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Abhandlungen

An Econometric Investigation of Currency Substitution and Capital Mobility in a Two-Country Portfolio-Balance Financial Asset Model

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I. Introduction

Currency substitution constitutes an issue in international finance that has been examined thoroughly by a number of empirical studies. Particular importance has been given to its implication with respect to the effectiveness of monetary control as well as to the determination of flexible exchange rates. More specifically, the currency substitution phenomenon can have important implications for monetary policy. If we assume that two currencies are substitutes, then the standard money demand function will shift with changes in the cost of holding foreign money. This, in turn, reduces the degree of monetary autonomy expected under the regime of flexible exchange rates (*Miles* (1978)) diminishing, as a result, the ability of domestic monetary authorities to control the volume of liquidity (*Girton/Roper* (1981), *Mckinnon* (1982), *Ramirez/Rojas* (1985), *Joines* (1985), *Cuddington* (1983)). The degree of destabilization of domestic money demand depends on the substitution elasticity between domestic and foreign monies. Furthermore, *Girton/Roper* (1981), *Boyer/Kingston* (1987), and *Isaac* (1989), assert that the degree of currency substitution affects the exchange rate volatility. Particularly, the reaction of exchange rates to disturbances becomes bigger as the degree of currency substitution increases. In other words, the degree of currency substitution influences the magnitude of change in the exchange rate. In the limiting case of perfect currency substitution, the exchange rate becomes indeterminate, in contrast to perfect bond substitution which does not produce indeterminacy.

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The results of empirical studies testing the importance of currency substitution effects in the money demand function in industrial countries are mixed. For example, *Miles* (1978), *Daniel/Fried* (1983) and *Giovannini/Turtelboom* (1992) found that U.S and Canadian dollars are substitutes, which means that the hypothesis of currency substitution is valid. In contrast, *Bordo/Choudhri* (1982) supported that the omission of some important variables from Miles' model bias the estimate of the coefficient of the interest rate differential which reduces the effect of currency substitution during the regime of flexible exchange rate. Moreover, *Brittain* (1981) in his multicurrency portfolio model for the U.S.A. and Germany supported the currency substitution hypothesis. On the other hand, *Ahking* (1984) poses some questions relative to Brittain's results on statistical grounds, since he found no convincing results in favor of the multicurrency portfolio model. In addition, *Bergstrand/Bundt* (1990) found that the currency substitution phenomenon has a limiting importance in the short-run, while its significance on monetary policy is hard to be ignored over the long-run.

In this paper our aim is to empirically test for the significance of substitution between the euro and the dollar. That is, the extent of monetary independence is assessed between the euro area and the U.S. economy. More specifically, the analysis will rely on a theoretical model of money demand function in an open economy and it will primarily investigate the extent to which international monetary interdependence may be a significant factor affecting European monetary policy. Thus, the domestic (euro area) money demand derived from a two-country portfolio balance framework is in the spirit of *Cuddington* (1983) and *Branson/Henderson* (1985).

The paper is organized as follows. In section 2, we investigate the currency substitution models and the asset market models and their effects on monetary policy[1]. In section 2, we will proceed with the specification of the theoretical model and we will also analyze the data used. In the section 3, we will present the empirical results as well as some stability and specification tests of our model. Particularly, we attempt to present tests for structural breaks (*Chow* (1960), *Kim/Siegmued* (1989) and *Banerjee* et.al (1992)), for unit root tests of *Kwiatkowski* et al. (KPSS test, 1992) and *Elliot* et al. (DFGLS test, 1996). Also, in this section we

[1] For an extensive analysis on these models see *Leventakis/Brissimis* (1991), *Brissimis/Leventakis* (1988), and *Giovannini/Turtelboom* (1992).

will apply the maximum likelihood cointegration technique proposed by *Johansen* (1996) and *Johansen/Juselius* (1990, 1992) to test for the possibility of cointegration between domestic money supply and the explanatory variables as well as the dynamic error correction model in order to assess the extent of adjustment to long-run equilibrium. Finally, the conclusions of the analysis will be presented in Section 4.

II. Specification of the Function of the Money Demand in an Open Economy

As pointed out, our analysis will be in the spirit of *Cuddington* (1983) and *Branson/Henderson* (1985), which supposes that the total financial wealth of the investors in the two countries is allocated between four different financial assets[2]. Residents in the two countries hold domestic currency money (M^d), foreign currency money (M^f), domestic currency-denominated non monetary assets (interest-bearing assets) referred to as domestic bonds (B^d), and foreign currency-denominated non monetary assets, referred to as foreign bonds (B^f). Domestic and foreign assets are assumed to be imperfect substitutes due to exchange rate risk and transaction costs. Making the assumption that the hypothesis of Purchasing Power Parity (*PPP*) holds, i.e.

$$P = S \cdot P^* \tag{1}$$

(where P and P^* are the levels of domestic and foreign prices respectively, and S is the exchange rate in units of domestic currency per unit of foreign currency), we are in the position to aggregate over the domestic and foreign countries in order to take total demand for each financial asset. Also, we assume that the investors do not suffer from money illusion, and then we can use asset demands of each country's residents in real terms (although under certain assumptions, the portfolio model expressing in nominal terms is equivalent to the model in real terms).

We will not proceed to a detailed description of the structural relationships of the complete model, something that is beyond the main purpose

[2] A considerable number of articles on domestic money demand does not take into account the foreign financial factors. In these articles also the papers of *Paleologos* (1982), *Sarantides/Varelas* (1985) and *Apergis* (1996), are included.

of the present study[3]. In equilibrium, total demand for each country equals to the total stock of domestic money. This leads to the following equilibrium condition in a semilogarithmic form:

$$(2) \qquad \begin{aligned} \log(M/P) &= \log(M^d/P) + \log(M^f/P) \\ &= f(x, r, r^* + x, W/P, Y/P) + g(-x, s - x, s^*, SY^*/P, SW^*/P) \end{aligned}$$

Equation (2) resulted by aggregating over the domestic and foreign countries total demand for each financial asset.

In Equation (2) M is the supply of domestic money expressed in domestic currency units, P is the domestic price level, Y and Y^* are domestic and foreign real income respectively, W and W^* are domestic and foreign financial wealth respectively, expressed in each country's currency, x is the expected rate of depreciation of the domestic currency relative to the foreign currency defined as $x = (S^e_{t+1} - S_t)/S_t$, (expected nominal rate of return on foreign money), where S^e_{t+1} is the expected future exchange rate and S_t is the exchange rate at time t in units of domestic currency per unit of foreign currency, r and $r^* + x$ are the nominal rate of return on domestic bonds are foreign bonds expressed in domestic currency respectively[4]. The nominal return on domestic money is exogenously equal to zero by assuming that money yields no pecuniary return. Expectations of exchange rate are proxied by the actual depreciation rate of the previous period.

In the above asset demand equation (2) we used nominal rather than real rates of return variables, by assuming that asset demands in the two countries are homogeneous of degree zero. Equation (2) models demand for domestic money by both domestic and foreign residents in a flexible exchange rate period, while for a fixed exchange rate period, where domestic and foreign assets are perfect substitutes, equation (2) is reduced to a conventional closed economy equation. The right hand side variables of equation (2) show the combined effects of changes in rate-of-return variables and scale variables on both domestic and foreign demands for domestic money. Changes in the expected rate of depreciation of the domestic currency affect domestic money demand directly (via the currency substitution terms) and indirectly (via capital mobility terms). To analyze

[3] For a complete description of the structural relationships see: *Brissimis/Leventakis* (1988), and *Branson/Henderson* (1985).

[4] $r^* + x$ is the foreign interest rate (r^*) adjusted for the expected depreciation rate (x).

these direct and indirect effects of the expected exchange rate depreciation on the domestic money demand we used a semi-logarithm version of equation (2):

$$\log(M/P) = -a_1x - a_2r - a_3(r^* + x) + a_4\log(W/P) + a_5\log(Y/P) + b_1(-x) - \\ - b_2(r - x) - b_3r^* + b_4\log(SW^*/P) + b_5\log(SY^*/P) \tag{3}$$

where the coefficients a_i and $b_i (i = 1, 2, ..., 5)$ are positive.

By grouping the terms which involve the expected exchange rate depreciation, the domestic interest rate and the foreign interest rate, equation (3) is written as:

$$\log(M/P) = -(a_1 + a_3 + b_1 - b_2)x - (a_2 + b_2)r - (a_3 + b_3)r^* + a_4\log(W/P) + \\ + b_4\log(SW^*/P) + a_5\log(Y/P) + b_5\log(SY^*/P) \tag{4}$$

Equation (4) can be re-written as:

$$\log(M/P) = c_1x + c_2r + c_3r^* + c_4\log(W/P) + c_5\log(SW^*/P) + \\ + c_6\log(Y/P) + c_7\log(SY^*/P) \tag{5}$$

where $c_1 = -(a_1 + a_3 + b_1 - b_2)$, $c_2 = -(a_2 + b_2)$, $c_3 = -(a_3 + b_3)$, $c_4 = a_4$, $c_5 = b_4$, $c_6 = a_5$, $c_7 = b_5$.

The parameter (c_1) of the expected rate of depreciation of the domestic currency (x) shows the four channels via a change in the variable x affects the domestic money demand. Two of these channels, a_1 and b_1 reflect the direct currency substitution[5], while the other two, a_3 and b_2 involve the capital mobility. Then we can explain the coefficient of x as reflecting only the currency substitution phenomenon. The currency substitution effect of x, which is given by the sum of $a_1 + b_1$ cannot be insulated from the estimated parameter of x. Also, the coefficients a_3 and b_2 involving the capital mobility effects of the expected depreciation rate on the domestic money demand, cannot be identified from the estimates of the parameters of domestic interest rate (c_2) and foreign interest rate (c_3), because both these parameters include domestic and foreign parameters. The cause of the inability to identify currency substitution effects is obviously the generalization of the money demand function to contain

[5] *McKinnon* (1982) called indirect currency substitution, the substitution between the domestic and foreign bonds. According to *Thomas* (1985) there is also an intermediate case, when the substitution is between money denominated in one currency and bonds denominated in the other currency.

demand for domestic money both by domestic and foreign residents. If foreign residents' demand is excluded, as *Cuddington* (1983) has done, then estimates of the parameters involving direct currency substitution can be resulted. As *Brissimis/Leventakis* (1988) argued, since the coefficient b_2, which shows the substitution parameter between domestic money and domestic bonds in the foreign country, enters in equation (4) with a positive sign, this leads to weaken the effect of expected exchange rate depreciation on domestic demand money, and probably to biased estimates of equation (5) against finding a significant role for currency substitution.

Finally, the positive effects of domestic and foreign wealth, (W and $W*$ respectively) reflects the assumption that all four assets in the above portfolio model are "normal assets". The inclusion of domestic wealth and foreign wealth as scale variables is a fact that distinguishes our money demand model in an open economy from the traditional money demand models that have ignored foreign scale variables from the estimation. Moreover, the wealth variable, as a scale variable, was used in the past with success in estimated money demand equations in open economy within the framework of modified monetary models of exchange rate determination (*Brissimis/Leventakis* (1985), *Frankel* (1982)). The domestic wealth is proxied by permanent income, the series of which are computed following the procedure of *Leventakis* (1993).

III. Testing for Structural Breaks and Cointegration – Empirical Implementation of VAR Model

As already has been reported in past sections, the theoretical models of currency substitution can be taken as an extension of money-demand functions to a multi-currency case. These theoretical models can be classified in three basic categories: "cash-in-advance models" (*Boyer/Kingston* (1987)), "transaction-costs models", and "ad hoc models"[6].

In this section we will investigate the time series properties of the data using recent developments in the econometrics of non-stationarities, and we will also present the results of currency substitution and capital mobility phenomena from the estimation of equation (5) for the Euro Area over the period 1990Q1–2006Q2 using quarterly observations (the

[6] *Giovannini/Turtelboom* (1992), and *Selcuk* (1994).

U.S. economy is taken as the foreign country in our model). The sample and the specification of equation (5) are relevant to a floating exchange rate regime.

The present study implements a multivariate vector autoregressive model (MVAR model) that helps us to explain the separate sources of stochastic disturbances to the currency-substitution (and capital mobility) process (*Blanchard* (1989), *Sims* (1980, 1992)). Equation (5) is essentially a long-run equilibrium relationship derived from economic theory. If this equilibrium model exists, the set of variables included in the model must be cointegrated even if the individual variables are non-stationary (*Engle/Granger* (1987)). According to *Engle/Granger* (1987), cointegrated variables must have an Error Correction Model (ECM) representation. ECM and cointegration approach are equivalent representations (*Paleologos* (1996)).

In this paper we will apply the maximum likelihood cointegration technique proposed by *Johansen* (1996) and *Johansen/Juselius* (1990). The Johansen-Juselius technique performs better than the single equation methods and alternative multivariate methods (e.g. *Stock/Watson* (1988), *Gonzalo* (1994)). However, before proceeding to test for cointegration and estimation of ECMs, it is necessary to test for structural breaks. The move to the single currency in January of 1999, which is also captured by the Chow test since a structural break has been occurred in 1999Q1 (Appendix I, part b), enable us to consider two sub-periods: 1990Q1–1998Q4 and 1999Q1–2006Q2. The first sub-period refers to pre-EMU period and according to Figure 1, a structural break appeared to have occurred during the time period 1993Q1–1995Q2 (see also Table 2, Appendix III), although this particular break is not confirmed by the Chow Test (see Appendix I, part b). This break is related to the Maastricht Treaty that came into force in November of 1993 and to the launching of Stage II of EMU (January 1994).The strengthening of central bank cooperation and monetary policy coordination led to a steady increase in money demand as the system moves towards the establishment of a common currency. The fact that during the nineties the euro area money demand function appeared rather stable is confirmed and justified by a number of studies[7]. During the second sub-period, which is connected with the shift to the single currency, a structural break

[7] For an excellent review of these studies as well as for the reasons for the relative money demand stability in the euro area, see *Calza/Sousa* (2003). See also the empirical studies of *Brand/Cassola* (2000) and *Coenen/Vega* (1999).

occurred in 2005Q3 (see, Appendix I, Figure 2 and part b (Chow Test)). This break was related to the sharp increase in crude oil prices and to the rise in the US interest rates both of which reduced the euro substitutability vis-à-vis the US dollar.

Overall, we see a relative stable demand function during the first sub-period, Figure 1, while in the second sub-period it appears less stable, Figure 2. Following the arguments put forward by *Calza/Sousa* (2003), the increased economic and financial integration, as a result of the single currency, may have given rise to more synchronized shocks in the euro area leading to a deterioration of statistical properties of euro area demand functions[8].

We now turn to establish the time series properties of the individual series used, *Kwiatkowski* et al. (1992) and *Elliot* et al. (1996) modern unit root tests. *Kwiatkowski* et al. (1992), proposed a test of unit roots, which is based on statistical multiplier Lagrange (LM) and is manufactured so that null hypothesis is reported in stationary time series X_t, while the alternative hypothesis is mentioned in non-stationary time series X_t. We point out that the critical values of control KPSS have been calculated by *Kwiatkowski* et al. (1992). Moreover, *Elliot* et al. (1996) extended ADF test, proposing the use exempted from tendencies of elements of X_t. For the testing of null hypothesis, the critical values that are presented by *Elliot* et al. (1996, p. 825) are used.

Table 1 (see Appendix II) presents DFGLS and KPSS unit root tests on each variable included in equation (5). Results for the order of integration reported in Table 1 show that the non-stationary hypothesis is rejected for the first differences of the series concerned, thus indicating that $\log(M/P)$, x, r, r^*, $\log(W/P)$, $\log(SW^*/P)$, $\log(Y/P)$ and $\log(SY^*/P)$ are all **I** (1).

In Table 1 (see Appendix II), it comes out that DF-GLS tests accepted the alternative hypothesis, it is to say that under review time series are stationary; so DF-GLS $(\hat{\tau}_\mu)$ and DF-GLS $(\hat{\tau}_\tau)$ are smaller than the critical values, in almost all the levels of importance. The critical values of DF-GLS $(\hat{\tau}_\mu)$ and DF-GLS $(\hat{\tau}_\tau)$ are presented by their *Elliot* et al. (1996, Table 1). Moreover, observing Table 1, it comes out that KPSS test accepted the null hypothesis, that is to say that under review time series are station-

[8] The instability in the function of the demand for money in the Euro Area during the periods 1993–1995 and 2005 is also verified by the Recursive Unit Root Test (Appendix III, Table 2), which is a further verification for the existence of structural breaks.

ary; then $\hat{\eta}_\mu$ and $\hat{\eta}_\tau$ are smaller than the critical values, in almost all the levels of importance. The critical values of $\hat{\eta}_\mu$ and $\hat{\eta}_\tau$ have been calculated by their *Kwiatkowski* et al. (1992, Table 1). Consequently, all these series can be inserted in the cointegration equations and then we can apply Johansen-Juselius cointegration technique (*Cuthbertson* et al., 1992).

Table 2 (see Appendix III) presents the recursive unit root test on each variable included in equation (5). In this unit root test, if the value is higher, in absolute terms, than the critical values (critical values by *Banerjee* et al. (1992)) then there is evidence for the acceptance of the null hypothesis. The results of Table 2 (see Appendix III) show that we can accept the null hypothesis of non-stationarity of the series, a fact which verifies the results of Table 1 in Appendix II. In particular, in Table 1 the endogenous variables are stationary in first differences, which mean non-stationary in levels. In Table 2, the variables are non-stationary and appear to have breaks in levels. According to all these processes, we can conclude that we have the possibility of advancing, in the next step of our analysis, the methodology of cointegration, using the technique of Johansen and Juselius. Thus, following the technique of Johansen and Juselius, we can check if there exists a long run relationship among the variables of model (5).

In Johansen and Juselius technique ((*Johansen* (1996); *Johansen/Juselius* (1990, 1992)) there are two statistics from the Johansen vector autoregressive tests that determine the rank of the cointegration space. One is the value of the likelihood ration (LR) test based on the maximum eigenvalue ($\lambda_{\max}$) of the stochastic matrix. The other is the value of the LR test based on the trace of the stochastic matrix (λ_{Trace}).

In addition a model with a four lag structure was selected using the information criterion of Akaike (AIC), Likelihood Ratio Sims statistics and the information criterion of Schwartz (SBC) (see Table 3, Appendix IV). Table 3 shows the tests of the lag structure for the VAR models.

The results from the trace and maximal eigen-value tests are shown in Table 4 (see Appendix V). The small sample adjustment of the statistics has been done according to the formula of *Reimers* (1992): $[(T - K^{*}P)/T]^{*}$ (Value of statistics), where T is the number of observations, K is the number of selected lags, and P is the number of variables in equation (5). The maximum eigenvalue likelihood ratio test statistic ($\lambda_{\max}$) shows the existence of one significant cointegrating relationship, and the trace likelihood ratio test statistic (T_r) shows the appearance of one or more cointegrating relationships against the alternative hypothesis of $r = 0$ (zero cointegrating relationship) (*Paleologos* (1996)). We accepted the existence of one cointegrating vector. Our decision to accept one cointegrating relationship was based on the evidence of the stronger $\lambda_{\max}$ test statistic (*Johansen/Juselius* (1990)), and the information criteria *Akaike/Schwartz*.

The results of Table 4 do not provide strong evidence that there is long run relationship among the variables $\log(M/P)$, x, r, r^{*}, $\log(W/P)$, $\log(SW^{*}/P)$, $\log(Y/P)$ and $\log(SY^{*}/P)$ due to structural breaks (Appendices I and III). Nevertheless, the evidence implies that monetary developments in the U.S. economy exert some influence on monetary policy in the EMU, either directly or indirectly.

Table 5 (see Appendix VI) shows the estimates of the normalized cointegrating relationships that resulted by using the full information likelihood (FIML) technique of Johansen. The eigenvectors were normalized on the $\log(M/P)$. If we judge from the signs of the estimated coefficients we observe that there is no violence to the Portfolio-Balance Financial Asset Model shown by equation (5). However, it is necessary to mention that the maximum likelihood cointegration procedure of Johansen, while allowing one to conclude about the appearance of long-run relationships among the variables of the VAR model, is unable to produce coefficient estimates with structural interpretation (*Dickey/Jansen/Thornton* (1994); *Alogoskoufis/Smith* (1991)).

Finally, Table 6 (see Appendix VII) shows the dynamic error correction estimates. The diagnostic and specification tests indicate that ECM representation is correctly specified. The RESET (Regression Specification Test) statistics reveal no serious omission of variables, indicating the correct specification of the model. LM is the Lagrange multiplier (LM) test that reveals no significant serial correlation in the disturbances of the error term. The JB (Jarque-Bera) statistics suggest that the disturbances of the regressions are normally distributed. The White F-statistics show the absence of simultaneity bias in the estimates.

The error-correction term ($EC_{(-1)}$) reflects short-run dynamics and appear in the set of regressors. The coefficients of the lagged values of x, r, r^{*}, $\log(W/P)$, $\log(SW^{*}/P)$, $\log(Y/P)$ and $\log(SY^{*}/P)$ are short-run parameters measuring the immediate impact of independent variable on $\log(M/P)$. The EC term is negative and highly significant. The obtained value of –0.123245 means that approximately 12.32 % of the discrepancy between the actual and the long-run domestic $\log(M/P)$ is corrected each year.

Our analysis indicates that all variables included in the long-run relationship are statistically significant. However the presence of structural breaks significantly reduces the strength of the aggregate long-run relationship. With respect to the dynamic adjustment not all variables appear to be statistically significant. The coefficients for exchange rate depreciation, foreign interest rate, foreign income and domestic wealth get correct and significant signs. Foreign wealth and domestic real output are significant at the 10 percent level. This suggests that disturbances abroad impact on the euro area money demand. However, in the case of foreign income and wealth and to a lesser extent with respect to foreign interest rate, their impact is considerably lower than the effect of the corresponding domestic variables. Finally, the impact of the variable capturing exchanger rate determination, which primarily captures the degree of currency substitution, appears to be significant manifesting the importance of euro-dollar substitution in international transactions.

IV. Concluding Remarks

The existence of structural breaks makes it rather difficult to analyze the sample period as a whole. This is reinforced by the fact that since the empirical results concerning the pre-EMU period have been based on constructed monetary aggregates their validity can be questioned both in light of the Lucas critique and aggregation bias (*Arnold/de Vries* (2000), *Spencer* (1997), and *Freitas* (2006)). Thus, it is more appropriate to concentrate on the two sub-periods separately. During the first sub-period, with the exemption of the 1993–1995 period, the money demand function appeared to be relatively stable and this is in line with previous empirical findings. During the second sub-period the demand for money function appeared to be less stable. This is indicative to the deeper financial integration in the euro zone which makes the shocks, from financial innovation, more synchronized.

The analysis confirms the existence of significant degree of monetary interdependence between euro and the dollar currency areas. That is, the coefficients capturing currency substitution and foreign income and to a lesser extent foreign wealth appear to be statistically significant and with the correct signs. Thus, the view that money demand in the euro area would be primarily affected by domestic shocks since it is a rather closed economy is not so valid, a fact which can have significant implications for ECB monetary policy. More specifically, it will cause the traditional money demand curve to shift which, in turn, makes it difficult for the monetary authorities to set monetary targets and in general reduces the degree of monetary autonomy expected under a system of flexible exchange rates. It is this sense that currency substitution undermines the stability of the international monetary system as *McKinnon* (1982) has argued.

This means that even in the case of large economies, currency substitution could cause serious problems to monetary strategy. That is, among large economies, whose financial assets are quantitatively significant and substitutable in the portfolios of international investors, further international monetary coordination may be necessary to maintain stable growth in their aggregate money supply in order to properly monitor price stability.

The substitution between the euro and the dollar may to a large extent reflect the increasing importance of the euro in the international financial markets. That is, the close substitutability of the two currencies underlines the importance of euro as an alternative choice of hard currency for international investors in terms of both credibility and liquidity. This definitely reduces the international role of the dollar and may impose greater discipline in the international monetary system (*Yeager* (2004)).

Overall, the shift to the single currency appears to add to the instability of the demand for money function in the euro zone from two sources. The first one stems from the higher financial integration that was brought about with the adoption of the euro. The second refers to closer interdependence with the dollar. The increasing role of the euro in the international transactions calls for greater coordination of monetary policies. This was more profound in the structural break that occurred in 2005, when the rising of both the US interest rates and the oil prices led to a considerable shift in the money demand function in the euro area.

Appendices

Appendix I: Testing for Structural Breaks

a) Recursive Residuals

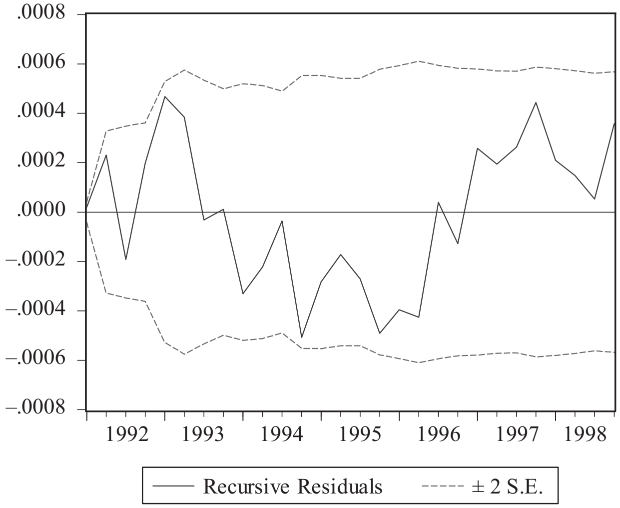

Figure 1: 1990q1 – 1998q4

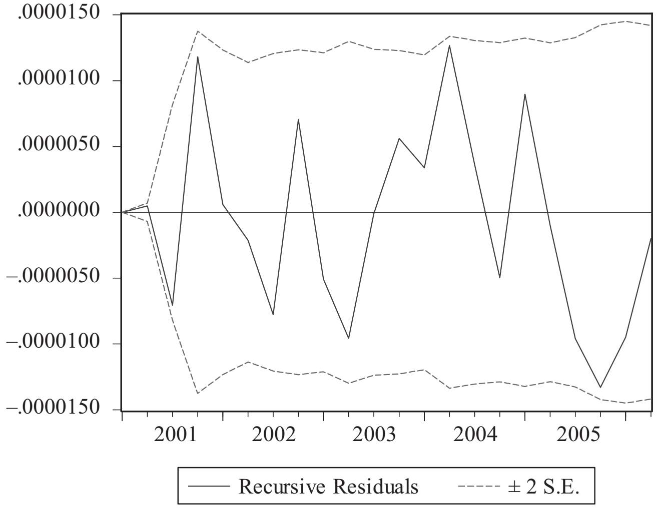

Figure 2: 1999q1–2006q2

b) Breakpoint Chow Tests

1999:Q1 F-statistic = 4.4133 (0.0445)*
2005:Q3 F-statistic = 69.548 (0.0000)**

*(**) In 1999:q1 and 2005:q3, there are the structural breaks, p-value in parentheses.

Appendix II: Modern Testing for Unit Roots (DFGLS Test and KPSS Test)

Table 1

Modern Testing for Unit Roots: 1990Q1–2006Q2

Variables	DFGLS test		KPSS test	
	DF-GLS ($\hat{\tau}_\mu$)	DF-GLS ($\hat{\tau}_\tau$)	$\hat{\eta}_\mu$	$\hat{\eta}_\tau$
$\Delta \log(M/P)$	–3.245561	–4.210412	0.295646	0.088646
ΔX_t	–4.004532	–4.079780	0.228667	0.091461
Δr_t	–4.462044	–5.448513	0.257809	0.056484
Δr_t^*	–8.581690	–8.735204	0.103947	0.089023
$\Delta \log(W/P)$	–8.684123	–8.998801	0.271663	0.105325
$\Delta \log(SW^*/P)$	–5.377933	–5.971157	0.291443	0.065353
$\Delta \log(Y/P)$	–8.616560	–8.244937	0.162620	0.059496
$\Delta \log(SY^*/P)$	–5.369866	–5.925041	0.248325	0.066093

Appendix III: Recursive Unit Root Test (Endogenous Structural Breaks)

Table 2

Unit Roots (Endogenous Structural Breaks): 1990Q1–2006Q2

Variables	$\hat{t}_{\max}DF$	$\hat{t}_{\min}DF$
$\log(M/P)$	–1.289 (Obs 22: 1995Q2)	–2.624 (Obs 63: 2005Q3)
X	–1.854 (Obs 16: 1993Q4)	–2.643 (Obs 63: 2005Q3)
R	–1.375 (Obs 17: 1994Q1)	–3.340 (Obs 64: 2005Q4)
r^*	–1.042 (Obs 18: 1994Q2)	–2.018 (Obs 64: 2005Q4)
$\log(W/P)$	–0.948 (Obs 13: 1993Q1)	–3.297 (Obs 64: 2005Q4)
$\log(SW^*/P)$	0.529 (Obs 24: 1995Q4)	–2.562 (Obs 65: 2006Q1)
$\log(Y/P)$	–1.329 (Obs 13: 1993Q1)	–4.249 (Obs 65: 2006Q1)
$\log(SY^*/P)$	–0.549 (Obs 14: 1993Q2)	–2.345 (Obs 63: 2005Q3)

The numbers in the columns are $\hat{t}_{\max}DF$ and $\hat{t}_{\min}DF$ statistics (*Banerjee* et al. (1992)). $\hat{t}_{\max}DF$ and $\hat{t}_{\min}DF$ for Recursive Unit Root test are the test statistics for endogenous structural breaks. *Banerjee* et al. (1992, Table 1, p. 277) provided critical values for this Recursive Unit Root test (Unit Root test based on Recursive Statistics). Critical values at the significant level 5% $(\alpha = 0.05)$ are $\hat{t}_{\max}DF = -1.99$ and $\hat{t}_{\min}DF = -4.33$.

Appendix IV: Test of the Lag Structure on the VAR Model (Equation 5)

Table 3

Lag	LogL	LR	FPE	AIC	SBC
0	1765.470	NA	3.30e–35	–56.69257	–56.4181
1	2501.005	1257.528	1.31e–44	–78.35499	–71.6704
2	2575.635	108.3345	1.03e–44	–78.69791	–72.0302
3	2645.650	83.56588	1.11e–44	–78.89193	–74.0319
4	*2766.565*	*113.1141**	*3.20e–45**	*–80.72790**	*–75.88477**

* Indicates lag order selected by the information criterion
LR: likelihood ratio Sims test for the choice of the lag structure of a VAR model (Sims, 1980) (each test at 5% significant level), FPE: Final Prediction Error, AIC: Akaike Information Criterion, SBC: Schwarz Information Criterion

Appendix V: Johansen – Juselius Cointegration Test

Table 4

Johansen – Juselius Cointegration Test among log(M/P), x, s, s^*, log(W/P), log(SW^*/P), log(Y/P) and log(SY^*/P)

H_0	$n-r$	λ_{trace}	λ^*_{trace}	95 %	H_0	λ_{max}	λ^*_{max}	95 %
$r \leq 7$	1	0.255261	0.131498	3.76	$r \leq 7$ $r \leq 8$	0.255261	0.131498	3.76
$r \leq 6$	2	6.770216	3.487687	15.41	$r \leq 6$ $r \leq 7$	6.514955	3.356189	14.07
$r \leq 5$	3	16.895630	8.703809	29.68	$r \leq 5$ $r \leq 6$	10.125410	5.216120	20.97
$r \leq 4$	4	45.950460	23.671449	47.21	$r \leq 4$ $r \leq 5$	29.054830	14.967640	27.07
$r \leq 3$	5	94.126260	48.489285	68.52	$r \leq 3$ $r \leq 4$	48.175800	24.817836	33.46
$r \leq 2$	6	163.426600	84.189461	94.15	$r \leq 2$ $r \leq 3$	69.300310	35.700160	39.37
$r \leq 1$	7	240.268000	123.774424	124.24	$r \leq 1$ $r \leq 2$	76.841390	39.584958	45.28
$r = 0$	8	341.570200	175.960406	156	$r = 0$ $r \leq 1$	101.302200	52.185982	51.42

r and $(n-r)$ indicate the number or eigenvectors and common trends respectively. λ_{trace} and λ_{max} show the trace and maximum eigenvectors statistics respectively for the unrestricted model. λ^*_{trace} and λ^*_{max} denote respectively the trace and maximum eigenvalue statistics adjusted for small sample of observations for the unrestricted model. Critical values at 95 % are taken from *Osterwald-Lenum* (1992), (tables 1* and 1).

Appendix VI: Maximum Likelihood Estimates of Cointegrating Vectors

Table 5

Variables	MLE of Cointegrating Vectors
$\log(M/P)$	1.000000
X_t	–0.0461943 (–22.0682)
r_t	–0.023302 (–2.08286)
r_t^*	–0.028820 (–3.12806)
$\log(W/P)$	0.033472 (2.99700)
$\log(SW/P)$	0.035537 (3.58100)
$\log(Y/P)$	2.246136 (8.80494)
$\log(SY*/P)$	0.049202 (4.96501)

Asymptotic t-statistics in parentheses.

Appendix VII: Dynamic Error Correction Model

Table 6

Estimations of Error Correction Equation Error Correction Estimates $\log(M/P)$, x, r, r^*, $\log(W/P)$, $\log(SW^*/P)$, $\log(Y/P)$ and $\log(SY^*/P)$

$$\Delta\log(M/P) = \underset{(-3.57356)}{-0.055513}\Delta x_{(-4)} - \underset{(-3.96898)}{0.020596}\Delta r_{(-4)} - \underset{(-2.85906)}{0.015330}\Delta r^*_{(-4)} +$$

$$+ \underset{(2.99901)}{1.531174}\Delta\log(W/P)_{(-4)} + \underset{(1.55934)}{0.005125}\Delta\log(SW^*/P)_{(-4)}$$

$$+ \underset{(1.68704)}{0.482608}\,\Delta\log(Y/P)_{(-4)} + \underset{(2.78237)}{0.005866}\Delta\log(SY^*/P)_{(-4)}$$

$$+ \underset{(3.63086)}{1.911533}\Delta\log(M/P)_{(-4)} - \underset{(-3.09465)}{0.123245}\mathrm{EC}_{(-1)}$$

$R^2 = 0.606831$, $\ddot{R}^{\,2} = 0.537449$, D.W. $= 1.75$, S.E. Equation $= 0.000172$, F-statistic $= 8.746147$, AIC $= -14.34685$, SBC $= -14.00081$

Test of Residual

Jarque-Bera (JB) = 9.54150
LM (4) = 8.432847

Ramsey Reset Test: (stability tests)

F-statistic = 0.565831
Log Likelihood Ratio = 2.367840

Coefficient Tests:

F-statistic = 3.312
Log likelihood Ratio = 15.942

White Heteroskedasticity Test:

F-statistic = 1.884286

Asymptotic t-statistics in parentheses, $\ddot{R}^2$ is the adjusted R^2, D.W. is the Durbin-Watson statistic, S.E. is the Standard Error of regression, JB is the Jarque-Bera test for the normality of the regression residuals, RESET is the Ramsey F-statistic for omitted variables, White is the White F-statistic for the Heteroskedasticity Test, AIC and SBC are the information criteria. LM is the Lagrange multiplier (LM) test fourth order serial correlation of the residuals. The LM statistic is asymptotically distributed as x^2 (d.f. $= 4$).

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Summary

An Econometric Investigation of Currency Substitution and Capital Mobility in a Two-Country Portfolio-Balance Financial Asset Model

This paper examines the extent to which the demand for money in the euro area responds to external economic developments. The euro area money demand is derived from a two-country portfolio balance framework with the US being the foreign economy, using quarterly data covering the 1990Q1–2006Q2 period. First, we tested for the existence of structural breaks. The move to the single currency in January 1999 allowed us to consider two sub-periods: 1990Q1–1998Q4 and 1999Q1–2006Q2. During the first, we see a relatively stable demand function, while in the second it appears to be less stable. This is largely due to the fact that the adoption of the single currency brought greater economic integration. Then, we use a multivariate vector autoregressive model (MVAR model). The results reveal significant degree of monetary interdependence during the second sub-period stemming from currency substitution and capital mobility. This, in turn, calls for further international monetary coordination to maintain stable growth in the aggregate money supply in order to properly monitor price stability. (JEL E41, E58, F41)

Zusammenfassung

Ökonometrische Untersuchung von Währungssubstitution und Kapitalmobilität – Zwei-Länder-Portfolio-Gleichgewichtsrahmen auf der Grundlage eines „Financial Asset Model"

In diesem Artikel wird das Ausmaß untersucht, in dem die Nachfrage nach Geld im Euro-Währungsgebiet auf externe Wirtschaftsentwicklungen reagiert. Abgeleitet wird die Geldnachfrage im Euro-Währungsgebiet von einem Zwei-Länder-Portfolio-Gleichgewichtsrahmen, wobei die US-Volkswirtschaft diejenige ist, die nicht dem Währungsgebiet des Euro angehört, und Zahlenmaterial für den Zeitraum 1. Quartal 1990 bis 2. Quartal 2006 verwendet wurde. Zunächst haben wir geprüft, ob strukturelle Brüche zu verzeichnen waren. Der Übergang zu einer einzigen Währung im Januar 1999 hat es uns ermöglicht, den Untersuchungszeitraum in zwei Teilzeiträume aufzuspalten, nämlich 1. Quartal 1990 bis 4. Quartal 1998 und 1. Quartal 1999 bis 2. Quartal 2006. Für den ersten Teilzeitraum stellen wir eine relativ stabile Nachfragefunktion fest, während die für den zweiten Teilzeitraum ermittelte weniger stabil zu sein scheint. Dies ist weitgehend auf die Tatsa-

che zurückzuführen, dass die Einführung einer einzigen Währung zu größerer Wirtschaftsintegration geführt hat. Danach haben wir uns eines MVAR-Modells (Multivariate Vector Autoregressive Model) bedient. Das Ergebnis ist ein beträchtliches Ausmaß an monetärer Interdependenz während des zweiten Teilzeitraums, die sich aus Währungssubstitution und Kapitalmobilität ergibt. Dieses wiederum erfordert weitere internationale monetäre Koordinierung zwecks Aufrechterhaltung eines stabilen Wachstums des gesamtwirtschaftlichen Geldmengenangebots, damit eine angemessene Preisstabilität gewährleistet werden kann.