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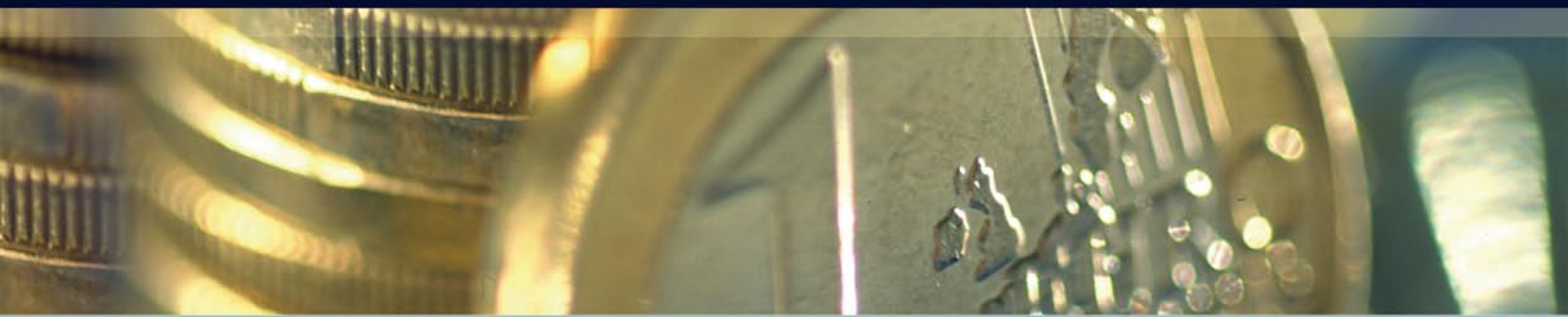

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The portfolio balance effect and reserve diversification: An empirical analysis

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ABSTRACT

The purpose of this study is to examine whether the portfolio balance effect, operating through the outstanding debts of US and euro area, and the signaling effect of sterilized intervention, operating through the relative composition of official reserves of developing and emerging countries, explain the developments of the euro/dollar exchange rate. The empirical analysis reveals that both effects are statistically significant and have the correct signs. The Clark-West testing procedure indicates that the model which relates the exchange rate to official reserves and the interest rate differential outperforms the random walk model in the forecasting accuracy.

Keywords: Present-value monetary model, Portfolio balance effect, signaling effect, sterilized intervention, VAR, forecast accuracy.

JEL classification: F31

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1. Introduction

Since the late 90's, the macroeconomic environment of the world economy has experienced three major developments: Firstly, the large increase in the US external debt, reflecting the large increase in the current account deficit, secondly, the introduction of the euro, which increased the expectations that the new currency will become a serious rival and even surpass the dollar as the main asset in the reserve portfolios, and thirdly, the increased willingness of developing and emerging countries to buy up surplus dollars in order to limit the appreciation of their currencies against the dollar. During the global liquidity crisis, the reserve holdings have provided self-insurance, as the countries that built up precautionary reserves were able to avoid large depreciations of their currencies. According to the IMF quarterly report on currency shares of global official reserves, in the third quarter of 2009, the world total foreign exchange reserves reached $7,861 billion, up from an average of $1,687 billion in 1999, with the largest holder being the developing countries, at $5,190 billion, followed by the industrial countries, at $2,670 billion. The claims in dollars in allocated reserves of emerging and developing countries increased from $259 billion in the first quarter of 1999 to $1,203 billion in the third quarter of 2009, while the claims in euro increased from $65 billion to $659 billion. Concerns that China, Russia and other developing and emerging countries would diversify reserves composition away from dollar toward euro assets should only matter if the portfolio balance effect is relevant.

If we assumed that the private investors were content with the existing composition of their portfolios before the shift, then the official reserve diversification will force them to adjust to the mirror image change in their asset allocation, that is, to hold more dollar assets and fewer euro assets. For private investors to accept this portfolio shift the dollar should decline against the euro and the dollar rate of return should rise, as predicted by the portfolio balance effect. If the foreign central banks' shift takes down significantly the dollar holdings, it will jeopardize the role of the dollar as a reserve currency. The impact of such official reserve diversification on private holdings of securities is equivalent to sterilized intervention in which the FED or the European Central Bank sells dollars against euro and takes actions to leave the monetary conditions unchanged.

In the empirical literature, three types of tests have been conducted in order to test the relevance of the portfolio balance channel for sterilized intervention. The first type is based on estimating reduced-form equations of the portfolio balance model (Lewis, 1988; Cushman, 2007), while the second type solves the portfolio balance model for the risk premium and then tests for perfect substitutability between domestic and foreign bonds (Dominguez and Frankel, 1993). A different approach, followed by Ghosh (1992), uses a forward-looking monetary model of the exchange rate determination, augmented with a risk premium, which is a function of domestic and foreign debt outstanding, and then tests for the significance of the portfolio balance effect, by controlling for any signaling effect of central bank intervention. The null hypothesis is that the exchange rate is determined by the pure monetary model, while the risk-augmented monetary model constitutes the alternative hypothesis. By examining the portfolio balance effect in the context of the present-value model, this approach allows the monetary model to provide a filter for removing the influence of agents' expectations of future fundamentals on the current exchange rate. In that sense, this approach is very appealing. In addition, this theoretical framework has a very important and robust insight in that it considers the exchange rate as an asset price, which depends on expectations of future fundamentals (Obstfeld, 1996). [2]

In this study, which is in the spirit of the third approach, we try to test two hypotheses for the euro/dollar exchange rate. The first hypothesis, which is tested in the context of the present-value monetary model, examines whether the portfolio balance effect, operating through the outstanding debts of US and euro area, has an impact on the exchange rate beyond the impact of the monetary fundamentals. The approach taken in testing this hypothesis controls for any signaling effects of the sterilized intervention of the FED or the European Central Bank about future monetary policies changes by focusing on the predicted exchange rate from the pure monetary model, which constitutes the null hypothesis. Under the alternative hypothesis that there exists a risk premium, any additional explanatory power should be the result of portfolio adjustments.

[2] Karfakis (2006) examined the present-value model for the euro/dollar exchange rate from January 1999 to March 2004. The weak form restrictions of the exchange rate model were not rejected by the data, but the most stringent restrictions were strongly rejected. Chinn (2008) and Alquist and Chinn (2008), using dynamic OLS co-integration analysis, rejected the sticky price version of the monetary model.

The second hypothesis, which is tested in the context of a reduced-form equation, examines whether the sterilized intervention of developing and emerging countries has an impact on the exchange rate through the signaling channel of the relative composition of official reserves.[3] The foreign central banks are buying up large amounts of dollars through sterilized intervention to prevent their currencies from appreciating against the dollar and at the same time to self insure against the effects of future crises. This policy attitude may signal to the market that the large dollar holders fearful of what might happen to the value of their hoards should there be a run on the dollar will continue to accumulate dollar reserves in the future and investing the intervention proceeds in dollar assets will appreciate further the greenback.

2. Deriving the present-value monetary model

Let's consider the money-income exchange rate model between the euro and the dollar. This model includes a domestic and foreign money market relationship,

$$m_t = p_t + y_t - a i_t + v_t \qquad (1)$$

$$m_t^* = p_t^* + y_t^* - a i_t^* + v_t^* \qquad (2)$$

an interest rate arbitrage relationship,

$$i_t^* - i_t = E_t(e_{t+1} | \Omega_t) - e_t + \rho_t \qquad (3)$$

[3] Dooley and Isard (1979) have shown that the risk premium depends on asset supplies and official intervention.

and a relationship between the nominal exchange rate its purchasing power parity value and the real exchange rate,

$$e_t = p_t^* - p_t + \varepsilon_t \qquad (4)$$

where e_t is the logarithm of the exchange rate, defined as dollars per euro, $E_t e_{t+1}$ is the logarithm of the expected exchange rate prevailing at time t+1, with expectations formed at time t and based on the agents' entire information set Ω_t, m_t and m_t^* are the logarithms of the domestic and foreign money stocks, y_t and y_t^* are the logarithms of the domestic and foreign real income, p_t and p_t^* are the logarithms of domestic and foreign price levels, i_t and i_t^* are the short term domestic and foreign interest rates, ρ_t is the risk premium, v_t and v_t^* are money demand shocks and ε_t is the real exchange rate. The domestic and foreign variables refer to euro area and USA, respectively.

Combining equations (1) to (4), assuming that the risk premium is zero and imposing the "non-bubbles" condition that $b^j E_t(s_{t+j})$ goes to zero as $j \to \infty$, yields:

$$e_t = (1-b)\sum_{j=0}^{\infty} b^j E_t(z_{t+j}|\Omega_t) + \omega_{1t} \qquad (5)$$

where $b = a/(1+a)$, $1-b = 1/(1+a)$, $z_t = (m_t^* - y_t^*) - (m_t - y_t)$ and $\omega_{1t} = b\sum_{j=0}^{\infty} b^j E_t(v_{t+j} - v_{t+j}^* + \varepsilon_{t+j})$.

Equation (5) says that the actual exchange rate is equal to the present discounted value of the monetary fundamentals. In other words, the exchange rate is an optimal predictor of the future monetary fundamentals, given the agents' entire information set. This is a requirement imposed by the model, which is tested by examining the hypothesis that e_t Granger causes z_t, given the past history of z_t.

Let us assume that the theoretical model estimated by the econometrician is given by:

$$\tilde{e}_t = (1-b)\sum_{j=0}^{\infty} b^j E_t\left(z_{t+j}|H_t\right) + \omega_{2t} \qquad (6)$$

where, H_t is the information set used by the econometrician. Under the null hypothesis that the monetary model is true, it will imply that: $\tilde{e} = e_t$. In this case, the two information sets Ω_t and H_t will be the same. This condition constitutes the strong restriction imposed by the model.

Let's define a vector autoregression (VAR) process in z_t and e_t, assuming that both variables are stationary in levels. Writing the VAR in a compact form yields:

$$X_t = A(L)X_{t-1} + \eta_t \qquad (7)$$

where, $$X = \left[z_t, z_{t-1}, \dots, z_{t-p+1}, e_t, e_{t-1}, \dots, e_{t-p+1}\right]'$$

$$\eta = [\eta_t^z, 0, \dots 0, \eta_t^e, 0, \dots, 0]'$$

$$A = \begin{bmatrix} \alpha_1 \dots \alpha_p & \beta_1 \dots & \beta_p \\ 1 \;\dots 0 & 0 \;\dots & 0 \\ & . & \\ & . & \\ 0 \;\dots 0 & 0 \;\dots & 0 \\ \gamma_1 \dots \gamma_p & \delta_1 \;\dots & \delta_p \\ 0 \;\dots 0 & 1 \;\dots & 0 \\ & . & \\ & . & \\ 0 \;\dots 0 & 0 \;\dots & 0 \end{bmatrix}$$

Define g' and n' as two selection row vectors with unity in the (p+1)-th and the first entries respectively and zeros elsewhere. Then, Equation (6) in terms of the VAR is given by:

$$g' X_t = (1-b) \sum_{j=0}^{\infty} b^j \, n' A^j X_t \qquad (8)$$

The infinite sum on the right-hand side of the above expression, under the assumption of stationarity, converges to: (see, Ghosh 1992)

$$\bar{e}_t = \xi_0 e_t + \sum_{j=2}^{p+1} \xi_j e_{t+1-j} + \sum_{j=1}^{p+1} \psi_j z_{t+1-j} + \omega_{3t} \qquad (9)$$

Under the null hypothesis that the monetary model is correct, the coefficient ξ_0 would be unity and all the other coefficients would be zero.

If we allow for a risk premium, the present-value model is given by:

$$e_t = (1-b) \sum_{j=0}^{\infty} b^j E_t\left(z_{t+j} | \Omega_t\right) + b \sum_{j=0}^{\infty} b^j \, E_t\left(\rho_{t+j} | \Omega_t\right) + \omega_{4t} \qquad (10)$$

This equation says that the actual exchange rate differs from its value determined by the pure monetary model, that is, from the present discounted value of monetary fundamentals, by the present discounted value of the risk premium. Thus, the current and future values of the risk premium affect the exchange rate and not the risk premium of an individual period. The null hypothesis of equality between the actual and the theoretical values of the exchange rate is tested in the context of the following equation:

$$\bar{e}_t = \xi_0 e_t + \sum_{j=2}^{p+1} \xi_j e_{t+1-j} + \sum_{j=1}^{p+1} \psi_j z_{t+1-j} + \sum_{j=1}^{p+1} \zeta_j \rho_{t+1-j} + \omega_{4t} \qquad (11)$$

Under the null hypothesis that the monetary model is true, the coefficient ζ_0 would be unity and all the other coefficients would be zero. Under the alternative hypothesis that there exists a risk premium, the coefficients ζ_j would be statistically nonzero.[4]

3. The data

We have used observations from the first quarter of 2000 to the third quarter of 2009 for the following variables:[5] the log of the exchange rate (e), defined as dollars per euro, the log of euro area narrow money supply (m), the log of US narrow money supply (m^*), the log of euro area real income (y), the log of US real income (y^*), the log of the federal debt held by private investors (f^*), the log of euro area general government consolidated debt (f), the log of the allocated reserves of emerging and developing countries in dollars ($r\$$), the log of the allocated reserves of emerging and developing countries in euro ($r€$), the three-month euro deposits Libor interest rate (i) and three-month dollar deposits Libor interest rate (i^*). Since the euro area government debt held by the Eurosystem is a very small proportion of the total debt, we are not netting it out. We have constructed the following variables: the debt differential (d), defined as f^*-f, the reserve differential (r), defined as $r\$$-$r€$, and the monetary fundamentals (z), defined as (m^*-y^*)-(m-y). Figures 1 to 4 plot the variables under consideration.

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[5] The starting point of the sample was dictated by the availability of the data for the euro area debt.

The exchange rate, interest rates and allocated reserves obtained from IMF, the monetary aggregates and real incomes from OECD, the euro area government debt from Eurostat and the US debt from Federal Reserve Bank of St. Louis.

4. Structural breaks and unit root tests

For each time series, we have estimated an AR(1) equation with a drift and used the Quandt Likelihood Ratio (QLR) statistic for testing for a significant structural break in an unknown point. This test statistic does not follow the standard F-distribution and its critical values are tabulated in Stock and Watson (2003). The results which are reported in Table 1 indicate that the time series concerned exhibit significant structural breaks.

In testing for a unit root in the presence of a structural break, we have used the methodology proposed by Perron (1988) and Zivot and Andrews (1992). The estimated equation, which allows for one time change in the level and the slope of the trend function of the series, has the following form:

$$\Delta x_t = \mu_0 + \mu_1 t + \mu_2 DU(\lambda) + \mu_3 DT(\lambda) + \mu_4 x_{t-1} + \sum_{j=1}^{k} \theta_j \Delta x_{t-j} + \zeta_t \qquad (12)$$

where x_t is a time series, $DU(\lambda)=1$ if $t>T\lambda$ and zero otherwise, $DT(\lambda)=t-T\lambda$ if $t>T\lambda$ and zero otherwise, $\lambda = TB/T$ and TB is the break point, which has been identified on the basis of the QLR test. The results reported in Table 2 show that the exchange rate, the monetary fundamentals, the debt ratio and the reserve ratio are all stationary, after allowing for a structural break point.

5. The effect of portfolio balance on the exchange rate

Having established that the exchange rate and the monetary fundamentals are stationary variables, we proceed by estimating a VAR model in de-meaned e_t and z_t. The model also includes three dummy variables, accounting for the structural breaks of the two variables, which identified using the QLR test. The lag length of the VAR was determined by reference to AIC and SBC. We started with a maximum lag order of 6 and chose the lag order with the best (that is, minimized) values of the respective information criteria. This procedure indicated that the optimal lag length of the VAR is one.

In the context of the VAR, the minimal requirement for the monetary model to be true is that the exchange rate should Granger-cause the fundamentals. The calculated value of the F statistic for testing the hypothesis that e_t Granger-causes z_t is equal to 3,85 (p=0,05), indicating that the exchange rate is an optimal predictor of the future monetary fundamentals as implied by the monetary model. In addition, the calculated value of the F statistic for testing the hypothesis that z_t Granger-causes e_t is equal to 22,02 (p=0,00), indicating that the monetary fundamentals have information content that helps predict the exchange rate. This result which is not need by the monetary model is quite helpful for purpose of our analysis in that the predicted value of the exchange rate incorporates valuable information which is associated with the monetary fundamentals. The Doornic-Hansen test for multivariate normality of residuals is not significant ($\chi^2(4)$=4,56 with p=0,34). The portmanteau Ljung-Box test indicates the absence of serial correlation in the VAR model ($\chi^2(9)$=39,83 with p=*0,16*). In addition, the model does respectably well in that the predicted and actual exchange rates are highly positively correlated. The correlation coefficient is 0,97 and under the null hypothesis of no correlation the value of t-test with 36 degrees of freedom is equal to 26,23, with two-tailed p =0,00.

Having verified the validity of the monetary model, we proceed to test the alternative hypothesis that there is a risk premium and it depends on the relative debt ratio, in the context of the following equation, which represents a re-parameterization of equation (11), that is,

$$e_t - \hat{e}_t = (1 - \xi_0)e_t + \sum_{j=1}^{k} \xi_j e_{t-j} + \sum_{j=0}^{k} \psi_j z_{t-j}$$

$$+ \sum_{j=0}^{k} \zeta_j d_{t-j} + \omega_{4t} \qquad (13)$$

where the dependent variable denotes the residuals from the estimating exchange rate equation of the VAR model.

If the relative asset supplies have an impact on the exchange rate beyond the impact of monetary fundamentals, then the sum of the coefficients of the debt differential must be positive and statistically nonzero. A relatively long lag length of six quarters was set up as a maximum and we chose the optimal lag with reference to information criteria. The AIC and SBC indicated that the optimal length was one. The results reported in Table 3 show that the sum of the coefficients of the debt differential is statistically different from zero and has a positive sign, indicating that an increase in the US debt relative to the euro area debt, it will increase the risk premium of the dollar assets and consequently the dollar will depreciates relative to its value implied by the pure monetary model. This effect is beyond any impact on the exchange rate through the monetary fundamentals. A more stringent test of the alternative hypothesis is to examine that all the coefficients of the debt differential are jointly equal to zero. The calculated value of the *F*-test, which is equal to 18,41 (p=0,00), indicates that the past history of the relative debt ratio has information content that helps predict the deviations of the actual exchange rate from its value predicted by the pure monetary model.

The coefficient of the actual exchange rate $(1-\xi_0)$ is statistically significant and its size implies that: $\xi_0 = 0{,}28$. One implication of this result is that the actual exchange rate it is not equal to the value implied by the pure monetary model augmented with a risk premium, but overreacts to changes in the monetary fundamentals, since the size of ξ_0 is less than unity.

An additional interesting result is that the monetary fundamentals differential affects positively the exchange rate, implying that an increase in the US monetary fundamentals relative to the euro area monetary fundamentals will push the exchange rate above its value predicted by the pure monetary model. This effect indicates that the strong restrictions of the monetary model are not satisfied.

All diagnostics indicate that the model is well specified, while the CUSUMSQ test reveals that instability in the parameter estimates does not exist.

6. The signaling effect of intervention

Even if, some of the expansion of official reserves of emerging and developing countries reflect conscious decision to self insure against the effects of future crises, the bulk of the accumulation of official reserves has resulted from purchases of dollars to prevent their currencies from appreciating against the dollar. From this perspective, the foreign central banks' reserve accumulation has been more than an instrument than a goal of national monetary and financial policy (Knight, 2006). This policy attitude may signal to the market that the large dollar holders fearful of what might happen to the value of their hoards should there be a run on the dollar will continue to accumulate dollar reserves in the future and investing the intervention proceeds in dollar assets will appreciate the greenback. This argument is in line with the position of Dooley et al (2004), according to which changes in the allocation of existing reserve holdings of Asian central banks away from dollar and toward the euro will influence market expectations about future flows of investment by these central banks. Any significant change in the investment choices would likely to threaten their pegs against the dollar, which would require an even higher accumulation of dollar assets, and increase the pressure on European

Central Bank to limit the appreciation of euro against the dollar in order to preserve the cyclical recovery of the euro area economy.

We examine the hypothesis that sterilized intervention operates through the signaling channel of the composition of official reserves by estimating the regression:[6]

$$e_t = \varphi_0 + \varphi_1 e_{t-1} + \sum_{j=1}^{k} \varphi_{2j} r_{t-j} + \sum_{j=1}^{k} \varphi_{3j}\left(i_{t-j} - i^*_{t-1}\right) + \eta_t \qquad (14)$$

where e_t is the logarithm of the exchange rate, r_t is the logarithm of the ratio of dollars to euro claims in the official reserves of emerging and developing countries, which proxies the intervention variable, $i_t - i^*_t$ is the interest rate differential, which captures the effects of monetary policy changes, operating through the uncovered interest parity condition, and η_t is a white-noise error term. Then, we test the signaling hypothesis that the coefficients φ_{2j} are significant and have negative sign, indicating that an increase in the relative reserve ratio will depreciate the euro/dollar exchange rate. The optimal lag length of equation (14) was determined by reference to information criteria. We tested equation (14) with various lags, starting with a maximum order of six lags, and chose the lag order with the best (that is, minimized) values of the respective information criteria. This procedure indicated that the optimal lag structure was six. The results reported in Table 4 show that the sum of the

[6] Humpage (1989) has used the regression (14) to test the hypothesis that the sterilized intervention operates through the signaling channel (Sarno and Taylor, 2002).

coefficients of the reserve ratio is significant and has the expected sign.[7] A more stringent test of the signaling hypothesis is to examine that all the coefficients of the relative reserve ratio are jointly zero. The calculated F statistic, which is equal to 8,95 (*p-value*=0,00), is highly significant, suggesting that the past history of the intervention variable has information content that helps predict the exchange rate.

The sum of the coefficients of the interest rate differential is significant and has a negative sign, indicating that when the interest rate of euro increases relative to the interest rate of dollar the exchange rate of the euro against the dollar is expected to depreciate, as predicted by the uncovered interest arbitrage condition. The one-period lagged exchange rate is statistically significant and the size of its coefficient indicates that the exchange rate exhibits a low persistence.

The diagnostic tests indicate that the estimated exchange rate equation is well-specified and the CUSUMSQ test reveals that it is stable over the sample period. The adjusted R^2 indicates that the model explains most of the exchange rate variation (Figure 4), while the unit root tests show that the regression residuals are stationary (Figure 5).

In turn, we compare its forecasting performance with that produced by a random walk model without a drift, using the adjusted mean squared prediction error statistic proposed by Clark and West (2006). The null hypothesis which is tested is that there is no difference in the forecasting accuracy of the two

[7] I have also estimated equation (14) with a dummy variable, accounting for the structural break in the exchange rate at 2002(2). The obtained results were very similar to those reported in the text.

competing models against the alternative that the exchange rate model, which incorporates the intervention variable and the interest rate differential, outperforms the random walk. The difference between the two prediction errors is asymptotically normally distributed. We have split the sample at the fourth quarter of 2007 and evaluated the forecasting accuracy of the models over the period of the global financial crisis. We have not applied a rolling regression approach to forecasting for two reasons: first, the exchange rate model does not exhibit parameter instability and second, that approach does not incorporate possible efficiency gains as the sample moves forward through time. The value of the computed Z statistic is equal to 17.49, which is statistically significant, indicating that the prediction error of the exchange rate model is smaller than the prediction error of the random walk model, thus the exchange rate model can beat the market at long horizons. This result implies that the exchange rate model could be used for guiding a position trading in the foreign exchange market, which involves taking a position and holding it for a relatively long period of time as long as the fundamentals are not deviating from the assumptions that the position is based on. On the other hand, the model cannot be used for guiding a day trading, which is based on analyzing high frequency data by using a technical approach.

7. Concluding remarks

In this paper, we have tested two hypotheses for the euro/dollar exchange rate. The first hypothesis, which is tested in the context of the present-value monetary model, examines whether the portfolio balance effect, operating through asset supplies of US and euro area, has an impact on the exchange rate beyond the impact of the monetary fundamentals. The second hypothesis, which is tested in the context of a reduced-form equation, examines whether the sterilized intervention of developing and emerging countries has an impact on the exchange rate through the signaling channel of the relative composition of official reserves.

The pure monetary model, which underlies the null hypothesis in the first case, is not statistically rejected by the data. In addition, the monetary fundamentals have information content that helps predict the exchange rate. This result, which is not needed by the monetary model, is quite helpful for the purpose of our analysis in that the predicted value of the exchange rate incorporates valuable information associated with the monetary fundamentals. Under the alternative hypothesis that there exists a risk premium, any additional explanatory power for the exchange rate should be the result of portfolio adjustments. The empirical analysis has revealed that the relative debt ratio has a statistically positive impact on the exchange rate beyond the impact of the monetary fundamentals.

The analysis of the second hypothesis shows that the relative reserve ratio, which proxies the intervention policy of emerging and developing countries, is highly significant and has the expected sign, implying that the sterilized intervention operates through the signaling channel. As the center of gravity of the world economy shifts towards the developing and emerging economies, which account for the largest share in international reserves, their willingness to diversify a significant part of their reserve holdings away from dollar and toward the euro assets is an important factor which could influence the future of the dollar as the major reserve currency.

Finally, the Clark-West testing procedure indicated that the model, which relates the exchange rate to official reserves and the interest rate differential, outperforms the random walk model in the forecasting accuracy.

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Table 1: The Quandt Likelihood Ratio test statistic for a structural break point

Variables	*e*	*z*	*d*	*r*
F-test	8,56***	15,62***	6,57**	16,43***
Break point	2002(2)	2005(1)	2002(3)	2002(2)

*** $p \le 1\%$, , ** $p \le 5\%$

Table 2: Unit root tests with structural breaks

	Constant	time	x(t-1)	DU	DT	$\sum_1^4 \theta_j$
e	-0,71	-0,004	-0,40	0,06		
	(-3,87)***	(-3,40)***	(-4,88)***	(2,28)		
z	-0,71	-0,004	-0,29	-0,06	0,004	
	(-4,39)***	(-3,91)***	(-4,32)**	(-6,15)***	(5,14)***	
d	-0,20	-0,01	-0,75	-0,03	0,02	3,18
	(-2,65)**	(-1,61)	(-4,12)**	(1,50)	(2,27)**	(4,062)***
r	0,58	-0,01	-0,38	-0,14	0,01	
	(6,96)***	(-2,17)***	(-7,60)***	(-3,90)***	(2,03)*	

Note: The numbers in parentheses are the values of the *t*-ratios. A maximum order of 4 lags was set up and the *F*-statistic was used to test the significance of the lag structural. If the 4 lags were insignificant, they were deleted from the estimated equation. In the case of the interest rate differential, which does not exhibit a structural break, the unit root hypothesis was tested by means of the ADF, ADF-GLS (Elliott, Rothenberg and Stock (1996)) and KPSS statistics (Kwiatkowski, et all, (1992)). The calculated *t* statistics were -3,52, -2,96 and 0,33 respectively, indicating that the interest rate differential is stationary. The critical values for the ADF test obtained from Mackinnon (1996).

*** $p \leq 1\%$, ** $p \leq 5\%$, * $p \leq 10\%$

Table 3: The effect of portfolio balance on the exchange rate

$$e_t - \bar{e}_t = (1 - \xi_0)e_t + \sum_{j=1}^{k} \xi_j e_{t-j} + \sum_{j=0}^{k} \psi_j z_{t-j} + \sum_{j=0}^{k} \zeta_j d_{t-j}$$

$1 - \xi_0$	$\sum_{j=1}^{k} \xi_j$	$\sum_{j=0}^{k} \psi_j$	$\sum_{j=0}^{k} \zeta_j$	$\psi_j = 0$	$\zeta_j = 0$
	***t(32)* test**			***F(2,32)* test**	
0,72	-0,60	0,14	0,07	18,41***	10,45***
(11,39)***	(3,06)***	(3,65)***	(6,04)***		

Diagnostic tests
Adjusted_R^2=0,69; *SEE*=0,022; *Ljung-Box Q test for serial correlation*: $\chi^2(19)$=26,14[p=0,13]
Test for null hypothesis of normal distribution: $\chi^2(2)$=0,18[p=0,91]

Note: Heteroscedasticity-autocorrelation robust standard errors are used. Numbers in parentheses are t-ratios. NO is the test for null hypothesis of normal distribution, *** $p \leq 1\%$.

Table 4: Testing the signaling hypothesis of sterilized intervention

$$e_t = \varphi_0 + \varphi_1 e_{t-1} + \sum_{j=1}^{k} \varphi_{2j} r_{t-j} + \sum_{j=1}^{k} \varphi_{3j}(i_{t-j} - i^*_{t-1})$$

φ_0	φ_1	$\sum_{j=1}^{k}\varphi_{2j}$	$\sum_{j=0}^{k}\varphi_{3j}$	$\varphi_{2j}=0$	$\varphi_{3j}=0$
		t(23) **test**		***F(6,23)*** **test**	
0,57 (9,49)***	0,37 (5,74)***	-0,57 (-9,40)***	-0,04 (-5,23)***	18,20***	12,15***

Diagnostic tests
*Adjusted_*R^2=0,9547; *SEE*=0,038; *Ljung-Box Q test for serial correlation*: χ^2(19)=18,84[*p*=0,47]
Test for null hypothesis of normal distribution: χ^2(2)=2,004[*p*=0,37]
Unit root tests for regression residuals: *DF*=-5,86***, *ADF-GLS*=-5,98***, *KPSS*=0,03***.

Note: Heteroscedasticity-autocorrelation robust standard errors are used. Numbers in parentheses are t-ratios, *** $p \leq 1\%$.

Figure 1. The dollar price of the euro (in logarithms)

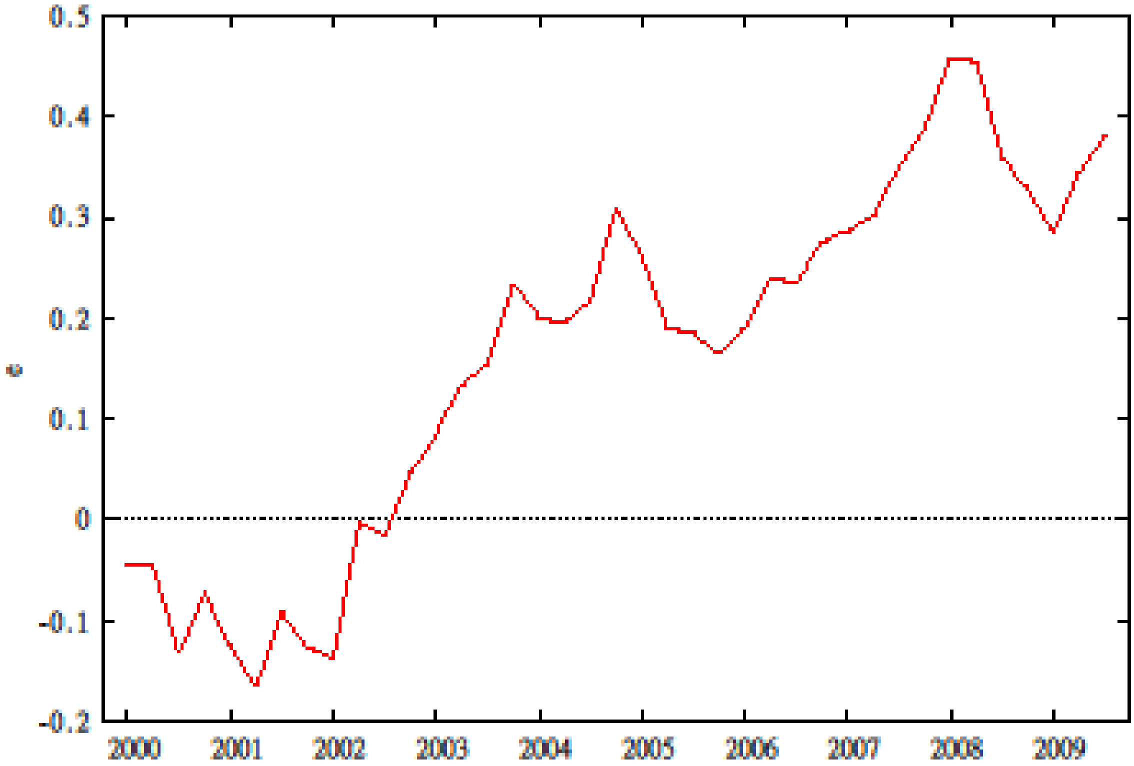

Figure 2. The difference between the monetary fundamentals of US and euro area

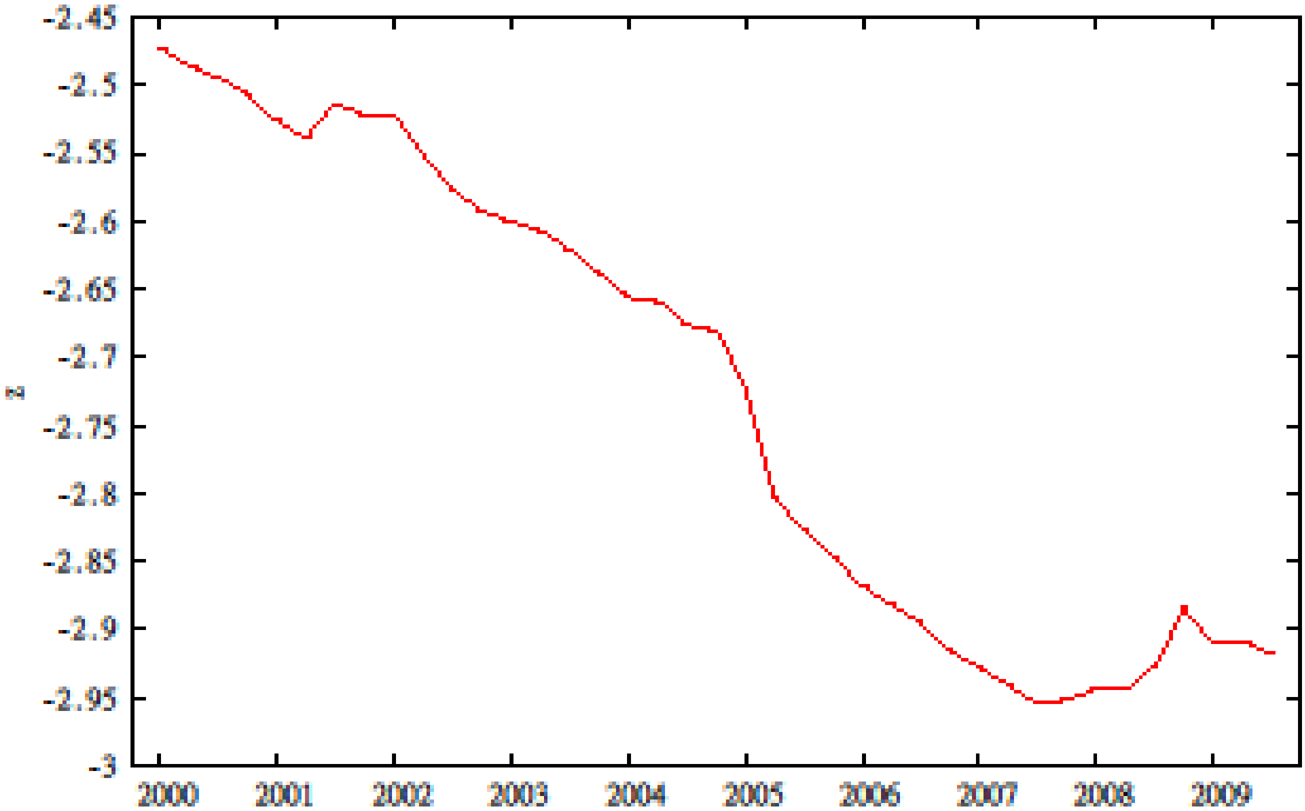

Figure 3. The debt differential between US and euro area (in logarithms)

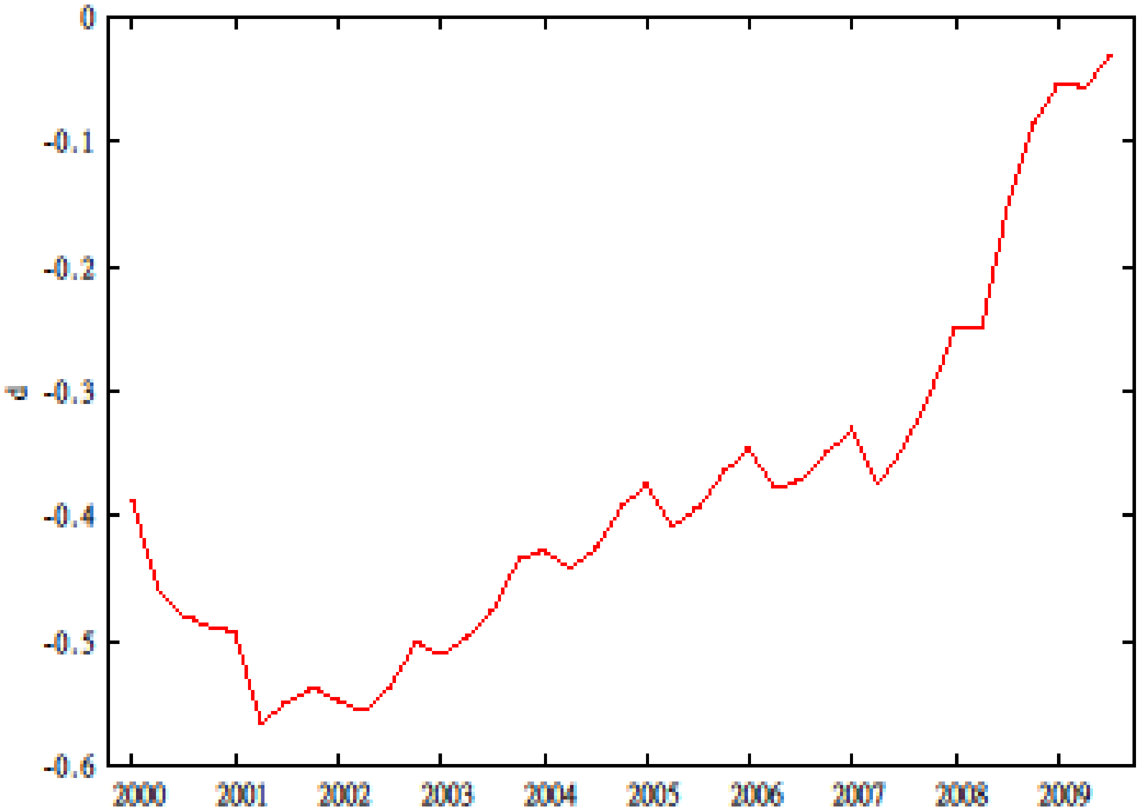

Figure 4. The reserve ratio of dollars to euro claims (in logs)

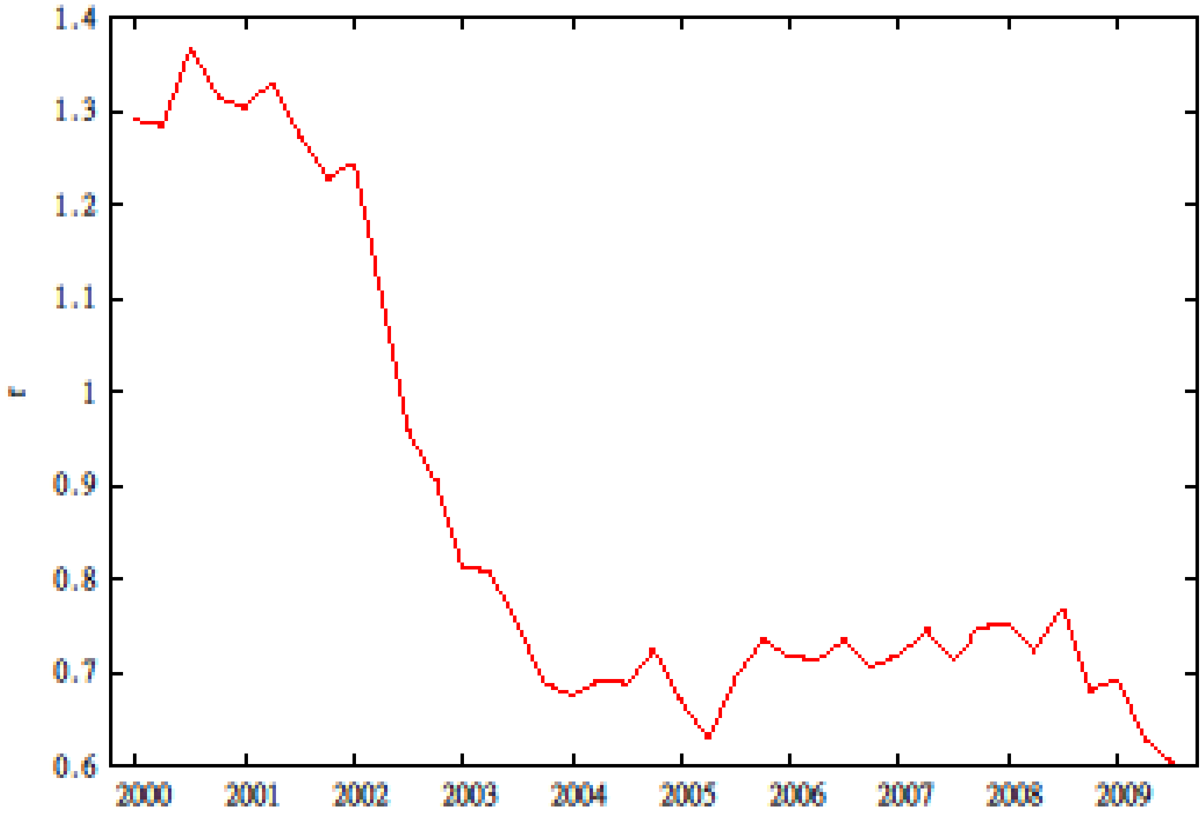

Figure 5. Actual and fitted values of the exchange rate model

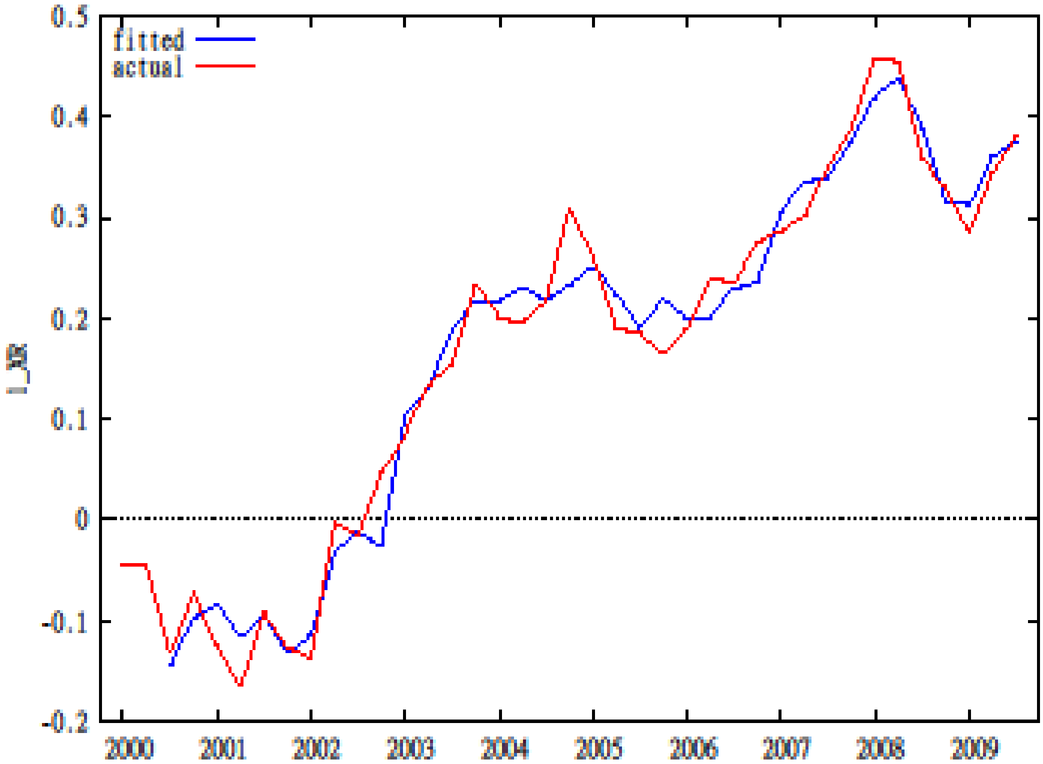

Figure 6. Regression residuals of the exchange rate model