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Research Article

Exchange Rates and Monetary Fundamentals: What Do We Learn from Linear and Nonlinear Regressions?

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This paper revisits the association between exchange rates and monetary fundamentals with the focus on both linear and nonlinear approaches. With the monthly data of Euro/US dollar and Japanese yen/US dollar, our linear analysis demonstrates the monetary model is a long-run description of exchange rate movements, and our nonlinear modelling suggests the error correction model describes the short-run adjustment of deviations of exchange rates, and monetary fundamentals are capable of explaining exchange rate dynamics under an unrestricted framework.

1. Introduction

The association between exchange rates and monetary fundamentals is specifically described in the flexible-price monetary model. See Dornbusch [1], Frankel [2], and Mussa [3]. The monetary model has been the workhorse of the exchange rate determination. However, since the study of Meese and Rogoff [4], the disconnection between exchange rates and macroeconomic fundamentals has been a strong consensus that the monetary model poorly explains exchange rate movements particularly over short-run horizon. Since then, researchers have been searching for more sophisticated approaches to modelling exchange rate movements with macroeconomic fundamentals. Generally there are two views to the poor performance of macroeconomic models. One is that standard theoretical economic models, such as purchasing power parity (PPP), monetary demand, uncovered interest parity (UIP), and monetary models, are inadequate. The other one argues that nonlinearity is possibly hidden in the relationship that usual linear specifications cannot obtain satisfactory results in empirical studies. Broadly speaking, there are five strands of literatures linking exchange rates to macro fundamentals in nonlinear channels. The first strand allows nonlinear formulation of variables in linear models, which use nonparametric methods to construct the data to fit a linear model. See Meese and Rose [5]. The second strand explains short-run nonlinear adjustment of exchange rates in an error correction model (ECM) which is based on a long-run cointegration relationship between exchange rates and macrofundamentals. See series studies by MacDonald and Taylor [6] and MacDonald and Marsh [7]. The third strand adopts threshold approaches, which assume the mean-reverting property of exchange rates, to capture the long-term stable influences and short-term dynamics. See Kilian and Taylor [8]. The fourth strand literatures assume that coefficients may be time-varying. The idea is based on Hendry and Clements [9]. The fifth strand is to apply the Markov switching method to the association between exchange rates and monetary fundamentals. With Markov-switching methods, Frömmel et al. [10] found the empirical evidence to the real interest differential model of Frankel [2]. Using the same approach, Grauwe and Vansteenkiste [11] test the relationship between the change in the nominal exchange rate and the change in corresponding macroeconomic fundamentals (the change in the nominal exchange rate is defined as $\Delta e_t = e_t - e_{t-1}$. The change in macroeconomic fundamentals, Δf_t, stems from the specification $f_t = \alpha_1(p_t - p_t^*) + \alpha_2(i_t - i_t^*) + \alpha_3(m_t - m_t^*)$, where p_t, i_t, and m_t denote, respectively, domestic price, long-term interest, and money supply. Asterisk represents the foreign variables). Grauwe and Vansteenkiste examine both the low inflation and high inflation countries and their analysis shows that, for high inflation countries, there is stable relationship between the news in fundamentals and the exchange rate changes while not for the low inflation countries due to the frequent regime switches.

We revisit the association between exchange rates and monetary fundamentals and examine both the long-run association and the short-run dynamics. In particular, with different nonlinear approaches, we centre on investigating nonlinear relations between exchange rates and monetary fundamentals. First, we use the error correction framework obtained from the long-run cointegration relationship to model the short-run deviation from the long-run steady-state values. Second, we use threshold methods to examine the possible regime changes in the system built by exchange rates and monetary fundamentals. Third, we use nonparametric methods to examine the explanation power of monetary fundamentals on exchange rates without directly specifying the nonlinearity in the models. In the primary long-run cointegration study the results demonstrate that the monetary model is a long-run description of exchange rate movements, which is consistent with the studies conducted by relevant literatures which adopt panel data techniques or use longer time series. The forecasting experiments of the error correction model show the short-run deviation model can outperform the random walk process. Over the same sample period, the nonparametric modelling indicates that the monetary fundamentals can explain the exchange rate movements and the forecasting ability outperforms the simple random walk process over most forecasting horizons. In contrast, our study of threshold approaches does not find convincing supports to the monetary exchange rate model.

Our study specifically investigates the relationship between the exchange rate Japanese yen/US dollar and Euro/US dollar and a vector of explanatory variables specified in the monetary model of exchange rates. Since the birth of Euro in 1999, the priority of international currencies, ranked according to their relative values to one other, has been completely turned over, within which the Euro is consistently ranked 1st. Meanwhile, in the foreign exchange market, the first three of the most traded currencies by value are United States dollar (USD), Euro (EUR), and Japanese yen (JPY), and we believe the two exchange rate pairs (Japanese yen/US dollar and Euro/US dollar) are typical representatives to conduct our empirical data analysis. Our study is distinct from other relevant studies, both methodologically and temporally. First, we intensively examine possible nonlinearities involved in the association between exchange rates and macroeconomic fundamentals with three different nonlinear methods, which are error correction model (ECM), threshold methods, and nonparametric methods. The error correction model is used to investigate the short-run adjustment of the deviation from long-run exchange rates, which is based on the long-run cointegration relationship between exchange rates and monetary fundamentals. The long-run steady relationship has been extensively identified by relevant studies. Threshold methods have been used to investigate the deviation of exchange rates from its long-run PPP values or monetary fundamental values. For two typical studies, see Killian and Taylor [8] and Sarno et al. [12]. We are among the pioneers to use threshold methods to directly investigate the association between exchange rates and monetary fundamentals. We adopt the nonparametric method to explain the association between exchange rates and monetary fundamentals without imposing any restrictions on the coefficients. Instead of estimating concrete parameters, with nonparametric methods, we emphasize the explanation power of the monetary fundamentals on exchange rates. Meese and Rose [5] use a nonparametric method to investigate monetary models while they impose homogeneities for the corresponding domestic and foreign series. Second, we use the Johansen cointegration procedure to examine the long-run association between exchange rates and monetary fundamentals. The long run cointegration is handled by the Johansen cointegration procedure, instead of the residual based cointegration test of Engle and Granger [13]. The two-step cointegration method of Engle and Granger [13] has low power when detecting a dormant long-run relationship and is criticized in view of its inference-making limitation. Moosa [14], and MacDonald and Taylor [15] argue that many of the studies done during the late 1980s and early 1990s using cointegration to test the monetary model and fail to reject the null hypothesis of no cointegration is because of the inappropriate test method, for example, the Engle-Granger method. Furthermore, in the cointegration analysis, we correct the small sample bias of the Trace test and examine the usual coefficient restrictions automatically imposed in relevant practical studies. Third, the dataset used in the empirical study is more recent and covers a wider span of time period from 1973 to 2007 for Japanese yen and from 1999 to 2007 for Euro, which secure an efficient parameter estimation. It is also worth mentioning that we examine the exchange rate concerning the new international currency Euro which has not been intensively examined so far due to the short observations.

This paper is set out as follows. Section 2 briefly presents the theoretical issue; Section 3 describes the dataset used in the empirical study; Section 4 examines the long-run association between exchange rates and macrofundamentals; Section 5 investigates the nonlinearity of exchange rate determination from three different aspects. In Section 6, we conclude this paper.

2. Theoretical Issues

We aim to examine the flexible-price monetary model on the exchange rates of Japanese yen/US dollar and Euro/US dollar. The flexible-price monetary model of Mussa [3] and Frenkel [16] contains three blocks: uncovered interest parity (UIP), stable money demand functions in the domestic and foreign countries, and purchasing power parity (PPP). Assuming uncovered interest parity (UIP) and rational expectations,

$$i_t - i_t^* = \Delta e_{t,t+1}^e \equiv E_t e_{t+1} - e_t, \quad (1)$$

where i_t is the long-term interest rate and e_t is the nominal exchange rate, which is defined as the domestic price of the foreign currency. Asterisk variables denote the foreign variables. E_t denotes the expectation at time t. Purchasing power parity (PPP) indicates

$$e_t = p_t - p_t^*, \tag{2}$$

where p_t denotes the consumer price index (CPI-based price). Combining money demand with money market equilibrium in the two countries, we have

$$\begin{gathered} M^d = Y^a \exp^{-\beta i}, \\ m_t - p_t = a y_t - \beta i_t, \\ m_t^* - p_t^* = a^* y_t^* - \beta^* i_t^*, \end{gathered} \tag{3}$$

where money demand equation M^d denotes the money demand of Cagan [17] style. m_t denotes the money supply (logarithm format). Combining all hypotheses above, we have

$$e_t = m_t - m_t^* - \alpha y_t + a^* y_t^* + \beta i_t - \beta^* i_t^*. \tag{4}$$

Most empirical studies examine the specifications as follows:

$$e_t = \beta_0 + \beta_1 \left(m_t - m_t^*\right) + \beta_2 \left(y_t - y_t^*\right) + \beta_3 \left(i_t^l - i_t^{l*}\right) + \varepsilon_t. \tag{5}$$

If we relax the coefficients restrictions, we obtain a more general specification specified as below:

$$e_t = \alpha_0 + \alpha_1 m_t + \alpha_2 m_t^* + \alpha_3 y_t + \alpha_4 y_t^* + \alpha_5 i_t^l + \alpha_6 i_t^{l*} + \varepsilon_t, \tag{6}$$

where the αs are the parameters to be estimated. The hypothesized values of α_1 and α_2 would be close to the restriction $\alpha_1 = -\alpha_2 = 1$, which indicates the standard monetary model. α_3 and α_4 should take on values which are close to the estimated income elasticity from money demand functions. α_5 and α_6 should take on values which are close to interest rate semielasticity from the demand for money. We relax the coefficient restrictions because relevant empirical studies such as MacDonald and Taylor [6, 18] and La Cour and MacDonald [19] suggest that the restrictions usually do not hold in the long-run cointegration association.

3. Data Description

Our empirical analysis uses monthly data concerning three mature economies including Japan, the United States, and the Euro area. Due to the data availability for the same series, our sample sizes vary for the two exchange rate pairs: for Euro/US dollar, the sample covers the period over January 1999 to June 2007 and for Japanese yen/US dollar the sample covers the period over January 1973 to August 2007 (increasing the sample up to date would be interesting but we see this as a separate paper as the issues imparted by the economic and financial crisis would have to be handled appropriately due to the extent and length of the crisis. Particularly, quantitative easing needs to be considered when the sample covers the recent economic and financial period.). The datasets come from International Money Fund (IMF) international financial statistics (IFS) online database. We choose the following series for our practical studies: RF.ZF for the exchange rates which represent the period average of the market rate; 61..ZG for the long-term government bond yield which is used to proxy the inflation effect; we use the industry production series 66..CZF to proxy the national production; for money supply, relevant literatures usually adopt the M2 as the proxy variable. We use 59MBC ZF M2 for U.S.A, 59MBUZW M2 for Euro Area, and 34..BZF for Japan.

In the empirical analysis, all the variables take logarithm format except the interest rates. For the variables used in the threshold models, we adopt different measures for the series. We focus on the change in the exchange rates and changes in the corresponding macro fundamentals. We calculate the difference of the percentage change during the last 12 month in the home country versus the percentage for the same horizon in the United States. As suggested by Frömmel et al. [10], this approach is adopted for two reasons. First, this approach avoids seasonal effects in the data and reduces the noise from short-term movements in exchange rates and the fundamentals. Therefore, this approach provides more stable results. Second, statistical offices and central banks commonly apply year to year changes to smooth the time series for growth rates of fundamentals to focus on their trend behaviour. We apply yearly changes to the exchange rate to achieve comparable data. The exchange rate change Δe_t is calculated as follows:

$$\Delta e_t = \frac{\left(e_t - e_{t-12}\right)}{e_{t-12}}, \tag{7}$$

and the corresponding contemporaneous monetary fundamentals are constructed as follows:

$$\Delta m_t = \frac{\left(m_t - m_{t-12}\right)}{m_{t-12}} - \frac{\left(m_t^* - m_{t-12}^*\right)}{m_{t-12}^*}. \tag{8}$$

Our empirical analysis centres on two empirical aspects. First, we examine whether there exists a long-run association between the exchange rate e_t and the monetary fundamentals including the money supply m_t, interest rate i_t, and production y_t, which are all measured as the level values. We investigate the long-run issue by the Johansen cointegration procedure. Second, we examine the nonlinearity involved in the association between exchange rates and monetary fundamentals. Sequentially, we investigate the nonlinearities with the error correction models derived from the long-run cointegration association, threshold models, and nonparametric models.

4. Long-Run Association

We firstly investigate the long-run equilibrium relationship between exchange rates and monetary fundamentals under the frame of the flexible-price monetary model. The descriptive statistics for the two pairs of exchange rates and macroeconomic fundamentals are reported in Table 1. The long-run analysis is the basis of the short-run error analysis conducted

Table 1: Descriptive statistics of exchange rates and macroeconomic fundamentals.

	Mean	Medium	Maximum	Minimum	Std. dev
Case of JPY/USD					
e_t (JPY/USD)	5.069925	4.902263	5.722604	4.426851	0.374557
y_t	4.399726	4.517532	4.700580	3.833945	0.231705
m_t	4.905912	4.832266	6.087354	3.588169	0.688862
i_t^l	4.845315	4.730000	10.30000	0.530000	2.864049
Case of RUR/USD					
e_t (EUR/USD)	−0.093723	−0.114816	0.158848	−0.328865	0.148013
y_t	4.624312	4.615279	4.737452	4.531767	0.044273
m_t	8.630551	8.649616	9.184298	8.182951	0.306038
i_t^l	4.444783	4.339600	5.698500	3.155500	0.661929
United States					
y_t	4.228155	4.187961	4.692934	3.758084	0.270884
m_t	7.921690	8.069718	8.885856	6.697405	0.607044
i_t^l	7.637215	7.390000	15.32000	3.330000	2.581466

Note: all the variables, exchange rate e_t, GDP y_t, and money supply m_t take logarithm formats except the inflation (i_t^l).

in the following subsection. The unrestricted specification of the long-run relationship between the exchange rate and the monetary fundamentals is specified in (6) as follows:

$$e_t = f\left(m_t, m_t^*, y_t, y_t^*, i_t^l, i_t^{l*}\right) + \varepsilon_t. \tag{9}$$

4.1. Unit Root Tests. We use the augmented Dickey and Fuller [20] unit root test to investigate the stationarity of the variables concerned. Table 2 demonstrates the unit root test results for the series concerned in our analyses. We report the test statistics for the cases of constant only and constant and trend in mean. We also test the unit roots for the series relative money supply ($m_t - m_t^*$), relative long-term interest rate ($i_t^l - i_t^{l*}$), and relative output ($y_t - y_t^*$). According to the results reported in Table 2, all of the variables appear to be $I(1)$ nonstationary variables, which means all the variables concerned in (6) are all nonstationary at levels while they are all stationary on first-difference. Thus, we have to use cointegration technique to examine the long-run association between these variables at levels. In the next subsection, we test the cointegration association between the nominal exchange rates and the monetary fundamentals. We assume the existence of cointegration vectors among these series and use Johansen likelihood ratio (LR) test to implement the tests [21, 22].

4.2. VAR Estimation and Cointegration Tests. As the cointegration analysis is based on an unrestricted VAR estimation, we firstly specify a vector autoregressive (VAR) model with nonzero intercepts and linear trends in the VAR specifications. The VAR models also include dummy variables to control for the presence of outliers. The choice of the leg length of the VAR is based on the Akaike information criteria (AIC) and we increase the lag length if the residuals are not whitened. The diagnostics tests for the VAR estimation results are reported in Table 3. Table 3 also reports the tests of autocorrelation, heteroskedasticity, and normality for the residuals. The multivariate LM autocorrelation tests indicate no autocorrelation in the residuals. In the case of Japanese yen/US dollar, the multivariate normality is clearly violated. Gonzalo [23] shows the performance of the maximum likelihood estimator of the cointegrating vectors is little affected by nonnormal errors. The Heteroskedasticity White tests accept the null hypothesis of no heteroskedasticity for the cases of Japanese yen and Euro. Moreover, Hansen and Rahbek [24] show that the cointegration estimates are not very sensitive to the heteroskedasticity effects in the residuals.

To obtain the cointegrating vector, we need to identify the intercept and the trend items in the cointegration analysis. Franses [25] analyzes the issue how to deal with the intercept and the trend in the practical cointegration analysis. Franses summarizes that there are two relevant representations for testing cointegration among most economic time series variables: one option is that there is an intercept in cointegrating relations but no trend in the cointegrating vector. The other option is that both intercept and trend are included in the cointegrating relations and no trend included in the VAR model. The second option is recommended when some series display trend stationary patterns. Considering no trend stationary process is involved in the series in our samples, we choose the first option.

To determine the number of cointegrating vector, we investigate the small sample correction factor of Johansen [26] to secure a correct test size. Cheung and Lai [27] and Gonzalo and Pitarakis [28] investigate the application of the Johansen procedure and conclude that, for small samples with too many variables or lags, the Johansen procedure tends to overestimate the number of cointegrating vectors. Omtzigt and Fachin [29] recently argue that small sample procedures appear to be an absolutely necessary addition to the toolkit of the econometrician working with nonstationary data. Omtzigt and Fachin [29] find that Bartlett-corrected

Table 2: Tests for a unit root in the data (cases of Japanese Yen, Euro, and USD).

	Level τ_μ	1st difference τ_μ	Level τ_τ	1st difference τ_τ
Series of Japan				
e_t	−1.3416 (1)	−14.9005	−2.0221 (1)	−14.8891
m_t	−1.1734 (1)	−17.7209	−2.4466 (1)	−17.7323
i_t^l	−0.9227 (1)	−17.4226	−3.2437 (1)	−17.4092
y_t	−1.0425 (4)	−6.6203 (3)	−1.9428 (4)	−6.6082 (3)
Series of Euro				
e_t	−0.6179 (1)	−6.9884 (1)	−2.6649 (1)	−7.1396 (1)
m_t	0.4878 (1)	−7.1413 (1)	−2.7195 (1)	−7.3862 (1)
i_t^l	−0.4614	−4.8391	−2.7454	−4.8819
y_t	0.1200 (1)	−14.8930	−0.8067 (1)	−14.8496
Series of U.S				
m_t	−2.6023 (1)	−6.5572 (2)	−1.9671 (1)	−10.6130
i_t^l	−1.1840 (2)	−15.0646 (1)	−2.4952 (2)	−15.0928 (1)
y_t	0.2095 (2)	−9.3949 (1)	−2.9683 (3)	−9.4207 (1)

Notes: the symbols e_t, m_t, i_t^l, and y_t denote, respectively, the spot exchange rate, the money supply, the long-term interest rate, and industrial production. The asterisk variables denote the foreign variables (see the text for data source and exact definitions). The reported numbers in the columns are the Dickey-Fuller statistics for the null hypothesis. τ_μ is the test statistic allowing for only constant in mean and τ_τ is the test statistic allowing for both constant and trend in mean. The numbers in parenthesis after these statistics indicate the lag length used in the autoregression, determined by the Schwarz information criterion. For the test statistics, the null hypothesis is that the series in question is $I(1)$.

Table 3: Misspecification tests of the VAR estimations.

	Euro/USD	Yen/USD
Autocorrelation LM Tests LM (1)	0.1209	0.2726
LM (4)	0.2625	0.9846
LM (8)	0.8715	0.9369
Heteroskedasticity White test	0.4301	0.2817
Normality test	0.0580	0.000

Notes: autocorrelation tests (LM (1), LM (4), and LM (8)) denote multivariate Godfrey [43] Lagrange multiplier (LM) type test for the first, fourth, and eighth order autocorrelations; the numbers reported are the P values for the corresponding test statistics; heteroskedasticity test denotes White [44] type test, P value is reported; normality test denotes the Jarque-Bera type test, P value is reported.

factor could be one of the procedures to correct small sample size bias. The Bartlett corrected trace test is computed using SVAR 0.45 (http://www.texlips.net/svar/).

Table 4 summarizes the cointegration test results with the Johansen procedure. We report both the trace test statistic and the trace test statistic adjusted for small sample of Johansen [26]. For the cases of Japanese yen and Euro, the results are supportive to the long-run validity of the monetary model. On the basis of the trace statistics, we may reject the hypothesis that there are no cointegrating vectors. The trace tests and Bartlett adjusted tests reject, for the case of of Japanese yen, the null hypothesis for $r \le 0$, $r \le 1$, $r \le 2$, and $r \le 3$ and reject the null hypothesis for $r \le 0$, $r \le 1$, and $r \le 2$ for the case of Euro. Thus, it appears that there are up to four statistically significant cointegrating vectors among the exchange rates and monetary fundamentals for the case of Japanese Yen and three cointegrating vectors for the case of Euro. One of the cointegrating vectors concerns the monetary model and the other could be money demand equations.

4.3. Coefficient Restriction Tests. Having justified the existence of the cointegration association between exchange rates and monetary fundamentals, we are to identify the cointegration relation. Pesaran and Shin [30] criticize the Johansen identification approach is purely a mathematical approach and advocate using the theory-guided approach to identify cointegrating vectors. In practice, the cointegration analysis emphasizes the use of relevant economic theories in the search for a long-run association [30]. The theory-guided approach takes Johansen's just identified vector β_J as given and replaces the "statistical" restrictions with the ones that are economically meaningful. Specifically, this approach usually imposes exclusion and normalization restrictions to identify the specification and then use x^2 statistics to test restrictions.

For our monetary exchange rate model, the most common and perhaps the most important restriction is to test whether there is proportionality between relative monies and the exchange rate. Researchers also test the equal and opposite coefficients restricted on the income and long-term interest rate. Table 5 summarizes several commonly imposed restrictions on the specification of monetary models given as (6). Table 5 reports the corresponding restriction test results.

In Table 5, the hypothesis H_1, $\beta_1 = -\beta_2 = 1$, is the hypothesis of a unit coefficient for money supplies. The hypothesis H_2, $\beta_3 = -\beta_4$, imposes homogeneity on incomes. Panel studies of Rapach and Wohar [31] and Groen [32] find the supportive empirical evidence. Mark [33] and Mark and Sul [34] examine the monetary model specified as $e_t = c + (m_t - m_t^*) + (y_t - y_t^*) + \varepsilon_t$ and they find supportive evidence. The hypothesis H_3, $\beta_5 = -\beta_6$, restricts equal magnitudes and opposite signs on the coefficients of interest rates. In the recent empirical literatures, these seven restrictions reported in Table 5 are usually rejected in empirical time series studies. MacDonald and Taylor [15] find

Table 4: Results of Johansen maximum likelihood estimation (cases of Japanese Yen and Euro).

	Trace test		Trace test (Bartlett corrected)	
	Test stat	5% critical	Test stat	5% critical
Japanese yen				
$r \leq 0$	150.7413*	125.6154	150.6390*	119.0333
$r \leq 1$	110.2436*	95.75366	109.8840*	90.6879
$r \leq 2$	73.20739*	69.81889	71.3363*	65.6812
$r \leq 3$	48.81493*	47.85613	47.0563*	44.7681
$r \leq 4$	26.41220	29.79707	26.9663	27.8897
$r \leq 5$	7.910242	15.49471	8.9030	14.5554
$r \leq 6$	0.008857	3.841466	0.0046	3.8415
Euro				
$r \leq 0$	148.0000*	125.6154	146.3251*	121.2331
$r \leq 1$	105.8670*	95.75366	104.0291*	90.9609
$r \leq 2$	70.55259*	69.81889	68.6458*	67.0571
$r \leq 3$	45.33103	47.85613	43.0012	44.4335
$r \leq 4$	21.03687	29.79707	22.4194	29.2753
$r \leq 5$	7.290067	15.49471	6.9106	14.975
$r \leq 6$	0.264802	3.841466	0.2377	3.8415

Notes: r denotes the number of cointegrating vectors; the 5% critical values of the Trace statistics are taken from Osterwald-Lenum [45]; asterisk (∗) denotes the rejection of the hypothesis of no cointegration at 5% significance level; critical values for Bartlett corrected trace test is based on Doornik [46]; Bartlett corrected trace test is computed using SVAR 0.45 (http://www.texlips.net/svar/); the top panel reports the tests for the case of Japanese yen and the bottom panel of the table reports the tests for the case of Euro.

Table 5: Some commonly imposed monetary restrictions for the monetary model and tests of some popular monetary restrictions.

	Japanese yen	Euro
$H_1 : \beta_1 = -\beta_2 = 1$	5.899603 [0.0151447]	9.656485 [0.001887]
$H_2 : \beta_3 + \beta_4 = 0$	5.582769 [0.0181229]	5.511429 [0.021989]
$H_3 : \beta_5 + \beta_6 = 0$	8.649896 [0.003271]	5.566310 [0.018309]
$H_4 = H_1 \cap H_2$	7.314196 [0.025807]	21.39208 [0.000023]
$H_5 = H_1 \cap H_3$	12.6985 [0.0017483]	10.00446 [0.006723]
$H_6 = H_2 \cap H_3$	8.698469 [0.012917]	6.106066 [0.047215]
$H_7 = H_1 \cap H_2 \cap H_3$	13.19954 [0.004224]	21.54746 [0.000081]

Notes: the left column of the table summarises commonly imposed restrictions on the specification of monetary model given as $e_t = \beta_1 m_t + \beta_2 m_t{}^* + \beta_3 y_t + \beta_4 y_t{}^* + \beta_5 i_t + \beta_6 i_t{}^* + \varepsilon_t$; the right columns under Japan and Euro represent the hypotheses summarized in the left column of the table; the numbers not in parenthesis are x^2 test statistics; the numbers in the square brackets are marginal significance levels.

that, for Germany, none of the restrictions can be accepted. Meanwhile, for UK and Japan, only one of the restrictions can be accepted, which is H_2. MacDonald and Taylor [6] test, for Japan, all the frequently imposed hypothesis and they reject the entire null hypothesis in their practical examinations. The test results reported in Table 5 indicate that all the restrictions are rejected, which supports our assumption of the cointegration relation between exchange rates and monetary fundamentals.

4.4. Long-Run Cointegration Relation. Given that we have rejected the coefficient restrictions on the monetary fundamentals in the cointegrating vectors, we can obtain the long-run equations which normalize cointegrating vectors on the exchange rate. For the case of Euro/US dollar, we have the long-run determination of the exchange rate as follows:

$$\begin{aligned} e_t = {} & \underset{(0.06297)}{-1.091229} m_t + \underset{(0.0165)}{0.042307} i_t^l - \underset{(0.73687)}{1.455781} y_t + \underset{(0.18923)}{1.398509} m_t^* \\ & - \underset{(0.01912)}{0.010852} i_t^{l*} + \underset{(0.5946)}{1.778461} y_t^* - \underset{(1.02745)}{4.394283}, \end{aligned} \tag{10}$$

and for Japanese yen/US dollar we have the determination equation as follows:

$$\begin{aligned} e_t = {} & \underset{(0.17319)}{-0.977372} m_t + \underset{(0.02465)}{0.133907} i_t^l - \underset{(0.33159)}{1.639267} y_t + \underset{(0.23411)}{1.501885} m_t^* \\ & + \underset{(0.01422)}{0.01271} i_t^{l*} + \underset{(0.4774)}{1.77208} y_t^* - \underset{(0.2361)}{1.248798}. \end{aligned} \tag{11}$$

Table 6: Tests of exclusion rRestrictions.

	Japanese yen/USD	Euro/US dollar
Money supplies	7.6256 [0.022086]	19.129 [0.000070]
Outputs	12.669 [0.001773]	12.129 [0.001515]
Interest rates	11.290 [0.003534]	7.5082 [0.023431]

Notes: this table reports the series exclusion tests on the monetary model normalized on the exchange rate; the numbers outside of the parenthesis are x^2 statistics and the numbers in square brackets are marginal significance levels.

All variables are specified in logarithms. Standard errors are reported in the parentheses. Thus, the normalized equations comprise the implied long-run elasticises. The results show that all coefficients are significantly different from zero. All the coefficients are correctly signed except the domestic and foreign money supplies in the case of Euro/US dollar and domestic/foreign money supply and foreign interest rate in the case of Japanese yen/US dollar.

4.5. Exclusion Tests. The zero restrictions on the elements of the cointegrating vector are tested with the help of likelihood ratio tests. We investigate if money supply, output, or interest rate can be excluded from the cointegration space. We report the test results in Table 6, within which the x^2 statistics indicate that the variable money supply, income, and interest rate are statistically significant in the cointegrating vector normalised on the exchange rate.

5. Nonlinear Associations

Having found the long-run cointegration relationship between the exchange rates and the monetary fundamentals, we move to examine possible nonlinearities involved in the association between exchange rates and monetary fundamentals. First, we use the error correction model (ECM) to investigate the short-run adjustment of the exchange rate deviations, which is based on the previous long-run cointegration analysis. Second, with two alternative nonlinear approaches, we investigate nonlinearities involved in the association between exchange rates and monetary fundamentals. The first approach is the threshold method, with which we investigate possible regime switches during the whole sample period. The second approach is the nonparametric approach, with which we relax the general structural equation specifications and coefficient restrictions and focus on how monetary fundamentals describe the exchange rate movements in an unspecified frame. Furthermore, we compare the forecasting ability in out-of-sample between these nonlinear models and random walk process.

5.1. Nonlinear Adjustments of the Exchange Rate Deviation. Our analysis of the short-run dynamics of Japanese yen/U.S dollar and Euro/U.S dollar is based on the long-run cointegration relationship identified in the previous section. The key objective is to use the error correction model (ECM) to examine the short-run deviation from the long-run values and investigate the forecasting performance in out-of-sample. In particular, we compare the forecasting performance between the ECM model and random walk processes. We formulate the error correction term (ecm_t) generated from the cointegrating associations in the last section. For Euro/U.S dollar, we have the error correction term ecm_t as follows:

$$\begin{aligned}\mathrm{ecm}_t = e_t &+1.091229m_t -0.042307i_t^l + 1.455781y_t \\ &-1.398509m_t^* + 0.010852i_t^{l*} \\ &- 1.778461y_t^* + 4.394283,\end{aligned} \tag{12}$$

and for Japanese yen/U.S dollar we have the error correction term ecm_t as follows:

$$\begin{aligned}\mathrm{ecm}_t = e_t &+ 0.977372m_t - 0.133907i_t^l + 1.639267y_t \\ &- 1.501885m_t^* - 0.01271i_t^{l*} \\ &- 1.77208y_t^* + 1.248798.\end{aligned} \tag{13}$$

In the error correction model, we also concern the domestic and foreign short-term interest rate, i_t^s and i_t^{s*}. We add one lag of the error correction term (ecm_{t-1}) to the short-run adjustment equations. The ECMs are simplified by sequentially removing insignificant variables based on t-value and F-test results. In the case of Euro/U.S dollar, we use the series over March 1999 to August 2005 to implement the in-sample estimation. The remaining two year's sample (September 2005 to August 2007) is used to implement the forecasting in out-of-sample. The in-sample estimation results and the corresponding diagnostics tests are reported in Table 7. The results indicate that error correction term in the exchange rate adjustment equation is statistically significant different from zero.

In the case of Japanese yen/U.S dollar, we use the sample over May 1973 to August 2005 to do the in-sample estimation and the remaining two year's sample (September 2005 to September 2007) to do the forecasting in out-of-sample. The in-sample estimation results and the corresponding diagnostics tests are reported in Table 8, which indicates that the error correction term in the exchange rate adjustment equation is statistically significant.

We finally test the adequacy of the estimated models by assessing their out-of-sample forecasting performances. The estimated ECM equations are used to forecast the exchange rate movements for five forecasting horizons, 1, 3, 6, 9, and 12 months ahead over the period September 2005 to August 2007. We use the root mean square error (RMSE) to compare the forecasting performances between the error-correction models and the random walk process. RMSE is defined as the sample standard deviation of forecast errors, which is a conventional criterion that weights greater forecasts errors

Table 7: Parameter estimates of the error-correction model (Euro/USD).

Dependent variable	Δe_t
Constant	0.070413 (0.0448)
Δm_t	−0.927896 (0.02464)
Δm_t^*	0.729711 (0.1135)
$\Delta^2 i_{t-1}^s$	0.0316083 (0.01119)
ecm_{t-1}	−0.207636 (0.04226)
R^2	0.91236
SE	0.005475
$F(4,96)$	264.5 [0.000]
AR 1–5 test: $F(5,67)$	1.9236 [0.1019]
Normality test: Chi^2(2)	9.2156 [0.0100]
Hetero test: $F(10,61)$	0.61123 [0.7984]
Hetero-X test: $F(20,51)$	0.53937 [0.9342]

Notes: the ECM model is estimated by ordinary least squares; R^2 is the coefficient of determination; SE is the standard error of the regression; figures in parentheses after coefficient estimates are standard errors; we also report the Lagrange multiplier serial correlation from lags one to five in residuals; heteroskedasticity test statistics are based on quadratic and cross-product form of the regressors; all the test statistics are distributed as central F distribution under the relevant null hypothesis, with the degree of freedom in parenthesis and marginal significance levels in squared brackets after the test statistics; the joint significance is tested with the aid of an F statistic while the significance of the error-correction term and other regressors are valuated with a T statistic.

Table 8: Parameter estimates of the error-correction model (Japanese yen/USD).

Dependent variable	Δe_t
Constant	0.007140 (0.000857)
Δe_{t-1}	−0.196340 (0.094108)
Δe_{t-2}	−0.142225 (0.056548)
Δm_t	−0.696862 (0.042555)
Δm_{t-1}	−0.270160 (0.074984)
Δm_{t-2}	−0.153279 (0.050455)
Δy_t	−0.240341 (0.052362)
Δi_t	0.007958 (0.003636)
Δi_t^{s*}	0.003006 (0.001549)
ecm_{t-1}	−0.014830 (0.006601)
R^2	0.7197
SE	0.014771
$F(9,403)$	121.8 [0.000]
AR 1–7 test: $F(7,372)$	1.5011 [0.1654]
Normality test: Chi^2(2)	21.272 [0.00018]
Hetero test: $F(18,360)$	4.0361 [0.0000]
Hetero-X test: $F(54,324)$	4.1976 [0.0000]

Notes: The ECM model is estimated by ordinary least squares; R^2 is the coefficient of determination; SE is the standard error of the regression; figures in parentheses after coefficient estimates are White [44] corrected standard errors; we also report the Lagrange multiplier serial correlation from lag one to seven in residuals; heteroskedasticity test statistics are based on quadratic and cross-product form of the regressors; all the test statistics are distributed as central F distribution under the relevant null hypothesis, with the degree of freedom in parenthesis and marginal significance levels in squared brackets after the test statistics; the joint significance is tested with the aid of an F statistic while the significance of the error-correction term and other regressors are valuated with a T statistic.

more heavily than smaller forecasts errors in the forecast error penalty:

$$\begin{aligned} \mathrm{RMSE} &= \left(\frac{1}{T}\sum_{t=1}^{T} e_{t+k,t}^2\right)^{1/2} = \sqrt{\frac{1}{T}\sum_{t=1}^{T} e_{t+k,t}^2} \\ &= \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(y_{t+k} - \widehat{y_{t+k}}\right)^2}. \end{aligned} \tag{14}$$

Given the calculated RMSEs for two or more forecasting models, we prefer the one with the smallest value of RMSE. Table 9 reports the forecasting power between the ECM models and random walk processes. The forecasting performances reported in Table 9 suggest that, in the case of Euro/US dollar, the ECM outperforms the random walk process over the four forecasting horizons. Meanwhile, in the case of Japanese yen/US dollar, the ECM outperforms the random walk process over all five forecasting horizons.

5.2. Threshold Approaches. The association between economic time series is commonly nonlinear when there is larger dynamics involved in a particular economy. Threshold models consider the situation when a particular series in the system, that is, the threshold variable, passes a certain point, that is, the threshold value, the relationship between the dependent variable and independent variables can get into another different regime, which is locally linear. Threshold methods have been applied widely in literatures of macroeconomics.

To model movements in exchange rates, threshold methods have been intensively adopted to model the univariate time series. The focus is either the exchange rate return or the deviation of exchange rates from their equilibrium values. On one hand the exchange rate return is assumed to follow a nonlinear adjustment process. Pippenger and Goering [35] estimate a self-exciting threshold autoregressive (SETAR) model for various monthly US dollar exchange rates and find that the change in the exchange rates follows a SETAR model and the SETAR produces better forecasts than the naïve random walk model in out-of-sample. However, there are some negative evidences to the same issue. Boero and Marrocu [36] compare the relative performance of nonlinear models such as the SETAR, smooth transition autoregressive (STAR), and GARCH types with their linear counterparts. Their empirical study examines monthly exchange rate returns of three most traded exchange rates French franc/U.S dollar, German mark/U.S dollar, and Japanese yen/U.S dollar series over the period January 1973 to July 1997. The empirical results suggest that if the attention is restricted to mean square forecast errors, the performance of the models tends to favour the linear models. On the other hand, exchange rate deviations from equilibrium are also found to follow a threshold nonlinear process. Sarno et al. [12] use a smooth transition autoregressive (STAR) model

Table 9: Out of sample forecasts: ECM monetary models.

Models	RMSE: forecasting horizon (months)				
	1	3	6	9	12
Euro/dollar					
ECM	0.019048978	0.019075327	0.020145789	0.021732	0.023211
RW	0.022554564	0.02265186	0.028065	0.024445	0.021827
Yen/dollar					
ECM	0.0164281746	0.0170305761	0.0181297815	0.0188239441	0.0188787073
RW	0.029062706	0.031616901	0.031721507	0.029177812	0.031630935

Notes: this table reports the forecasting performances between ECM models and random walk (RW) process for the exchange rate Japanese yen/US dollar (yen) and Euro/US dollar (Euro), over the period September 2005 to September 2007.

to explain the nonlinear behaviour of the deviation of the exchange rate dollar-sterling and dollar-mark from the level suggested by simple monetary fundamentals. The deviation is specified as $d_t = e_t - (m_t - m_t^*) + (y_t - y_t^*)$ (all other variables are defined as previously). Similarly, with the same model specification as Sarno et al. [12], Sekioua [37] uses threshold autoregressive (TAR) model to investigate the deviation of the nominal exchange rate from its long-run equilibrium values predicted by monetary fundamentals. Sekious's study rejects the null hypothesis of linearity and nonstationarity and detects nonlinear mean reversion in the deviation. Kilian and Taylor [8] examine the deviation of exchange rate e_t from purchasing power parity (PPP) fundamentals f_t, $f_t = p_t - p_t^*$. With exponential smooth transition autoregressive (ESTAR) model of Terasvirta [38], they find that, near the long-run equilibrium, the deviation from the economic fundamentals is approximated by a random walk.

Conventional empirical studies of the monetary exchange rate model rely on a single state relationship between exchange rates and monetary fundamentals. We attempt to use threshold methods to relax the assumption of a single state and examine the possible regime switches involved in the economic system. The association between exchange rates and monetary fundamentals has not been directly examined with threshold methods. One significantly relevant study we find is that Nakagawa [39] examines the association between the real exchange rate and the real interest differentials by introducing threshold nonlinearity to take account of the band of the price adjustment due to the transaction cost, which is identified by $|q| \leq c$, where q is the real exchange rate and c is the constant band. Nakagawa finds the real exchange rate exhibits mean reversion and it has association with the real interest differential outside the band.

5.2.1. Threshold Effect Tests. In our threshold model, we use the interest rate as the threshold variable to determine the number of regimes involved in the association. There are two reasons to choose the interest rate as the threshold variable: one reason is because that interest rate is the main driving force in the monetary model to impact the movements of exchange rates. Moreover, the threshold effect tests indicate that, among the several monetary fundamentals, the interest rate is the best choice to be the threshold variable. Table 10 reports the Hansen [40] test result of threshold effects for the two exchange rates. We report the P value for the test statistics in the parenthesis. The test result indicates that there are threshold effects involved in the interest rates for the two cases. Specifically, the tests reported in Table 10 show that there are two regimes for both Euro/US dollar and Japanese yen/US dollar.

Table 10: Regime number tests [40].

	Euro/USD	Japanese yen/USD
1/2	33.622475 (0.028795)	396.355735 (0.00000)
2/3	34.289795 (0.7700)	1527.248850 (0.63000)

Notes: the threshold effect tests are based on the term of interest rate; 1/2 and 2/3 denote, respectively, the hypothesis test is null hypothesis of 1 regime against 2 regimes and 2 regimes against 3 regimes; figures not in the parenthesis are the test statistics of the F-statistic of Hansen [40]; figures in the parenthesis are the simulation-based P values for the test statistics.

5.2.2. Threshold Model Analysis. Given that we have found the threshold effect involved in a particular time series, it is natural to model the association in a threshold model. The general format of a two-regime threshold model can be specified as follows:

$$\begin{aligned} y_i &= \theta_1' x_i + e_i \quad \text{for } q_i \leq \gamma, \\ y_i &= \theta_2' x_i + e_i \quad \text{for } q_i > \gamma, \end{aligned} \tag{15}$$

where q_i denotes the threshold variable (i.e., Y_{t-d} in the SETAR model), which is used to split the sample into two regimes. γ is the threshold value. The random variable e_i is a regression error. Our empirical threshold model focuses on the restricted form monetary model since the unrestricted form of the monetary model could concern too many parameters. See the data description section for the detailed data definition; the restricted form of the monetary model in our study is specified as follows:

$$\Delta e_t = c + \alpha \Delta m_t + \beta \Delta y_t + \delta \Delta i_t^l + \varepsilon_t. \tag{16}$$

Figures of the yearly changed exchange rates and macroeconomic fundamentals, as defined in (7) and (8), are demonstrated in Figures 1, 2, 3, 4, 5, 6, 7, and 8 which demonstrate fairly similar patterns after 1999 (the sample for EUR/USD starts from January 1999 that the graphs of EUR/USD are

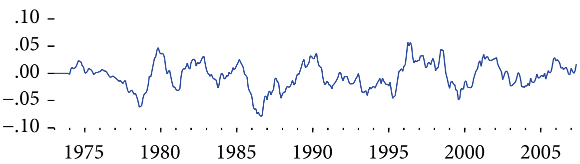

Figure 1: Yearly Changed Exchange rate JPY/USD. Note: this figure shows the yearly changed exchange rate JPY/USD, which is calculated as $\Delta e_t = (e_t - e_{t-12})/e_{t-12}$ and examined in the threshold modelling in Section 5.2.2. See the text for more details.

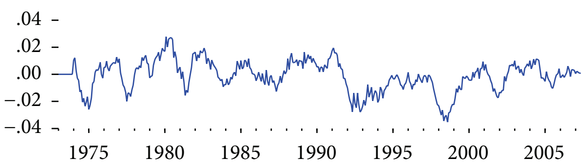

Figure 2: Yearly Changed GDP (Case of JPY/USD). Note: this figure shows the yearly changed GDP in the case of JPY/USD, which is calculated as $\Delta m_t = (m_t - m_{t-12})/m_{t-12} - (m_t^* - m_{t-12}^*)/m_{t-12}^*$ and examined in Section 5.2.2 threshold modelling. See the text for more details.

relatively flatter and less volatile due to the smaller sample and less observations). Before estimating the threshold model. we preestimate the association with the linear specification for the exchange rate Euro/US dollar and Japanese yen/US dollar. Table 11 reports the least square estimation results, which obviously violate the theoretical monetary exchange rate model. Only the coefficient on the money supply, for Japanese yen, is significant but wrongly sighed. All other coefficient estimates are insignificant, even if correctly signed. We consequently proceed to the threshold model estimation. For a case of two-regime model, the linear model in (16) can be extended to a two-regime model. In regime 1, we can have specification as follows:

$$\Delta e_t = c_1 + \alpha_1 \Delta m_t + \beta_1 \Delta y_t + \delta_1 \Delta i_t^l + \varepsilon_{1t}. \tag{17}$$

For the regime 2, we have the equation as follows:

$$\Delta e_t = c_2 + \alpha_2 \Delta m_t + \beta_2 \Delta y_t + \delta_2 \Delta i_t^l + \varepsilon_{2t}. \tag{18}$$

The estimation results are reported in Table 12, which demonstrate most coefficients are not statistically significant and wrongly signed even if they are significant. Additionally, we also use the deviation of the exchange rates from their monetary fundamental values as the threshold variable to estimate the nonlinear model, within which the deviation is based on the error correction term derived from the cointegration analysis in the last section. However, this still cannot improve the estimation results in terms of the coefficient signs and magnitudes. The estimations do not get improved even if we consider the endogeneity of the explanatory variables.

5.3. Nonparametric Approach. Without specifying the specific nonlinearity, nonparametric approaches can model the nonlinear association between exchange rates and monetary

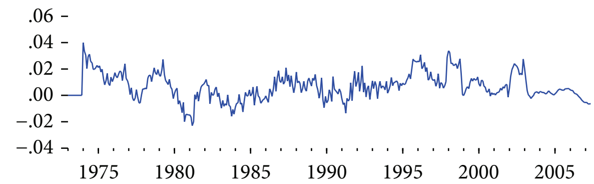

Figure 3: Yearly Changed Money Supply (Case of JPY/USD). Note: this figure shows the yearly changed money supply in the case of JPY/USD, which is calculated as $\Delta m_t = (m_t - m_{t-12})/m_{t-12} - (m_t^* - m_{t-12}^*)/m_{t-12}^*$ and examined in Section 5.2.2 threshold modelling. See the text for more details.

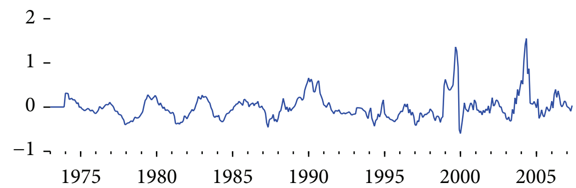

Figure 4: Yearly Changed Inflation (Case of JPY/USD). Note: this figure shows the yearly changed inflation in the case of JPY/USD, which is calculated as $\Delta m_t = (m_t - m_{t-12})/m_{t-12} - (m_t^* - m_{t-12}^*)/m_{t-12}^*$ and examined in Section 5.2.2 threshold modelling. See the text for more details.

fundamentals. Nonparametric methods do not make any auxiliary assumptions on the functional form of the associations between the variables. Instead of estimating parameters, the objective of nonparametric methods is to directly estimate the regression $y_t = f(x_t) + \varepsilon_t$, $t = 1, \ldots, T$. Most methods of nonparametric approaches implicitly assume that $f(\cdot)$ is a smooth and continuous function. Nonparametric methods can be adopted when the hypothesis under the classical regression methods cannot be verified or when we only focus on the predictive quality of the model and not its specific structure.

5.3.1. Locally Weighted Regression. Our nonparametric study uses the locally-weighted regression (LWR), which was developed by Cleveland et al. [41] and Cleveland and Devlin [42]. Meese and Rose [5] use locally weighted regression to examine classical monetary models. However, their analysis focuses on the restricted forms of monetary models, within which they impose homogeneity for the corresponding series between domestic and foreign economies. We examine the unrestricted form of the flexible-price monetary model. Moreover, our analysis uses more recent and longer span of the datasets than their study.

5.3.2. Nonparametric Analysis. Our nonparametric framework concerns two pairs of exchange rates and monetary fundamentals including money supplies, productions, and long-term interest rates. To get consistent estimates of locally weighted regression, we use a single lag of the explanatory variables in our estimations since all the explanatory variables involved cannot be weakly exogenous. We normalize all the

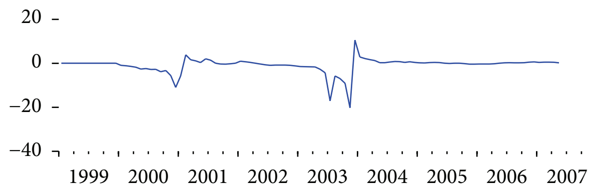

Figure 5: Yearly Changed Exchange rate EUR/USD. Note: this figure shows the yearly changed exchange rate EUR/USD, which is calculated as $\Delta e_t = (e_t - e_{t-12})/e_{t-12}$ and examined in the threshold modelling in Section 5.2.2. See the text for more details.

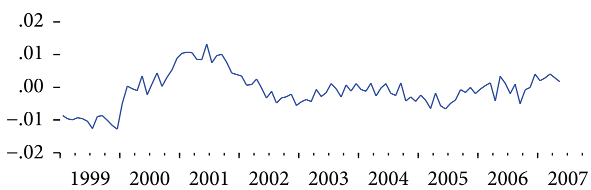

Figure 6: Yearly Changed GDP (Case of EUR/USD). Note: this figure shows the yearly changed GDP in the case of EUR/USD, which is calculated as $\Delta m_t = (m_t - m_{t-12})/m_{t-12} - (m_t^* - m_{t-12}^*)/m_{t-12}^*$ and examined in Section 5.2.2 threshold modelling. See the text for more details.

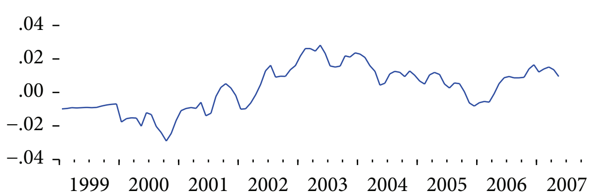

Figure 7: Yearly Changed Money Supply (Case of EUR/USD). Note: this figure shows the yearly changed money supply in the case of EUR/USD, which is calculated as $\Delta m_t = (m_t - m_{t-12})/m_{t-12} - (m_t^* - m_{t-12}^*)/m_{t-12}^*$ and examined in Section 5.2.2 threshold modelling. See the text for more details.

concerned series by dividing their corresponding standard deviations before we implement the regressions. We conduct the nonparametric regression with the unrestricted form of the monetary model which allows all the concerned monetary variables to function individually. The idea of unrestricted form of the monetary model is similar to the unrestricted cointegration vector analysis which allows all the involved regressors to contribute to the exchange rate determination. The equation is specified as follows:

$$e_t = f\left(m_{t-1}, m_{t-1}^*, y_{t-1}, y_{t-1}^*, i_{t-1}^l, i_{t-1}^{l*}\right) + \varepsilon_t, \qquad (19)$$

where all the concerned variables are defined as previously. The quality of the estimation depends less on the shape of the weight function than on the distance function (bandwidth), which makes it important to choose the most appropriate bandwidth. We aim to choose a value that is not too small (keeps bias low) or not too large (not induce more sampling variability). In our empirical study, we follow suggestions of Cleveland and Devlin that we choose the weight function

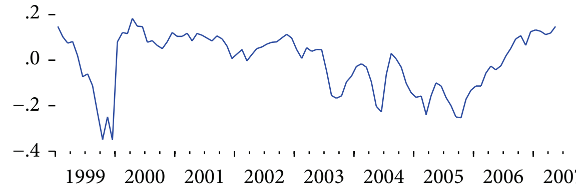

Figure 8: Yearly Changed Inflation (Case of EUR/USD). Note: this figure shows the yearly changed inflation in the case of EUR/USD, which is calculated as $\Delta m_t = (m_t - m_{t-12})/m_{t-12} - (m_t^* - m_{t-12}^*)/m_{t-12}^*$ and examined in Section 5.2.2 threshold modelling. See the text for more details.

Table 11: Linear model estimations.

Δe_t	Euro/USD	Japanese yen/USD
Δm_t	1.297600 (0.4824)	−1.186818 (0.0000)
Δi_t	−1.749120 (0.4194)	0.029403 (0.8006)
Δy_t	6.161777 (0.1613)	2.995027 (0.5451)
c	−0.082095 (0.3253)	0.000823 (0.8969)

Notes: the exchange rate change Δe_t is calculated as $\Delta e_t = (e_t - e_{t-12})/e_{t-12}$ and the corresponding contemporaneous monetary fundamentals are constructed as $\Delta m_t = (m_t - m_{t-12})/m_{t-12} - (m_t^* - m_{t-12}^*)/m_{t-12}{}^*$ (see texts for detailed explanations); numbers not in parenthesis are the coefficient estimates; numbers in the parenthesis are the P values for the corresponding parameter coefficient significance tests.

$w(\nu) = (1-\nu)^3$ for $0 \leq \nu \leq 1$. For distance function $\rho(\cdot)$, we use the Euclidean distance function, specified as $\rho(x, x_i) = [\sum (x - x_i)^2]^{1/2}$, which denotes the Euclidean distance between x and x_i. To choose window size, we test a range of ρ between 0.4 and 1.0.

Nonparametric approaches give sufficient freedom to the concerned variables. We leave the last two years data for the use of forecasting in out-of-sample. Table 13 reports the in-sample estimation and out-of-sample forecasting performances for the unrestricted form of the monetary model. Overall, the estimation results reported in Table 13 show that monetary fundamentals have significant explanation power to the movements in exchange rates, in terms of the higher coefficients of the determination in in-sample estimations. In out-of-sample forecasting, the experiments show that the unrestricted form of the LWR monetary models outperform the random walk process for the cases of Euro and Japanese yen.

6. Summary and Conclusion

Based on the flexible-price monetary model, this paper revisits the association between exchange rates and monetary fundamentals with the extended span of time series for the exchange rate Japanese yen/US dollar and Euro/US dollar. Using the Johansen cointegration procedure, our study demonstrates the validity of the flexible-price monetary model to describe the long-run association between exchange rates and monetary fundamentals. Furthermore, our intensive nonlinear studies suggest various nonlinearities involved in the relationship. The experiments of the error correction

Table 12: Threshold model estimations.

Δe_t	Euro/USD		Japanese yen/USD	
	Regime 1	Regime 2	Regime 1	Regime 2
Δm_t	0.2443710 (0.8167169)	−0.1849082 (0.8932050)	−1.371777 (0.119426)	−1.389924 (0.203891)
Δi_t	1.190002 (2.183613)	−0.292207 (1.63636)	0.014266 (0.030913)	−0.010649 (0.036219)
Δy_t	1.533665 (1.808895)	0.06692503 (2.560614)	0.826844 (0.640419)	0.613519 (4.002981)
c	0.159589 (0.771334)	0.0206816 (0.149416)	$-6.15E-05$ (0.001691)	0.002338 (0.008586)

Notes: the exchange rate change Δe_t is calculated as $\Delta e_t = (e_t - e_{t-12})/e_{t-12}$ and the corresponding contemporaneous monetary fundamentals are constructed as $\Delta m_t = (m_t - m_{t-12})/m_{t-12} - (m_t^* - m_{t-12}^*)/m_{t-12}^*$ (see texts for detailed explanations); figures not in parenthesis are the coefficient estimates; figures in the parenthesis are the test statistics for the coefficient significance tests.

Table 13: Estimates and forecasting with locally-weighted regression (unrestricted monetary model).

R^2					
Euro/USD	0.975				
Japanese yen/USD	0.990				
	RMSE: forecasting horizons (months)				
	1	3	6	9	12
Euro/USD					
LWR	0.015990752	0.016666489	0.013968866	0.01491226	0.01612644
RW	0.016776875	0.028087996	0.044902497	0.05961996	0.07480505
Yen/USD					
LWR	0.020281574	0.028250091	0.029957215	0.030992282	0.032026553
RW	0.021142813	0.030467316	0.034595556	0.03579283	0.041196816

Notes: this table reports the forecasting performances between local-weighted regression and random walk (RW) process for the unrestricted form of the monetary model, on the exchange rate Japanese yen/US dollar (yen) and Euro/US dollar (Euro), over the period September 2005 to September 2007.

model suggest the short-run deviation of the exchange rates from the long-run equilibrium values can be captured by the error correction model, which outperforms the random walk process in terms of the forecasting in out-of-sample. The locally-weighted regression of nonparametric approaches show that monetary fundamentals can describe well the movements in exchange rates in a completely unrestricted frame. Moreover, the forecasting power of the nonparametric model is mostly better than the random walk process. We do not find the support of the exchange rate monetary model in the experiment of threshold models. But we do not rule out the possibility of the existence of the threshold models for the monetary model since some other issues involved can contribute to obtaining the negative results. For instance, it could be because of the choice of the threshold variable or the choice of the threshold method.

The monetary model does not perform well in empirical studies though it is the workhorse of the determination of nominal exchange rates. Our intensive studies show if we treat the model carefully and adopt appropriate econometric methods, we can see some success of the monetary model in empirical studies.

Conflict of Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

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