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Currency substitution and money demand in Euroland

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This papers tests the stability of the demand for money in the euro area in the context of an open economy. A sample consisting of quarterly data covering the 1982:2-1999:3 period is considered. The main finding is that the US long term rate of interest plays a significant role in the European money demand relationship. This result holds for different combinations of variables forming the vector auto-regressive system. This evidence suggests that currency substitution vis-à-vis the US dollar may be an important factor influencing the ECB monetary policy.

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Key-Words: EMU, Money Demand, International Currencies, Currency Substitution.

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1. Introduction

Following the German tradition, the European Central Bank (ECB) assigns a “prominent role for money". Money is viewed as the nominal anchor of the Euro-system and the *First Pillar* of the ECB strategy. In accordance, a “reference value” for the rate of monetary expansion is being announced. Such "reference value" does not have the strength of an intermediate target (see ECB, 1999). Lack of controllability of the money supply over the short-run, uncertainty concerning the transmission mechanism in the Euro-system and the recognition that the launch of the euro would represent a significant structural break lead the ECB to adopt instead a weak type of money targeting, in which there is no commitment to correct deviations over the short-term. In addition, a *Second Pillar* (“a general assessment of price stability using a broad range of indicators”) was formulated, opening a window to less orthodox approaches to price stability. The ECB framework reflects, thus, a balance between continuity with the Bundesbank policy, so as to inherit credibility, and flexibility, as required to operate in the global environment. In any case, either as source of information or as intervention indicator, money has a major role in the ECB policy formulation.

Not surprisingly, the stability and information content of EU-wide monetary aggregates became a very topical issue in the research agenda (some references below; for a survey see Browne et al., 1997). This research benefited from the rapid development in the cointegration literature, which has raised the possibility of models combining traditional steady-state functions with complex short-term dynamics to be reasonably stable over periods of substantial institutional change. In general, empirical exercises addressing the stability and information content of monetary aggregates in the euro-area have been able to identify stable money demand relationships. Still, there is a controversy as to whether such stability is applicable to the post-EMU money demand. Indeed, since empirical studies have been based on constructed pre-EMU monetary aggregates, their validity has been questioned both in light of the Lucas critique and aggregation bias (discussions, for example, in Beyer et al. 2001, Arnold and de Vries, 2000, Fagan and Henry, 1999, Hayo, 1999, Spencer, 1997, Arnold, 1994).

This paper questions the information content of euro area monetary aggregates from a different angle. In a financial environment marked by absence of capital controls and growing international portfolio diversification, the agents’ ability to shift the location and the currency denomination of their asset holdings may have a destabilising impact on money demands. If the demand for money in Europe responds to monetary developments in US, then the rate of money growth in the euro-area may become a poor indicator of risks to price stability. To this aim, we investigate whether currency substitution vis-à-vis the US dollar applies to the European money demand. A money demand system for the euro-area is estimated and the currency substitution hypothesis is tested by the significance of the US long term interest rate in the long run money demand relationship. This test is consistent with the assumption of complete bond markets, as demonstrated by Thomas (1985), and briefly explained in Appendix 1. Previous tests for the currency substitution hypothesis using this approach include Bergstrand and Bundt (1990) and Mizen and Pentecost (1994). Experimenting alternative combinations of variables in the VAR system, we consistently obtain a significant and positive coefficient for the US long term interest rate in the euro-area money demand relationship. This evidence suggests that currency substitution vis-à-vis the US dollar may be an important factor influencing the ECB monetary policy.

The phenomenon of International Currency Substitution became a central issue in monetary economics and one that should increase importance in the future[1]. Technology and globalisation are blurring the distinction between national and international uses of money, opening a channel through which domestic money markets are exposed to shocks occurring abroad. This phenomenon is a matter of concern for policymakers, as it rises the unpredictability of the money demand and reduces the effectiveness of monetary policy. As argued by many authors, in the presence of currency substitution, a flexible exchange rate regime does not ensure monetary autonomy, as had once been thought[2].

In Europe, the CS debate was revived during the transition to EMU, giving rise to the so-called "indirect approach to CS" (see Artis, 1996, for a survey). Following this literature as capital controls were phased out in individual countries, residents' demand for monetary assets became increasingly influenced by European variables, raising the question as to

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[1] For a suggestive evidence, see Doyle (2000). The author estimated the amount of foreign-held US Dollars, Deutsche Marks and Swiss Franks for the period of the 1960s through the 1990s. The results obtained point to a sharp increase in the extent of world-wide currency substitution along the 1990s.

[2] The implications of currency substitution are discussed, for example, in Miles (1978), Karaken and Wallace, (1981), McKinnon, (1982), Boyer and Kingston (1987), Freitas (2000). For a survey, see Giovannini and Turtelboom (1994).

whether stable money demand functions could be estimated at the national level. As long as foreign currency holdings were denominated in European currencies, however, *internalisation* could be achieved by aggregating up (the argument backs from McKinnon, 1982). This question was addressed by Bekx and Tulio (1989), Kremers and Lane (1990), Bayoumi and Kenen (1993), Cassard et al. (1994) and Spencer (1997), who found that EU-wide monetary aggregates are indeed more stable and/or more helpful to predict national inflation rates than the correspondent national aggregates[3]. This evidence revived the confidence on the role of quantitative money targets and favoured the view that the ECB would be able to implement monetary policy more effectively than individual central banks[4].

A different question is whether CS vis-à-vis the US dollar remains as a potential source of instability. This question was subject to scrutiny in the first wave of estimates addressing EU-wide monetary aggregates (Bekx and Tullio, 1989, Kremers and Lane, 1990, Artis et al., 1993, Artis, 1996, Tullio et al., 1996, and Monticelly and Strauss-Khan, 1993). In this literature, ECU-dollar substitution was tested by the significance of a variable capturing the expected exchange rate depreciation in the money demand equation. This test has the inconvenient of relying on a proxy for the expected exchange rate depreciation. The proxies used were the long term interest rate differential in Bekx and Tullio (1989); the dollar-ECU *nominal* exchange rate in Kremers and Lane (1990); the *actual* exchange rate depreciation in Monticelly and Strauss-Khan (1993); and the dollar-ECU *real* exchange rate in Artis et al. (1993), Artis (1996) and in Tullio et al. (1996). Regardless the quality of the proxies used, it is remarkable that in all these studies the respective coefficient was found to be significant. It

[3] A different approach was followed by Monticelli (1996), who investigated whether the inclusion of different types of cross border deposits in the definition of money improves the properties of the estimated money demand equation. Contrary to the evidence found at the national level by Angeloni, Cotarelli and Levi (1994), Monticelli (1996) found that at the European level none of the "extended" measures outperformed the one obtained by the sum of traditional national definitions (see also Fagan and Henry, 1999). These studies however overestimate the amount of foreign currency deposits held inside the euro-area at the cost of those held abroad, because UK (and hence the City) was considered member of the monetary union.

[4] Whether this "indirect approach" provides evidence of intra-European CS is a different question. As noted, for example, by Fagan and Henry (1999), the superiority of EU-wide estimates can be attributed either to a statistical averaging effect or to asymmetric shocks that offset each other in the aggregate, of which intra-European CS is a only special case. For direct tests suggesting the existence of intra-European currency substitution, see Melvin (1985).

is, thus, surprising that the most recent money demand estimates for the euro-area (Funke, 2001, Brand and Cassola, 2000, Coenen and Vega, 1999, Fagan and Henry, 1999, Fase and Winder, 1998, Spencer, 1997) have been entirely devoted to the closed economy portfolio balance model.

This paper differs from previous tests on euro-dollar substitution, in three aspects: first, estimation is based only on observed variables. The currency substitution hypothesis is tested by the significance of the US dollar interest rate, rather than by the significance of a proxy for the expected exchange rate depreciation. Second, the underlying framework is a microeconomic model of money demand, in which the distinctive feature of money is accounted for (Thomas, 1985). Third, we use recent ECB data, that includes the 11 qualified countries forming the euro-area.

The paper proceeds as following. Section 2 presents the model to be estimated. Section 3 describes the variables used and the data sources. Section 4 presents the empirical evidence. Section 5 concludes.

2. Theoretical considerations

In the currency substitution literature, two main approaches have been followed: the Portfolio Balance Model (PBM, Cuddington, 1983, 1989) and the Liquidity Services Model (LSM, Miles, 1978, Thomas, 1985).

The PBM follows the aggregative tradition of postulating money demand functions that depend positively on a scale variable, such as income or wealth, and negatively on the return of each alternative asset. Since the domestic currency may depend negatively on the expected exchange rate depreciation through both substitutability vis-à-vis the foreign currency (currency substitution) and substitutability vis-à-vis the foreign bond (capital flight), followers of the PBM have claimed that a negative influence of an expected exchange rate depreciation term in the money demand is not necessarily evidence of CS (see Cuddington, 1983, for details).

The PBM has two main shortcomings. First, as noted by Branson and Henderson (1985), gross substitutability between all assets is not always consistent with individual optimisation. Second, this approach is not capable of explaining why money is held despite being dominated by interest-bearing bonds. A closer scrutiny of the properties of the money demand in light of firmer microeconomic foundations was made by Thomas (1985). Assuming that money reduces transaction costs, this author demonstrated that borrowing and lending opportunities separate ownership of currencies from portfolio decisions. That is, on one hand, an individual agent selects his currency holdings, based on liquidity services and user costs. On the other hand, she borrows or lends to achieve the desired overall portfolio composition. An optimal currency hedge is created and the denomination structure of the individual portfolio is independent of the currency holdings. Opportunity cost variables influencing portfolio asset demands in general, including the expected inflation and exchange rate depreciation fail to influence money demands, as long as they are not embedded in the nominal interest rates (see Appendix 1 for details).

Following this result, Bergstrand and Bundt (1990) proposed a the following empirical model (see also Mizen and Pentecost, 1996):

$$m_t = \beta_0 + \beta_1 i_t + \beta_2 j_t + \beta_3 y_t + u_t \,, \tag{1}$$

where *m* is the log of real money balances, i and j are the nominal interest rates on domestic and foreign bonds respectively, *y* is the log of real income, *u* is a random error term and *t* is a time index. The expected signs for this model are $\beta_1 < 0$, $\beta_2 \geq 0$ and $\beta_3 > 0$. The extent of currency substitution is given by the sign and significance of β_2.

Recent estimates of the money demand in the euro-area can be seen as restricted versions of (1), with $\beta_2 = 0$ (Funke, 2001, Brand and Cassola, 2000, Coenen and Vega, 1999, Hayo, 1999, Fagan and Henry, 1999, Spencer, 1997). In the exercise below, this restriction is subject to a statistical scrutiny: if $\beta_2 = 0$ holds, then the currency substitution hypothesis is rejected[5].

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[5] It should be noted that, under uncovered interest rate parity, this is equivalent to test for CS investigating the significance of expected depreciation. Sticking with (1), however, one has the advantage of relying only on observed variables.

3. Variables and data used

Vector error correction models account for both long run relationships and short term dynamics. Since imposing $\beta_2 = 0$ in the long run money demand relationship is not the same as estimating the system without the foreign interest rate among the regressors, we also display the estimations results of systems in which the foreign interest rate is omitted (systems i, iii, v in Table 1). This will allow the reader to evaluate the uncertainty concerning the estimates.

On the other hand, variables other than those appearing in the long run money demand relationship may have a role in the process of dynamic adjustment to the long run equilibrium. To capture this possibility, in the exercise below, we run VAR systems including two variables not appearing in (1). These are the short term interest rate and the euro-area inflation rate.

The short term interest rate appears in Funke, (2001) and in Cassard et. al (1994) as the opportunity cost of money. In this case, its coefficient is expected to be negative. In Fase and Winder (1998) and Coenen and Vega (1999), the opportunity cost role is hated by the long term interest rate. These authors then interpreted the short term interest rate as a proxy for the M3 own return, expecting a positive coefficient. The performance of this variable as proxy for the M3 own rate has been, however, poor. For this reason, the most recent practice has been to drop this variable from the long term money demand relationship and use it to identify a second co-integrating vector capturing the slope of the yield curve (Brand and Cassola, 2000, Coenen and Vega, 1999).

Some recent estimates for the euro-area have considered the inflation rate as an argument of the money demand function (see, for example, Fase and Winder, 1998). In light of the PBM, this captures an eventual substitutability between money and real assets. In light of LSM, however, the ownership of currencies is separable from portfolio decisions, so that the inflation rate does not appear in the money demand equation. In practice, the recent evidence with euro-area aggregates suggests that this variable, although enriching the short term dynamics of the model, may be dropped from the long term money demand relationship to form an orthogonal relationship, together with the long run interest rate (Brand and Cassola, 2000, Coenen and Vega, 1999).

The estimation exercise uses quarterly data, from 1982:2 to 1999:3[6]. The variables used are the log of the (seasonally adjusted) real M3 in the euro-area (*m*)[7], the log of real GDP in the euro-area (*y*), the euro-area inflation rate (π), the short-term interest rate in the euro-area (*s*) the 10-year government bonds yields in the euro-area (*i*) and the 10-year government bonds yields in the euro-area in US (*j*). All European variables are from the ECB database, as displayed in Brand and Cassola (2000). The US dollar interest rate is from the IFS.

4. Estimation results

Table 1 reports the estimation results obtained using alternative Vector Autoregression (VAR) systems. Estimates are obtained using the Johansen-Juselius maximum likelihood approach (discussed, for example, in Cheung and Lai, 1993) and the PcFiml version 9.10, (Dornik and Hendry, 1997)[8]. The first stage of this procedure is to estimate an unrestricted VAR model in the reduced form, where all variables in the system are explained in terms of their own lagged variables. In this step, all variables are treated as endogenous and no *a priori* structural restriction is imposed.

Table 1 presents the estimation results with VAR systems combining different variables, as described in the legend. For comparative purposes, the number of lags in the VAR models was set the same in all systems (i)-(vi). Taking into account the usual information criteria, the PcFiml F-tests for system reduction and also the common practice in previous works using this sample (Brand and Cassola, 2000, Coenen and Vega, 1999), the lag-length was set equal to 2. The algorithm then factorises this VAR model and tests the

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[6] Although ECB data is available from 1980:1, our experiments revealed that the quality of the fit improves significantly after removing the first observations from the sample (coincidentally, both Coenen and Vega, 1999, and Brand and Cassola, 2000, reported outliers in the beginning of the sample).

[7] It should be noted that, since foreign currency holdings in the domestic banking system are included in the ECB official aggregate, some euro-dollar CS is already "internalised". Recent ECB data suggests that residents' foreign currency deposits inside the EU amounts to 2.5-3.0% of total deposits.

[8] Unit root tests indicating that all variables are non-stationary are available from the author upon request.

number of distinct cointegrating vectors. The trace tests for the number of cointegrating vectors are displayed in Part I of Table 1[9].

Part II of Table 1 displays the estimated coefficients of the normalised cointegrating vector representing the money demand, as well as the correspondent standard errors. The standard errors can be used to calculate Wald tests of hypothesis about the coefficients, which are asymptotically distributed as $\chi^2(1)$. As a special case, a zero restriction on a particular coefficient may be assessed comparing the correspondent t-ratio to the usual 5% critical level, 1.96[10]. Part III of Table 1 displays the likelihood ratio (LR) test for the joint restrictions used to identify the cointegrating vectors and the money demand relationship.

Column (i) of Table 1 displays the estimation results of a system consisting on the variables *m*, *i*, and *y*, only. The trace test for reduced rank suggest the existence of a unique cointegrating vector at the 95 percent level. The parameters of the cointegrating vector representing the money demand are reported in Part II of Table 1. This cointegrating vector relates real balances to real income and the domestic long term interest rate, as in a closed economy. The estimated income elasticity is 1.3 and the Wald test for a unit income elasticity gives a $\chi^2(1)$ test value of 38.1 ($[(1.3\text{-}1.0)/0.048]^2$), indicating rejection at the 1% significance level. Rejection of unit income elasticity is common to estimates (i)-(vi) and is in accordance to the previous literature on euro-area money demand (see, for example Brand and Cassola, 2000, Coenen and Vega, 1999). The semi-elasticity of the domestic interest rate is negative, as expected, and significant ate the 1% level.

Column (ii) displays the estimation results of a system containing all the variables included in Equation (1). The trace statistic suggests the existence of a unique co-integrating vector at the 5% significance level. The coefficients of the normalised co-integrating vector in part II have signs in accordance to the theoretical model described in Appendix 1. Remarkably, the semi-elasticity of the foreign interest rate is of the same magnitude as that of the domestic interest rate. All t-ratios suggest statistical significance and, in particular, the

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[9] As in both Brand and Cassola (2000) and Coenen and Vega (1999), residual non-normality is the main estimation problem across systems. For this reason, cointegration is evaluated only on the basis of the trace test, which is likely to be more robust to some forms of non-normality than the maximal eigenvalue test (Cheung and Lai, 1993).

[10] Denoting by β the estimated coefficient and by *s* the standard error, the Wald test is $t^2 = (\beta/s)^2 \sim \chi^2(1)$. The square root of the 5% critical level $\chi^2_{0.95}(1) = 3.84$ is 1.96.

LR test for the hypothesis of "no currency substitution", $\beta_2 = 0$, indicates rejection at the 1% significance level.

System (iii) expands system (i) by adding the euro-area inflation rate to the variable set. As expected, the trace test for reduced rank now suggests the existence of two co-integrating vectors, at the 5% significance level. Following the recent literature, two long run relationships were identified, one for the money demand function (displayed in the table) and a second for a relationship between the nominal interest rate and the inflation rate (not displayed)[11]. The LR test statistic for the identifying restrictions is 70% and its recursive estimation suggests that these restrictions are valid throughout the sample period[12]. The signs of the money demand coefficients are in accordance to the closed economy model of money demand and the t-ratios suggest significance.

Column (iv) expands the system (iii) by adding the US dollar long term interest rate. The trace statistics suggest again the existence of two cointegrating vectors at the 5% significance level, which are identified as in (iii). The p-value of the LR-test for the identifying restrictions is now 93% and its recursive estimation does not point to any break throughout the sample period. The money demand coefficients are again in accordance to equation (1) and the implied t-ratios suggest overall significance. The hypothesis of "no currency substitution" is again rejected at the 1% significance level.

Columns (v) and (vi) expand (iii) and (iv) by including the money market interest rate (*s*) among the regressors. Contrary to what expected, the trace statistics do not point to a third cointegrating vector. Hence, we proceed as before, identifying two cointegrating vectors, one for the money demand an other for an unrestricted relationship involving the long term

[11] Conen and Vega (1999) were able to identify a Fisher equation. In the Brand and Cassola sample (our sample), however, a positive relationship between inflation and the nominal interest rate holds with a beta coefficient equal to 1.69. Brand and Cassola (2000) interpreted this as an equilibrium relationship, due to the impact of taxation. A simpler reasoning, however, can be found, on the basis of a sample peculiarity: during the transition to EMU, interest rates were initially high in some countries, in order to fight inflation and were allowed to decline as inflation curbed down. This translates into a positive relationship between inflation and the real interest rate in this particular sample, but it does not mean that such relationship can be used to forecast inflation or interest rates in the future.

[12] Results of recursive estimation are available upon request.

interest rate, the short term interest rata and the inflation rate[13]. The p-values of the LR test for the identifying restrictions is 26% in (v) and 36% in (vi), suggesting a poorer overall performance, as compared to systems (iii)-(iv). In case of equation (v), the coefficient of the domestic interest rate is significant only at 5%.

Comparing the performances of models (i)-(vi), we observe the following: First, the coefficient of the foreign interest rate gets a positive and significant sign across equations. Recursive estimation (available upon request) also suggest that this coefficient is relatively stable, even across a turbulence period, such as the EMS crisis. This evidence accords to the theoretical model underlying equation (1) and is suggestive of euro-dollar substitution. Second, the estimated semi-elasticity of the domestic interest rate in the money demand equation is relatively stable across systems where the foreign interest rate is included, but it varies substantially across systems where the foreign interest rate is omitted. This suggests that the omission of the foreign interest rate from the VAR system involves a misspecification. If so, this problem affects all the recent estimates addressing the euro-area money demand relationship (Funke, 2001, Brand and Cassola, 2000, Coenen and Vega, 1999, Hayo, 1999, Fagan and Henry, 1999, Spencer, 1997). Third, when the US dollar interest rate is included among the regressors, its coefficients gets a magnitude similar to that obtained by the domestic interest rate. This suggests that the demand for money in the euro area is equally exposed to financial disturbances occurring in the euro bond market and in the dollar bond market. Finally, the model is not likely to benefit with the presence of the domestic money market interest rate among the regressors.

5. Conclusions

The notion that different national currencies may be substitutes in demand has received considerable attention in recent years. This substitutability has potentially important implications for the conduct of monetary policies. When two currencies are substitutes in

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[13] In alternative, one may impose three co-integrating vectors: (a) the money demand; (b) the positive relationship between inflation and the long term interest rate (as in iii-iv) and (c) a stable "spread" between the long term interest rate and the short term interest rate (as Coenen and Vega, 1999 and Brand and Cassola, 2000). The results obtained under this alternative (available upon request), do not differ qualitatively from those displayed in columns v-vi.

demand, then the quantity of each actually demanded depends upon the costs of holding both currencies. When this is so, monetary developments in one country impact on the other country' money market. For this reason, it has been argued that, in the presence of currency substitution, a flexible exchange rate system does not ensure monetary autonomy, as had once been thought.

In this paper, we investigate whether currency substitution vis-à-vis the US dollar applies to the Euro-area money demand. To this aim, we test the stability of a money demand equation for the euro-area, experimenting different combinations of variables in the vector auto-regressive system. We consistently find a significant and positive coefficient for the U.S. long term rate interest rate in the European money demand equation, suggestive of euro-dollar substitution. This result stresses the need to account for the interdependence nature of the international monetary system, as the ECB designs its monetary policy.

Although this result may be supportive of currency substitution, it may also be a consequence of other channels through which monetary developments in US affect real money demand in Europe. For example, it could be that European monetary authorities responded to changes in US interest rates or to changes in other variables influenced by US interest rates, adjusting the money supply. Whatever the link is, this does not change the main result that interdependence matters.

The exercise implemented in this paper shares with the previous literature the limitation of being based on constructed pre-EMU monetary aggregates. In light of the Lucas critique, the coefficients estimated above may have little value for forecasting and policy prescription[14]. The aim of the exercise is not however, to defend particular elasticity values for the money demand equation so as to justify any money supply rule. On the contrary, by stressing the interdependent nature of the international monetary system, we add an argument to the general case for caution in the interpretation of the information content of EU-wide monetary aggregates.

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[14] For example, it has been argued that the emergence of the euro as international currency will enhance its substitutability vis-à-vis the dollar. In that case the coefficients estimated above would be underestimating the extent of CS, but the conclusion that interdependency matters would be reinforced.

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Table 1: Johansen-Juselius estimates

System	(i)	(ii)	(iii)	(iv)	(v)	(vi)
I. Trace tests for reduced rank:						
r=0	33.3 *	53.2 *	69.7 **	92.9 **	90.43 **	118.1 **
r<=1	13.5	25.3	32.3 *	52.4 *	54.6 **	73.6 *
r<=2	1.0	10.9	13.9	26.5	27.3	42.96
r<=3	-	0.1	2.1	12.3	13.5	26.8
II. Estimates of long run coefficients in the money demand equation (standard errors in parentesis):						
m - real money	-1	-1	-1	-1	-1	-1
y - real income	1.30 **	1.40 **	1.30 **	1.37 **	1.34 **	1.39 **
	(0.048)	(0.056)	(0.040)	(0.050)	(0.034)	(0.043)
i - euro area long term interest rate	-0.0057 **	-0.0083 **	-0.0062 **	-0.0085 **	-0.0034 *	-0.0076 **
	(0.0022)	(0.0028)	(0.0020)	(0.0025)	(0.0017)	(0.0023)
j - US long term interest rate		0.0098 **		0.0083 **		0.0085 **
		(0.0035)		(0.0031)		(0.0027)
III. Tests on the linear restrictions imposed on cointegrating vectors						
LR statistic (X^2)	-	-	0.15	0.13	2.64	3.22
d.f.	-	-	1	2	2	3
p-value	-	-	0.70	0.93	0.26	0.36

Notes: A *(**) means significant at the 5% (1%) level.
Variables used: (i): *m, y, i*; (ii) *m, y, i, j*; (iii) *m, y, i, π;* (iv): *m, y, i, j, π;* (v): *m, y, i, s, π;* (vi): *m, y, i, j, s, π.*
Legend:
m - Seasonally adjusted real M3 in the euro-area (logs)
y - Seasonally adjusted real GDP in the euro-area (logs)
i - 10-year government bonds yields in the euro-area
j -10-year government bonds yields in the US
s - Short-term interest rate in the euro-area
π - Euro-area inflation rate (*π*).

Appendix 1. The underlying theoretical model

Consider a one good economy, in which individuals have unrestricted access to four assets: euro-currency (M), dollar-currency (F), euro-denominated bonds (A) and dollar-denominated bonds (B). Real wealth is defined as:

$$w = m + f + a + b\,, \tag{A1}$$

where $m = M/P$, $f = EF/P$, $a = A/P$, $b = EB/P$, P is the price level in the euro-area and E is the nominal euro-dollar exchange rate.

Each consumer is endowed with a constant flow of a non-storable good, denoted by y, and maximises a lifetime utility function of the form:

$$\mathrm{E}\int_{o}^{\infty} e^{-\rho t}\frac{c^{1-\phi}}{\phi}dt\,, \tag{A2}$$

where c denotes real consumption and ϕ is the Arrow-Pratt measure of relative risk aversion.

Domestic and foreign securities have certain nominal returns, represented by i and j, respectively. Currency holdings earn zero nominal returns. There is uncertainty concerning real returns, because the domestic price level and the exchange rate evolve stochastically, according to:

$$\frac{dP}{P} = \pi dt + \sigma dZ \tag{A3}$$

$$\frac{dE}{E} = \varepsilon dt + \gamma dX \tag{A4}$$

In (A3)-(A4), dZ and dX are standard Wiener processes. Denoting by ρ the covariance between the stochastic processes (A3) and (A4) and using the Ito' s lemma, we obtain the real returns to domestic bonds, domestic money, foreign bonds and foreign money:

$$\left(i + \sigma^2 - \pi\right)dt - \sigma dZ \tag{A5}$$

$$\left(\sigma^2 - \pi\right)dt - \sigma dZ \tag{A6}$$

$$\left(j + \varepsilon + \sigma^2 - \pi - \rho\right)dt - \sigma dZ + \gamma dX \qquad \text{(A7)}$$

$$\left(\varepsilon + \sigma^2 - \pi - \rho\right)dt - \sigma dZ + \gamma dX \qquad \text{(A8)}$$

Despite being dominated by interest-bearing assets, money is held because it reduces transaction costs[15]. Following Végh (1989) and Sahay and Végh (1996), we postulate transaction costs (τ) to depend positively on the real consumption level (c) and negatively on the amount of real money balances relative to consumption:

$$\tau = cv\left[\frac{m}{c}, \frac{f}{c}\right], \qquad \text{(A9)}$$

with $v(.) \geq 0$, $v_k \leq 0$, $v_{kk} > 0$ (k=$1,2$), $v_{12} \geq 0$ and $\Delta = v_{11}v_{22} - v_{12}^2 > 0$.

The flow budget constraint of the representative agent depends on the amount of saved wealth allocated to the available assets and on real returns. Using (A1), (A5)-(A8) and (A.9) this is:

$$dw = \Phi dt + \left(w - a - m\right)\gamma dX - w\sigma dZ \qquad \text{(A10)}$$

with

$$\Phi = \left(\sigma^2 - \pi\right)m + \left(\varepsilon + \sigma^2 - \pi - \rho\right)f + \left(i + \sigma^2 - \pi\right)a + (j + \varepsilon + \sigma^2 - \pi - \rho)b + \left(y - c - \tau(.)\right).$$

The consumer problem is to maximise (A.2), subject to (A10). From the first order conditions in respect to a , m and f, follows:

$$\frac{b+f}{w} = \left(\frac{1}{\phi}\right)\left(\frac{j + \varepsilon - i}{\gamma^2}\right) + \left(1 - \frac{1}{\phi}\right)\left(\frac{\rho}{\gamma^2}\right) \qquad \text{(A11)}$$

$$i + v_1\left(\frac{m}{c}, \frac{f}{c}\right) = 0 \qquad \text{(A12)}$$

$$j + v_2\left(\frac{m}{c}, \frac{f}{c}\right) = 0 \qquad \text{(A13)}$$

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[15] An alternative specification is that money enters in the utility function. The two approaches become functionally equivalent when the utility function is weakly separable, as happens to be the case in most of the literature. For a stochastic model with money in utility and currency substitution, see Smith (1995).

Equation (A11) is the well known optimal portfolio rule in a world with two assets (references in Branson and Henderson, 1985). It states that the optimal share of assets denominated in foreign currency is a weighted average of two terms, the weights depending on the coefficient of relative risk aversion, ϕ. The first term captures the speculative component. The term ρ/σ^2 gives the proportion of assets denominated in dollars that minimises the portfolio' s purchasing power risk. Hence, according to (A11), the consumer is induced to move away from the minimum risk portfolio by the expected return differential and the extend to which it moves depend on its risk aversion.

Equations (A12)-(A13) state that currency holdings in each denomination depend only on their marginal productivity in the production of liquidity services and user costs. Opportunity cost variables influencing portfolio asset demands in general, including the expected inflation and exchange rate depreciation, fail to influence money demands, as long as they are not embedded in the nominal interest rate.

Taken together, equations (A11)-(A13) show that borrowing and lending opportunities separate ownership of currencies from portfolio decisions. On one hand, an individual agent selects his currency holdings based transaction services and opportunity costs. On the other hand, she borrows or lends to achieve the desired overall portfolio composition. An optimal currency hedge is created and the denomination structure of the individual portfolio is independent of the currency holdings.

The demands for domestic and foreign money are implicitly defined by (A12) and (A13) and take the form:

$$m = cL^m(i, j),$$

with $L_i^m = -\frac{cv_{22}}{\Delta} < 0$ and $L_j^m = \frac{cv_{12}}{\Delta} > 0$ (A14)

$$f = cL^f(i, j),$$

with $L_i^f = \frac{cv_{21}}{\Delta} > 0$ and $L_j^f = -\frac{cv_{11}}{\Delta} < 0$ (A15)

To interpret, assume that the dollar interest rate declines once-and-for-all accompanied by an offsetting rise in the euro-dollar expected depreciation rate. Since the expected return differential remains unchanged, the proportion of total asset holdings (money and bonds) denominated in each currency will also remain unchanged. However, if currencies are substitutes, the decline in the user cost of the foreign currency will induce a cash switching from euro-currency to dollar-currency. In order to keep the currency composition of the overall portfolio unchanged, the consumer offsets the cash switching buying euro-denominated bonds and selling dollar-denominated bonds.

Now suppose that the dollar interest rate declines alone (that is, with the expected exchange rate depreciation remaining constant). Since the opportunity cost of holding dollar-currency declines, individuals will switch their cash holdings from euros to dollars. At the same time, since the expected return differential becomes favourable to dollar bonds, the individual buys dollar-denominated bonds and sells euro denominated-bonds. In the end, he will have a greater exposure to dollar denominated assets.

A special case occurs when the marginal productivity of the domestic currency in the production of liquidity services does not depend on the amount of foreign currency holdings ($v_{12} = 0$). In that case, the optimal money demands simplify to:

$$m = cL^m(i)$$

$$\text{with } L_i^m = -\frac{c}{v_{11}} < 0 \qquad \text{(A14a)}$$

$$f = cL^f(j),$$

$$\text{with } L_j^f = -\frac{c}{v_{22}} < 0 \qquad \text{(A15a)}$$

The system (A14)-(A15) gives the optimal money demands in the presence of currency substitution. In this case, a rise in the user cost of the domestic money implies a shift towards the foreign currency. The system (A14a)-(A15a) corresponds to the case in which there is no substitutability between currencies. In this case, the demand for domestic money is the same as in a closed economy (see, for example, Branson and Henderson, 1985). Residents in the euro-area may hold some dollars to facilitate transactions, but the amount of dollars-currency holdings does not depend on the amount of euro-currency holdings. In the particular case in which foreign currency provided no liquidity services at all (that is, if $v_2 = v_{22} = 0$), then condition (A13) would not hold in equality and the optimal demand for dollar currency would be zero. In this extreme case, the demand for euros would still be as described by (A15a).