

Third-Currency Effects in a Tri-Polar Model of Foreign Exchange^{*}

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Abstract

This paper investigates possible contribution of third-currency effects to exchange rate movements. It reopens the subject of currency substitution and examines whether the third-currency effects change when the third-currency is a complement as opposed to when it is a substitute for currencies appearing in a bilateral exchange rate quote. The analysis and tests are carried out within a simple macro-econometric model with one common permanent component driving the system of bilateral exchange rates for the US dollar, the Japanese yen and the euro.

Keywords: Exchange Rate Modeling, Currency Substitution, Third-currency Effects

JEL Classification: F31, F36, F42

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1 Introduction

Recent studies of empirical models of exchange rates, see e.g. Cheung et al. (2003a, 2003b), reveal that models of the nineties do not do any better job than those of the seventies, Meese and Rogoff (1983), in terms of their forecasting ability relative to a naïve random walk. One strand of the literature thus focused on models in which the exchange rate is thought of as an asset price; see e.g. Engel and West (2004). Such models are then able to generate random walk behavior of exchange rates under plausible assumptions and to some extent demonstrate existence of reverse causality from exchange rates to fundamentals. Nevertheless, one of the conclusions Engel and West (2004) make is that there are likely to be other unobserved factors affecting the exchange rate.

One candidate factor is third-currency effects. Brandt et al. (2003), Kingston and Melecky (2003), MacDonald and Marsh (2004), and Nucci (2003) find significant evidence of third-currency effects on exchange rates. Hodrick and Vassalou (2002) demonstrate third-country effects for bond yields, in addition. Brandt et al. start from an identity postulating that exchange rates depreciate by the difference between domestic and foreign marginal utility growth. They argue that marginal utility growth implied by the equity premia requires much more variation in exchange rates to what we observe. This indicates significant correlation of marginal utilities across countries. Hence, the third-currency effects may be significant components of the pricing kernels for exchange rates. Kingston and Melecky offer theoretical justification of third-currency effects based on non-separable currency preferences. Their empirical findings are in line with such theory. MacDonald and Marsh look at currency spillovers in a setup of three

major currencies similar to that introduced in this paper. They find significant spillovers from third-currencies fundamentals. Further, if the spillover effects are incorporated in the short-run models of exchange rate dynamics they are able to beat a random-walk forecast of the exchange rates over relatively short horizons. They do not consider the term structure of interest rates, though, and do not relate their results to the subject of currency substitution, as we do in this paper. Similarly, Nucci finds some evidence that the term structures of forward premiums of third currencies contain significant information for exchange rate forecasting in addition to information in the currency's own forward premium. Hodrick and Vassalou find that their multi-country models help to explain exchange rate dynamics better than their two-country counterparts and that the third-country effects appear to be significant in most cases considered.

This paper reopens the subject of currency substitution by examining whether third-currency effects can be linked to currency substitution or currency complementarity. The analysis and hypotheses tests are carried out within a simple macro-econometric model with one common permanent component driving the system of bilateral exchange rates for the US dollar, the Japanese yen and the euro. We find evidence of currency complementarity between the yen and the euro and currency substitution of the dollar for both the euro and the yen. Moreover, the third-currency effects exhibit a pattern consistent with our findings on the degree of complementarity and substitution among the three currencies.

The paper is organized as follows. Section two outlines the model and its properties. Section three describes the data and its organization, and presents unit root tests. In section four the estimations are carried out and commented on.

Section five contains tests and discussion on currency substitution, complementarity and third-currency effects. Section six concludes.

2 The Model

Consider uncovered interest parity (UIP) for each of the three major currencies expressed in levels of the current spot rates:

$$\begin{bmatrix} s_{1t} \\ s_{2t} \\ s_{3t} \end{bmatrix} = E_t \begin{bmatrix} s_{1t+1} \\ s_{2t+1} \\ s_{3t+1} \end{bmatrix} + \begin{bmatrix} i_{1t}^* - i_{1t} \\ i_{2t}^* - i_{2t} \\ i_{3t}^* - i_{3t} \end{bmatrix} \quad (1)$$

where s_t is the spot rate defined in terms of the direct quotation, i.e. the domestic currency over the foreign currency, and i_t and i_t^* are the domestic and foreign interest rates corresponding to the period over which the UIP is defined.

Assume further that an endogenous system of the three major currencies is governed by a single common factor, f_t :

$$\begin{bmatrix} s_{1t} \\ s_{2t} \\ s_{3t} \end{bmatrix} = \mathbf{J}f_t + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix} \quad (2)$$

where \mathbf{J} is a $3 \times (3 - r)$ matrix of coefficients and \mathbf{u}_t is a vector of shocks. The number r is given as a difference between the number of the spot rate series (three) and the assumed number of common factors (one). This gives us r of two co-integrating vectors we expect to find. The common factor is thus thought of as being equivalent to the common permanent component (the common trend). The common factor is assumed to be a function of a set of arbitrage conditions that eliminate any opportunities of a risk free return. The set of arbitrage conditions is the vector of UIP conditions outlined in (1).

Consider now the conditional expectation of the vector of the $t + 1$ period spot rates. We assume that the information set contains variables that summarize current information in other exchange rate markets, i.e. the remaining two bilateral spot rates, the long-run equilibria given by the corresponding purchasing power parities (PPP), and information on the prospects of the economy associated with a given currency in the system. The latter is assumed to be captured by the yield curve spread. The three pieces of information delivered by the spot rates, the yield curve spread and PPP correspond to short-run, medium-run and long-run equilibrium rates, respectively. In an unrestricted form the conditional expectation is expressed as:

$$E_t \mathbf{s}_{t+1} = g(\mathbf{s}_t, \mathbf{y}\mathbf{c}_t, \mathbf{p}_t) \quad (3)$$

where \mathbf{p}_t is a vector of price levels in a given economy. $\mathbf{y}\mathbf{c}_t$ is a vector of yield curve spreads defined as $\mathbf{y}\mathbf{c}_t \equiv \mathbf{r}_t - \mathbf{i}_t$ with \mathbf{r}_t being a vector of long-term interest rates, i.e. the maturity of the asset corresponding to r_t is greater than the maturity of the asset corresponding to i_t . Assuming the function $g(\cdot)$ is linear we can write $E_t \mathbf{s}_{t+1}$ as:

$$E_t \mathbf{s}_{t+1} = \Phi_1 \mathbf{s}_t + \Phi_2 (\mathbf{r}_t - \mathbf{i}_t) + \Phi_3 \mathbf{p}_t \quad (4)$$

where the Φ 's are 3×3 coefficient matrices all elements of which are unrestricted. Putting together (1), (2) and (4) gives:

$$\begin{aligned} (\mathbf{I} - \mathbf{J}\Phi_1) \begin{bmatrix} s_{1t} \\ s_{2t} \\ s_{3t} \end{bmatrix} &= \mathbf{J}'\Phi_2 \begin{bmatrix} r_{1t} - i_{1t} \\ r_{2t} - i_{2t} \\ r_{3t} - i_{3t} \end{bmatrix} + \mathbf{J}'\Phi_3 \begin{bmatrix} p_{1t} \\ p_{2t} \\ p_{3t} \end{bmatrix} + \mathbf{J} \begin{bmatrix} i_{1t}^* - i_{1t} \\ i_{2t}^* - i_{2t} \\ i_{3t}^* - i_{3t} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix} \\ \mathbf{A} \begin{bmatrix} s_{1t} \\ s_{2t} \\ s_{3t} \end{bmatrix} &= \mathbf{B} \begin{bmatrix} i_{1t} \\ i_{2t} \\ i_{3t} \end{bmatrix} + \mathbf{C} \begin{bmatrix} r_{1t} \\ r_{2t} \\ r_{3t} \end{bmatrix} + \mathbf{D} \begin{bmatrix} p_{1t} \\ p_{2t} \\ p_{3t} \end{bmatrix} + \mathbf{J} \begin{bmatrix} i_{1t}^* \\ i_{2t}^* \\ i_{3t}^* \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{bmatrix} \end{aligned} \quad (5)$$

where $A = (I - J\Phi_1)$, $B = -(J + J\Phi_1)$, $C = J\Phi_2$ and $D = J\Phi_3$.

Given our assumption that the system in (5) is driven by a single permanent component we expect the $(I - J\Phi_1)$ matrix of coefficients to have a deficient rank. More specifically, we expect to find two co-integrating vectors for the variables in the system. This raises questions of how to identify this model and what currency should be selected as a common denominator. The identification issue will be discussed later but for now consider the choice of the unifying spot rate.

Given that we are dealing with three currencies, three different bilateral quotes can be formed. In addition, three pairs of the bilateral quotes can be put together such that each pair has its own unifying currency. For instance, in the case of bilateral quotes eur/usd and jpy/usd the unifying currency is the dollar. The unifying currency is however not restricted to appear in the denominator of the quote only. For example, eur/usd and eur/jpy have the euro as the unifying currency. In most studies the dollar is chosen as the unifying currency see e.g. MacDonald and Marsh (2004). We consider two possible unifying currencies, the US dollar and the euro, so that the results are not influenced by the specifics of only one currency, e.g. measurement errors¹.

For the purpose of estimation we assume that the variables on the RHS of equation (5) are all weakly exogenous and thus uncorrelated with the vector of shocks, u_t . We claim that the pass-through effect of the exchange rates on the price levels in the big economies considered here, i.e. the United States, the European Union and Japan, is negligible and thus assumed to be zero. Similarly,

¹ These can arise from, for instance, alignment errors.

we argue that the monetary policy rules in those big economies are of a Taylor rule type and do not involve exchange rates. Furthermore, we assume that the interest rates are not influenced implicitly either since the effect of the exchange rate on the output gap, i.e. its coefficient in the familiar IS equation, is close to zero. Finally, the exchange rate does not enter in any way the relationship describing the term structure of the interest rates².

3 Data Description and Unit Root Tests

The vector of the spot exchange rates, \mathbf{s}_t , comprises of logs of the EUR/USD, JPY/USD and EUR/JPY bilateral exchange rates. However, preceding the introduction of the euro in January 1999, the euro bilateral exchange rates are approximated by its DEM counterparts. The vector of prices in the three countries, \mathbf{p}_t , is approximated by logs of the consumption price indexes (CPIs). The two vectors of interest rates \mathbf{i}_t and \mathbf{r}_t , which are deemed to characterize the shorter and longer ends of the yield curve, respectively, are approximated by three-month and six-month LIBOR rates for the corresponding currencies. One-month LIBOR is not used here to approximate the shorter end of the yield curve due to problems with its availability. The LIBOR rates are employed as they are likely to be more market determined than corresponding national interest rates. The data spans the period from January 1983 to February 2004 and are obtained from the IMF's International Financial Statistic.

² Some support for the above assumptions can be found in McCarthy 2000, Valderama (2004) and Hufner and Schroder (2002).

We test for the order of integration of the series by employing the ADF-GLS test proposed by Elliott, Rothenberg, and Stock (1996). This test improves on the low power of the conventional ADF test in finite samples by estimating the coefficients on the deterministic variables in the test specification prior to the estimation of the coefficient of interest. The results are reported in table 1:

****** Table 1 Here ******

All the variables appear to be integrated to order one, $I(1)$. Although there are good theoretical grounds suggesting that the interest rates should be stationary we should be better off by treating them as $I(1)$ if they appear to behave as such. The only difficulty in determining the order of integration is experienced when dealing with the U.S. *cpi* series which is found to be integrated to order even higher than $I(2)$. When applying other tests, e.g. ADF, KPSS, Ng-Perron, PP, the results are mixed as well. Since the conventional ADF test strongly rejects the hypothesis that the U.S. *cpi* series is integrated to order higher than $I(1)$, the series is regarded as $I(1)$ further on.

The lag length q for the system in equation (5) is determined in encompassing manner by applying the Hannan and Quinn's log iterated criterion (HQC). Paulsen (1984) shows that the HQC along with the Schwartz information criterion (SIC) is a weakly consistent measure for determining the true lag order in the presence of unit roots (stochastic trends). Jacobson's (1990) Monte-Carlo study suggests that the HQC criterion shows greater accuracy in choosing the true lag compared to the SIC. We thus use the HQC to determine the lag order for the system in (5) considering a maximum of eight lags. The results are reported in table 2:

**** Table 2 Here ****

4 Estimations

4.1 Preliminary Estimation and Hypotheses Tests

The system of equations described in (5) is estimated using the autoregressive distributed lag approach (ARDL) to co-integration due to Pesaran and Shin (1995) and Pesaran et al. (1996). The error-correction form of the ARDL model is given by an equation where the dependent variable in first differences is regressed on the lagged values of the dependent and independent variables in levels and first differences.

$$\Delta \mathbf{y}_t = \phi \mathbf{y}_{t-1} + \beta \mathbf{x}_{t-1} + \sum_{j=1}^p \delta_j \Delta \mathbf{y}_{t-j} + \sum_{j=0}^q \gamma_{i,j} \Delta \mathbf{x}_{i,t-j} + \varepsilon_t \quad (6)$$

where \mathbf{y}_t is a $n \times T$ matrix of endogenous variables, \mathbf{x}_t is a $k \times T$ matrix of observations on the weakly exogenous variables and deterministic variables. The latter includes a constant and a shift dummy variable corresponding to the introduction of the euro in January 1999. $\Delta \mathbf{y}_{t-j}$ and $\Delta \mathbf{x}_{t-j}$ are the j -period lagged values of $\Delta \mathbf{y}_t \equiv \mathbf{y}_t - \mathbf{y}_{t-1}$ and $\Delta \mathbf{x}_t \equiv \mathbf{x}_t - \mathbf{x}_{t-1}$, respectively, and $\varepsilon_t \equiv (\varepsilon_1, \dots, \varepsilon_T)'$ is a $T \times 1$ vector of residuals. The disturbances ε_t are assumed to be independently distributed and independent of the regressors, i.e. $E(\varepsilon_t | \mathbf{x}_t) = 0$. The lag length p is chosen as described in section 3 and q is set to zero. Further, the underlying $ARDL(p, q)$ model is assumed to be stable, which ensures that $\phi < 0$, and thus there exists a long-run relationship between \mathbf{y}_t and \mathbf{x}_t defined as:

$$\mathbf{y}_t = -(\beta' / \phi) \mathbf{x}_t + \eta_t \quad (7)$$

where η_t is a stationary process. The coefficient standard errors are then obtained using the familiar *delta method*.

Applying the ARDL model to the system in (5) produces results presented in table 3. We report the parsimonious version of the estimations, i.e. all the insignificant variables are eliminated using the general-to-specific approach. At this stage we merely normalize on the spot rates before looking into full identification of the system for the two different cases where the unifying currencies are the dollar and the euro.

****** Table 3 Here ******

Before we turn to an estimation of the identified system and interpretation of the results we test some hypothesis that might increase efficiency of the estimation and introduce some well-established theoretical patterns. Namely, we test whether PPP can be imposed on the data, whether UIP holds, whether there is significant information coming from other markets (market efficiency) and overall significance of the third-currency effects on a given bilateral exchange rate. Market efficiency is tested by making the coefficients of the other two bilateral quotes equal and opposite. Third-currency effects are tested by setting all the coefficients of the variables related to the third currency to zero. Outcomes of the tests are reported in table 4:

****** Table 4 Here ******

The test of the PPP hypothesis is applicable only to the pairs of eur/jpy and jpy/usd. Let us explain the test on the case of eur/jpy. When PPP is tested in the eur/jpy equation $s_t = (\text{eur/jpy})_t$ and the null hypothesis (H0) is $d_{11} = -d_{12}$ where the latter two are the corresponding elements of the matrix \mathbf{D} in equation (5). When the strict PPP is tested the H0 is set to be $d_{11} = 1 \wedge d_{12} = -1$. Both hypotheses are accepted in the case of eur/jpy and rejected for jpy/usd.

Testing of UIP is only applicable to the parsimonious equations for eur/usd and jpy/usd. When UIP is tested $s_{2t} = (\text{eur/usd})_t$ and the H0 is $b_{21} = -d_{22}$. When the strict UIP is put to a test the H0 is $b_{11} = -1 \wedge b_{22} = 1$ consistently with the logic of equation (1). Both UIP versions are rejected for eur/usd and the strict UIP is rejected for jpy/usd.

The market efficiency is tested for all the pairs. When $s_{1t} = (\text{eur/jpy})_t$ the H0 of market efficiency is formulated as $a_{12} = -a_{13}$. When the strict version of market efficiency is tested the H0 is set to $a_{12} = 1 \wedge a_{13} = -1$. If the H0 is not rejected one can write

$$\begin{aligned} \text{eur}_t - \text{jpy}_t &= a_{12}(\text{eur}_t - \text{usd}_t) - a_{12}(\text{jpy}_t - \text{usd}_t) \\ &= a_{12}(\text{eur}_t - \text{jpy}_t) \end{aligned} \quad (8)$$

and in this case the two other pairs, i.e. eur/usd and jpy/usd cancel out. One may think of this test as revealing some kind of a measurement error and there is no significant information coming from the other exchange rate markets. The case when $a_{12} = 1$ is then analogous and one gets

$$\text{eur}_t - \text{jpy}_t = (\text{eur}_t - \text{usd}_t) - (\text{jpy}_t - \text{usd}_t) = \text{eur}_t - \text{jpy}_t \quad (9)$$

producing a true statement that postulates efficiency of the associated exchange rate market. The strict version of market efficiency is rejected in all cases, however, the weaker version is accepted for the pair eur/usd. Hence the latter can be regarded as having the most efficient market among the three pairs considered.

Finally, significance of third-currency effects for each exchange rate is tested as follows. For instance, when $s_{1t} = (\text{eur/jpy})_t$ the H0 becomes $a_{13} = b_{13} = c_{13} = d_{13} = j_{13} = 0$. The H0 is rejected for all pairs so that the third-currency effects are indeed important for the development of each of the exchange rates.

4.2 Estimation of the Identified System

Using the preliminary estimations and hypotheses tests carried out in the preceding section we can now progress to the system identification and estimation. The assumption that the system described in (5) is driven by one common permanent component implies that we have to deal with two co-integrating vectors. The theoretical assumption is supported by the trace and maximum-eigenvalue co-integration rank tests (see e.g. Johansen, 1995). Results of the tests are shown in table 5:

****** Table 5 Here ******

Hence we have to impose a set of two restrictions on each of the two co-integrating vectors to identify them. In addition, the two sets of restriction are required to be independent of each other. Considering two cases with different unifying currencies, the euro and the dollar respectively, we impose following restrictions upon the matrix \mathbf{A} that are in line with the accepted hypotheses:

$$\mathbf{A}_{eur} = \begin{bmatrix} 1 & 0 & \beta_1 \\ \beta_2 & 1 & \beta_2 \end{bmatrix} \quad \text{and} \quad \mathbf{A}_{usd} = \begin{bmatrix} \beta_3 & 1 & \beta_3 \\ \beta_4 & 0 & 1 \end{bmatrix} \quad (10)$$

Again the general-to-specific approach is adopted. The resulting estimates of the identified system are provided in table 6:

****** Table 6 Here ******

The estimates in table 6 suggest that significant information about the development of the eur/jpy and jpy/usd rates come from the complementary markets trading jpy/usd and eur/jpy, respectively. The short-term interest rates seem to considerably influence the eur/jpy and eur/usd pairs with the LIBOR on the dollar playing the major role. On the other hand, the pair jpy/usd appears to be almost unaffected by the changes in the short-run rates. The longer-term

interest rates impact on all the pairs with the euro and the dollar rates dominating. All the exchange rates are affected by changes in the national price levels where the coefficients on the Japanese CPI are significantly higher than the corresponding coefficient for the US and EU CPI's.

In general, the estimations seems to deliver a significant evidence on the importance of the third-currency effects, i.e. changes in fundamentals associated with currencies that do not appear in quotation of the bilateral exchange rates. We have not discussed much the signs, i.e. direction, of the estimated effects up to this point. In this respect one should be curious about whether some general patterns can be detected and put into some perspective. For this reason let us now consider conditions of currency substitution and complementarity for some guidance.

5 Currency Substitution and Complementarity

Brittain (1981) introduced an informal graphical test for currency substitution. Such a graphical tool has been recently augmented by Kingston and Melecky (2004) to inspect both currency substitution and complementarity. A comparison of velocities of monetary aggregates associated with the currencies of interest is the focal point here. Currencies should be considered elements of internationally diversified portfolios. *Ceteris paribus*, an increase in demand for (velocity of) one currency, presumably due to a relative higher expected yield, would induce portfolio reallocation according to relative characteristics of its individual elements. As a result the velocity of currency substitutes falls and the velocity of currency complements rises, according to the degree of substitution or

complementarity between given currencies. Considering e.g. the euro and the US dollar, rising velocity of US quasi money contrasted with falling velocity of EU quasi money suggests that there is substitution between the euro and the dollar. In the same manner, significant co-movements of specified velocities would suggest currency complementarity between the two currencies.

The velocity is calculated as $v_t = gdp_t - mq_t$ where gdp is the log of nominal GDP and mq is the log of the quasi money supply in a given country. We chose quasi money since this type of money is more related to the speculative demand which we believe has a major influence on the exchange rate development. In addition, we present a comparison of step-wise (recursive) correlations between the differences in velocities of national quasi money aggregates for the EU, the US and Japan. The correlation-coefficient estimates over the period 1975:Q1 to 2003:Q4 are (standard errors in brackets):

$$\rho(eu, jap) = 0.121_{(0.095)}, \quad \rho(eu, us) = -0.195_{(0.094)}, \quad \rho(jap, us) = -0.035_{(0.095)}$$

Plots of the velocities and the estimated recursive correlations are available in figure 1:

****** *Figure 1 Here* ******

The recursive correlation coefficients for the pair of the EU and Japan velocities suggest that currency complementarity is present. The estimates are only marginally significant, though. On the other hand, the recursive correlation between the EU and the US velocities imply a significant currency-substitution relationship. Finally, the pair of velocities in Japan and the US produces recursive correlation coefficients implying currency substitution between the yen and the

dollar. The correlations are, however, rather insignificant. This leaves us with inconclusive results for the yen versus the dollar.

In the next exercise we look at the levels of the series and regress the velocities against each other in accord with the bilateral quotes. We use the fully modified OLS (FMOLS) due to Phillips and Hansen (1990) that corrects for the bias that emerges when two variables with a unit root are consistently estimated by OLS. The results are summarized below:

$$\begin{aligned}
 v_t^{EU} &= 0.792 v_t^{JAP} - 2.197 \\
 &\quad (0.193) \quad (0.615) \\
 v_t^{EU} &= -0.538 v_t^{US} - 0.535 \\
 &\quad (0.353) \quad (0.140) \\
 v_t^{JAP} &= -0.936 v_t^{US} - 3.550 \\
 &\quad (0.291) \quad (0.116)
 \end{aligned} \tag{11}$$

These results assert the conclusions we have derived from the pair-wise correlation between the differences of the velocities. Namely, that the Japanese yen and the euro appear to be currency complements and that the US dollar acts as a substitute for both the Japanese yen and the euro.

Now, let us return to the estimation results presented in table 6 and see whether the information on currency substitution and complementarity can help us reveal some systematic patterns. We summarize the signs on the fundamentals associated with each economy in table 7:

****** Table 7 Here ******

The insight one should get from table 7 can be explicated in the following way. We first consider the interest rates related to the currencies in the bilateral exchange-rate quote and later move on to the third-currency effects.

The unconditional effect of the short-run interest rates on the exchange rate is expected to be in line with the UIP, i.e. $s_t = \varphi_1 i_t - \varphi_2 i_t^*$ where $\varphi_1 > 0$ and $\varphi_2 > 0$, and in ideal case $\varphi_1 = \varphi_2 = 1$. However, one should bear in mind that this fundamental relationship in international finance is based on currency substitution and not currency complementarity. One can expect that in the case of currency complements one currency will dominate another. If for instance, $s_t = (\text{eur/jpy})_t$ and the euro was the dominating currency then one would expect that in $s_t = \varphi_1 i_t - \varphi_2 i_t^*$ (φ_1, φ_2 unrestricted) $|\varphi_1| \gg |\varphi_2|$ and φ_2 would be not significantly different from zero and rather negative. This comes from the fact that the feature of currency complementarity or substitution is independent of relative yields and thus the effect of interest rate differential is secondary in such relationships. Now, we augment the UIP identity so that it includes the yield curve spread, $r_t - i_t$, and thus encompasses a part of the term structure. The stylized equation is arranged in such a way that it is in line with the UIP logic:

$$s_t = \varphi_2 (r_t^* - i_t^*) - \varphi_1 (r_t - i_t) = \varphi_1 i_t - \varphi_2 i_t^* - \varphi_1 r_t + \varphi_2 r_t^* \quad (12)$$

The analogue for the complementary currencies emphasizing the expected signs is:

$$s_t = \varphi_2 (r_t^* - i_t^*) + \varphi_1 (r_t - i_t) = \varphi_1 i_t + \varphi_2 i_t^* - \varphi_1 r_t - \varphi_2 r_t^* \quad (13)$$

Turning over to the third-currency effects, the expected impact is dependent again on whether the third currency is a complement to or a substitute for the currencies in the quote. For instance, if we add the third-currency effects associated with the US dollar to the equation describing the eur/jpy exchange rate one would expect the coefficients' signs on the dollar interest rates to be opposite to those on the euro and the yen interest rates.

The results summarized in table 7 are strongly consistent with what we have just outlined. Further more, the support coming from the pairs eur/jpy and eur/usd is substantial, in case of the short-run rates perfectly matching the outlined scheme. Although we obtain some evidence of price-level effects, derivation of some general patterns is rather difficult since we have been able to establish PPP only for the eur/jpy rate. The attempt to identify the PPP for the estimated vectors can be to some extent complicated by the recent long-lasting deflationary pressures in Japan.

Given our setup, the obtained results can be to a certain degree compared with those of MacDonald and Marsh (2004) and Hodrick and Vassalou (2003). MacDonald and Marsh (pp. 105, table 2, column 1 and 2) find, judging by the signs on the interest rates, that the mark and the dollar appear to be substitutes as in our case. On the other hand, the yen and the dollar appear to be rather complements than substitutes. Since they do not report how significant the coefficient estimates are the results for Japanese yen seems indecisive owing to the relatively small magnitude of the estimates. Hodrick and Vassalou examine the short-run dynamics of exchange rates and work with restricted interest rate differentials. They find (pp. 1284, table 2) some evidence of currency complementarity between the Japanese yen and the German mark where the mark seems to be the dominating currency, as in our case. This relationship appears equivocal, though, when cross rates to the British pound are used.

6 Conclusion

We have investigated third-currency effects on exchange rates. In addition, we have examined whether the third-currency effect changes when the third currency is a complement as opposed to when it is a substitute for currencies appearing in a bilateral exchange rate quote. We find evidence of significant third-currency effects when looking at the system of three major currencies, i.e. the US dollar, the euro and the Japanese yen. We have established some patterns for the expected coefficients' signs attached to the long-term and short-term interest rates in exchange rate models when currency substitution and/or currency complementarity is present. In this respect we find that the Japanese yen complements the euro and that the dollar acts as a substitute for both the euro and the yen.

It would be interesting to see whether the third-currency effects, once included in exchange rate models, increase forecasting performance of such models. Similarly, employing the information on currencies complementarity or substitution as data derived priors for forecasting models is another interesting exercise that we would like to consider in our future research.

References

- [1] Boyer, R. S., Kingston, G. H. (1987). Currency Substitution under Finance Constraints. *Journal of International Money and Finance* 8, 235-250.
- [2] Brandt, M.W., Chochrane, J.H., Santa-Clara, P. (2003). International Risk Sharing is Better Than You Think, or Exchange Rates are Too Smooth. *Journal of Monetary Economics*, forthcoming.
- [3] Brittain, B. (1981). International currency substitution and the apparent instability of velocity in some European economies and in the United States. *Journal of Money, Credit and Banking* 13, 135-155.
- [4] Cheung, Y., Chinn, M. D., Pascual, A. G. (2003a). Empirical Exchange Rate Models of the Nineties: Are Any Fit to Survive? Department of Economics, University of California, Santa Cruz.
- [5] Cheung, Y., Chinn, M. D., and Pascual, A. G. (2003b). What Do We Know about Recent Exchange Rate Models? In-Sample Fit and Out-of-Sample Performance Evaluated. CESifo Working Paper 902.
- [6] Elliott, G. - Rothenberg, T. - Stock, J. H. (1996). Efficient Tests for an Autoregressive Unit Root. *Econometrica*, vol. 34, p. 813-836.
- [7] Engel, C., West, K. D. (2004). Exchange Rate and Fundamentals. *Journal of Political Economy*, forthcoming.
- [8] Hufner, F. P., Schroder, M. (2002). Exchange Rate Pas-Through to Consumer Prices: A European Perspective. Centre for European Economic Research Working Paper, 02-20.
- [9] Hodrick, R., Vassalou, M. (2002). Do we need multi-country models to explain exchange rate and interest rate and bond return dynamics? *Journal of Economic Dynamics and Control* 26, 1275-1299.
- [10] Jacobson, T. (1990). On the Determination of Lag Order in Vector Autoregressions of Co-integrated Systems. *Computational Statistics*, 10, 177-192.
- [11] Johansen, S. (1995). *Likelihood-based Inference in Co-integrated Vector Autoregressive Models*, Oxford University Press.
- [12] Kingston, G. – Melecky, M. (2003). Currency Preferences and the Australian Dollar. University of New South Wales, Sydney, unpublished.
- [13] MacDonald, R., Marsh, I., W. (2004). Currency Spillovers and Tri-Polarity: a Simultaneous Model of the U.S. Dollar, German Mark and Japanese Yen. *Journal of International Money and Finance*, 23, 99-111.

- [14] McCarthy, J. (1999). Pass-Through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialized Economies. The New York Area Macroeconomics Workshop, Federal Reserve Bank of New York.
- [15] Meese, R. – Rogoff, K. (1983). Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample? *Journal of International Economics* 14, 3-24.
- [16] Nucci, F. (2003). Cross-Currency, Cross-Maturity Forward Exchange Premiums as Predictors of Spot Rate Changes: Theory and Evidence. *Journal of Banking and Finance* 27, 183-200.
- [17] Paulsen, J. (1984). Order Determination of Multivariate Autoregressive Time Series with Unit Roots. *Journal of Time Series Analysis*, 5, 115-127.
- [18] Pesaran, M. H. – Shin, Y. – Smith, R. J. (1996). Testing for the Existence of a Long-Run Relationship. DAE Working Paper, 9622, Cambridge University.
- [19] Pesaran, M.H. – Shin, Y. (1995). An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis. DAE Working Paper, 9514, Cambridge University.
- [20] Phillips, P. C. B. – Hansen, B.E. (1990). Statistical Inference in Instrumental Variables Regression with I(1) Processes. *Review of Economics Studies*, 57.
- [21] Valderrama, D. (2004). Does a Fall in the Dollar Mean Higher U.S. Consumer Prices? *FRBSF Economic Letter*, 21, (August 13).

Tables

Table 1 Unit Root Tests

Variable	Unit root test: ADF-GLS	
	Levels	1 st differences
eur/usd	C,T,0[-1.4102]	C,0[-16.6871]***
jpy/usd	0[-1.4627]	0[-15.4114]***
eur/jpy	C[0.2355]	C[-12.3874]***
p_eu	C,T,1 [-0.3495]	C,0[-13.0747]***
p_jap	C,12[-0.1252]	11[-1.9855]**
p_us	C,T,12[-1.5212]	C,11[-0.2542] C,1[-7.0513]***
i_eu	C,2[-0.4318]	1[-9.1717]***
i_jap	C,3[-0.2509]	2[-8.1040]***
i_us	C,8[-0.7128]	7[-5.8260]***
r_eu	C,2[-0.5511]	1[-8.8249]***
r_jap	C,0[0.3223]	0[-16.7137]***
r_us	C,8[-0.6070]	7[-5.9078]***

Table 2 Lag Length Selection for Endogenous Variables

Variable	Selected Lag Length in Equation		
	eur/usd	jpy/usd	eur/jpy
eur/usd	1	1	1
jpy/usd	2	1	1
eur/jpy	1	1	1

Table 3 Estimation of the Under-Identified System in (5)

Variable	eur/jpy	eur/usd	jpy/usd
eur/jpy	-1	0.6175 (0.1194)***	1.1536 (0.1747)***
eur/usd	-----	-1	-----
jpy/usd	0.5451 (0.0810)***	-0.68139 (0.1137)***	-1
i <i>currency 1</i>	0.0363 (0.0087)***	0.4001 (0.1621)***	-----
i <i>currency 2</i>	0.2085 (0.1077)**	-0.3326 (0.1189)***	-----
i <i>currency 3</i>	-0.2037 (0.0619)***	0.0571 (0.0226)***	-----
r <i>currency 1</i>	-----	-0.4482 (0.1685)***	-----
r <i>currency 2</i>	-0.25002 (0.1069)**	0.3167 (0.1212)***	-----
r <i>currency 3</i>	0.2275 (0.0621)***	-----	0.0221 (0.0121)*
p <i>currency 1</i>	2.1821 (0.7331)***	-----	-3.2952 (1.4424)**
p <i>currency 2</i>	-1.5666 (0.4091)***	1.4898 (0.5848)***	1.2960 (0.6886)*
p <i>currency 3</i>	-1.1215 (0.4310)***	-2.6474 (1.2642)**	-----
D99	-0.5469 (0.0352)***	-----	0.5120 (0.0935)***
constant	-----	8.8053 (3.9633)**	13.2786 (3.8550)***

currency 1 is the currency quoted in the numerator of the relevant bilateral exchange rate, *currency 2* is the currency quoted in the denominator and *currency 3* is the currency that does not appear in the bilateral quote. Standard errors are in the parentheses. *, **, *** - stands for the significance at the 10 %, 5 % and 1 % level, respectively. ----- shows that a given variable is insignificant and was eliminated from the regression.

Table 4 Hypotheses Tests

Hypothesis	eur/jpy	eur/usd	eur/usd
PPP	1.5472 [0.214]	na	10.8748 [0.004]
Strict PPP	2.6534 [0.265]	na	5.6712 [0.017]
UIP	5.2544 [0.022]	0.2128 [0.645]	na
Strict UIP	14376.5 [0.000]	138.3199 [0.000]	na
Market Efficiency	45.2695 [0.000]	0.29548 [0.587]	43.5782 [0.000]
Strict Market Efficiency	45.2695 [0.000]	270.7667 [0.000]	43.5782 [0.000]
Third-currency Effect	293.2757 [0.000]	47.5558 [0.000]	43.6181 [0.000]

**** Table 5 on the next page ****

Table 6 Estimation of the Identified System

System Variable	Unifying Currency EUR		Unifying Currency USD	
	eur/jpy	eur/usd	eur/usd	jpy/usd
eur/jpy	-1	0.6491 (0.0984)***	0.6491 (0.0984)***	1.1536 (0.1747)***
eur/usd	-----	-1	-1	-----
jpy/usd	0.6201 (0.0462)***	0.6491 (0.0984)***	0.6491 (0.0984)***	-1
<i>i currency 1</i>	0.0293 (0.0082)***	0.3402 (0.1124)***	0.3402 (0.1124)***	-----
<i>i currency 2</i>	0.1883 (0.1063)*	0.34018 (0.1124)***	0.34018 (0.1124)***	-----
<i>i currency 3</i>	-0.2092 (0.0626)***	0.058652 (0.0215)***	0.058652 (0.0215)***	-----
<i>r currency 1</i>	-----	-0.39021 (0.1177)***	-0.39021 (0.1177)***	-----
<i>r currency 2</i>	-0.2351 (0.1065)**	0.31697 (0.1157)***	0.31697 (0.1157)***	-----
<i>r currency 3</i>	0.2311 (0.0624)***	-----	-----	0.0221 (0.0121)*
<i>p currency 1</i>	1	-----	-----	-3.2952 (1.4424)**
<i>p currency 2</i>	-1	1.4220 (0.5199)***	1.4220 (0.5199)***	1.2960 (0.6886)*
<i>p currency 3</i>	-0.5747 (0.0485)***	-2.3852 (1.1911)**	-2.3852 (1.1911)**	-----
D99	-0.5227 (0.0269)***	-----	-----	0.5120 (0.0935)***
constant	-----	7.7909 (3.8187)**	7.7909 (3.8187)**	13.2786 (3.8550)***

currency 1 is the currency quoted in the numerator of the relevant bilateral exchange rate, *currency 2* is the currency quoted in the denominator and *currency 3* is the currency that does not appear in the bilateral quote. Standard errors are in the parentheses. *, **, *** - stands for the significance at the 10 %, 5 % and 1 % level, respectively. ----- shows that a given variable is insignificant and was eliminated from the regression.

Table 5 Cointegration Rank Tests

H0	Eigenvalue	Trace Statistic	1 % Critical Value	Max-Eigenvalue Statistic	1 % Critical Value
r==0	0.246496	100.5539*	35.65	71.88729*	25.52
p <= 1	0.093381	28.66663*	20.04	24.90030*	18.63
p <= 2	0.014719	3.766328	6.65	3.766328	6.65

* denotes rejection of the hypothesis at the 1 % significance level

Table 7 Impacts of the Economic Fundamentals – a Summary

Coefficient/Equation	eur/jpy	eur /usd	jpy/usd
i eu	Positive	Positive	-----
i jap	Positive	Positive	-----
i us	Negative	Negative	-----
r eu	-----	Negative	Positive
r jap	Negative	----	-----
r us	Positive	Positive	-----
p eu	Positive	-----	-----
p jap	Negative	Negative	Negative
p us	Negative	Positive	Positive

Figures

Figure 1 Velocity Correlations – a Comparison

