited,” *Oxford Bulletin of Eonomics and Statistics*, 64, 361-380.

Hargreaves, C., (1994), *Nonstationary Time Series Analysis and Cointegration*, New York: Oxford University Press.

Haynes, S. E. and J. A. Stone, (1981), “On the Mark: Comment,” *American Economic Review*, 71(5), 1060-1067.

Husted, S. and R. MacDonald, (1998), "Monetary-Based Models of the Exchange Rate: A Panel Perspective," *Journal of International Financial Markets, Institutions and Money*, 8, 1-19.

Jeong, J., (2000), "What Drives Exchange Rates? The Case of the Yen/Dollar Rate," *Multinational Business Review*, 8(2), 31-36.

Johansen, S. and K. Juselius, (1990), "Maximum Likelihood Estimation and Inference on Cointegration-with Applications to the Demand for Money," *Oxford Bulletin of Economics and Statistics*, 52, 169-210.

Johansen, S. and K. Juselius, (1992), "Testing Structural Hypotheses in a Multivariate Cointegration Analysis of the PPP and the UIP for UK," *Journal of Econometrics*, 53, 211-244.

Kearney, C. and R. MacDonald, (1990), "Rational Expectations, Bubbles and Monetary Models of the Exchange Rate: The Australian/US Dollar Rate During the Recent Float," *Australian Economic Papers*, 29, 1-20.

Lucas, R. E. Jr., (1982), "Interest Rates and Prices in a Two-Country World," *Journal of Monetary Economics*, 10, 335-360.

Luintel, K. B. and M. Khan, (1999), "A Quantitative Reassessment of the Finance-Growth Nexus: Evidence from a Multivariate VAR," *Journal of Development Economics*, 60, 381-405.

Lutkepohl, H., (1982), "Non-Causality Due to Omitted Variables," *Journal of Econometrics*, 19, 367-378.

MacDonald, R. and M. P. Taylor, (1991), "The Monetary Approach to the Exchange Rate: Long-Run Relationships and Coefficients Restrictions," *Economics Letters*, 37(2), 179-185.

MacDonald, R. and M. P. Taylor, (1992), "Exchange Rate Economics: A Survey," *IMF Staff Papers*, 39(1), 1-57.

MacDonald, R. and M. P. Taylor, (1994), "The Monetary Model of the Exchange Rate: Long-Run Relationships, Short-Run Dynamics and How to Beat a Random Walk," *Journal of International Money and Finance*, 13(3), 276-290.

McMillin, W. D., (1991), "The Velocity of M1 in the 1980s: Evidence from a Multivariate Time Series Model," *Southern Economic Journal*, 57, 634-648.

McNown, R. and M. Wallace, (1989), "Cointegration Tests for Long Run Equilibrium in the Monetary Exchange Rate Model," *Economics Letters*, 31, 263-267.

McNown, R. and M. Wallace, (1994), "Cointegration Tests of the Monetary Exchange Rate Model for Three High-Inflation Economies," *Journal of Money, Credit, and Banking*, 26(3), 396-410.

Meese, R. A. and K. Rogoff, (1983), "Empirical Exchange Rate Models of the Seventies: Do They Fit Out-of-Sample?" *Journal of International Economics*, 14, 3-24.

Meese, R. A., (1986), "Testing for Bubbles in Exchange Markets: A Case of Sparkling Rates?" *Journal of Political Economy*, 94, 345-373.

Miyakoshi, T., (2000), "The Monetary Approach to the Exchange Rate: Empirical Observations from Korea," *Applied Economics Letters*, 7, 791-794.

Moersch, M. and D. Nautz, (2001), "A Note on Testing the Monetary Model of the Exchange Rate," *Applied Financial Economics*, 11, 261-268.

Moosa, I. A., (1994), "The Monetary Model of Exchange Rates Revisited," *Applied Financial Economics*, 4(4), 279-287.

Ohno, K., (1989), "Testing Purchasing Power Parity and the Dornbusch Overshooting Model with Vector Autoregression," *Journal of the Japanese and International Economies*, 3(2), 209-226.

Osterwald-Lenum, M., (1992), "A Note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics: Four Cases," *Oxford Bulletin of Economics and Statistics*, 54, 461-472.

Paruolo, P., (1996), "On the Determination of Integration Indices in I(2) Systems," *Journal of Econometrics*, 72, 313-356.

Rasula, J. A. and D. S. Wilford, (1980), "Estimating Monetary Models of the Balance of Payments and Exchange Rates: A Bias," *Southern Economic Journal*, 47(1), 136-146.