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Kari Heimonen

Substituting a Substitute Currency – The Case of Estonia

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Contents

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Kari Heimonen *)

Substituting a Substitute Currency – The Case of Estonia

Abstract

This study evaluates substitution of foreign currency balances in Estonia, a transition economy neighbouring countries participating in EMU. The focus is on substitution between dollar and euro balances in the three basic functions of money – unit of account, store of value and means of payment. While traditional models for currency substitution concentrate on substitution between a domestic currency and aggregate foreign currency balances, we look for substitution between the dollar and the euro or euro-related foreign currency balances. We find substitution between dollarization and euroization to be asymmetric in the short run, which suggests that inertia, irreversibility and ratchet effects favour the euro. No significant evidence of asymmetries in the long run was detected. In general, the traditional model for currency substitution explains the dynamics of the euro and dollar as substitute foreign currencies.

Keywords: euro, dollar, currency substitution, currency demand.
JEL Classification: F31, E41, G11

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1 Introduction

Ahead of the euro's launch, the new currency was expected to seriously challenge the US dollar's preeminent role as the world's leading monetary vehicle and substitute currency. Portes and Rey (1998), Hartman (1998) and McCauley (1997) all predicted that that the euro would serve as a substitute for the dollar as an internationalized currency. Among Central and East European Countries (CEECs), especially those hoping to join the EU and participate in Economic and Monetary Union (EMU), substitution of euros for dollars seems quite likely.[1] In effect, economies formerly regarded as *dollarized* look destined to become *euroized*.[2] This study examines the dynamics of this shift in substitute currencies. We do this by estimating the degree of substitution between euro and US dollar balances in Estonia, and then use Estonia as a representative transition CEEC.

Dollarization in CEECs, particularly the Baltics, has been subject of several recent studies. Korhonen (1996) and Vetlov (2001) consider dollarization in Lithuania, Sarajevs (2000) studies Latvia and Sahay and Végh (1996) attempt to determine the extent of dollarization in 15 transition economies including the Baltics. Overall, CEECs have been moderately dollarized (see Baliňo, Bennet and Borensztein, 1999). In principle, several factors favour dollarization in those countries. First, currency substitution is expanded because of the loss in purchasing power of domestic money. Second, foreign currency may act as a substitute for domestic bonds. Finally, increased economic integration between CEECs and the EU may expand demand for foreign currency balances. These factors not only im-

[1] The shift from dollar into euro could be strong among the EU candidate countries (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia) and EU transition accession countries (Cyprus, Malta and Turkey).

[2] *Dollarization* in often used interchangeably with *currency substitution*. An economy is said to be dollarized or euroized when these currencies serve, like the domestic money, in all three functions of money. Technically speaking, however, dollarization refers to the use of a foreign currency as store of value and unit of account. Currency substitution happens in the late stage of dollarization. For different definitions of dollarization and currency substitution see Calvo (1996), Giovannini and Turtelboom (1994), Calvo and Végh (1992) and McKinnon (1985).

pact demand for foreign currency balances in the economy, but also the denomination of the currency demanded as a substitute. In other words, substitution can also occur between foreign currencies serving as substitutes for a domestic currency. This aspect of currency substitution has generally been overlooked in studies on currency substitution and dollarization. However, the dynamics between the world's two major international currencies, the dollar and the euro, can be expected to gain importance in international monetary economics for several reasons.

Not least is the fact that substitution of a substitute foreign currency may decrease the monetary autonomy of both the central bank issuing the currency used as a substitute and the central bank in the country where that foreign currency serves as a substitute.[3] It is important to assess the potential impact of CEEC currency substitution on ECB monetary policy because in addition to possible harmful symmetric impacts on the autonomy of the monetary policy, currency substitution may have asymmetric impacts on government finance. For example, the country whose currency is substituted loses seigniorage income to the central bank circulating the currency used as the substitute. The higher a country's domestic inflation and its degree of currency substitution, the greater the seigniorage losses. On the other hand, a high level of euroization among CEECs implies low costs for joining EMU.

There is, of course, the possibility that the US dollar maintains its leading position, keeping euroization at a low level and thus limiting this phenomenon's impact on ECB monetary policy. However, if euroization overtakes dollarization, even regionally, the ECB could see its autonomy in monetary policy threatened by widespread external use of the euro. Indeed, the ECB itself may promote or discourage euroization through its policies. A negative attitude towards the currency board arrangements or full euroi-

[3] The impaired effects of currency substitution on monetary policy are based on seminal work of MacKinnon (1982). He argues that *"international currency substitution destabilises the demand for individual national monies so that one cannot make much sense out of year-to-year changes in purely national rates of inflation"* (p. 320). In principle, then, a large external use of euro balances could have severe negative impacts on the EMU-area as it affects the transmission of monetary policy and impairs ECB monetary policy focused on money growth and inflation targeting.

zation might hinder the external use of the euro and reduce overall use of the euro.[4]

The dynamics of substitution between substitute currencies also deserve study. Evidence of ratchet effects and inertia propose substantial costs attributed to the use of particular currency has been noted by e.g. Ahumada (1992), Kamin and Ericsson (1993), Guidotti and Rodriquez (1992), Mongardini and Mueller (2000), Piterman (1988), Dornbusch and Reynoso (1989) and Dornbusch, Sturzenegger and Wolf (1990). Correspondingly, the absence of a ratchet effect might suggest that neither the dollar nor the euro has reached a sufficiently high share of the currency balance to overcome substantial and specific investment costs. It might also imply that neither currency provides superior network externalities.[5]

The main purposes of the present study are to estimate possible portfolio shifts among the substitute currencies related to the substitution of substitute currencies in the CEECs and identify the dynamics of such substitution, focusing on the short-term ratchet effect and long-run Enders and Siklos (2001) threshold cointegration. We also test the efficacy of traditional theories of currency substitution in evaluating substitution between euros and dollars.

The study is organized as follows. Section two discusses the determinants of an international currency. Section three defines the concepts of capital flow, currency substitution and dollarization/euroization. It introduces the traditional Miles (1978) model of currency substitution and applies it to substitution between the dollar and the euro. Section four tests several specifications for the Miles model on the substitutability between euro and dollar in Estonia. Section five provides a few concluding remarks.

[4] In a speech in Calgary on 8 September 2000, ECB Chairman Wim Duisenberg noted *“The ECB has adopted a neutral stance towards the international use of euros”.* Nonetheless, the ECB acknowledges that the internationalization of a currency is mainly a market-driven process and that price stability will foster the attractiveness of the euro as an international currency.

[5] The demand for a currency can be explained by the network externalities it provides. Thus, a currency may still be demanded even when the opportunity cost of holding it exceeds the opportunity cost of holding a substitute currency. See Dowd and Greenway (1993).

2 Determinants for the Substitution of the Substitute Currency – From Dollarization to Euroization among CEECs

In principle, substitution of dollar balances with euros depends on how well the euro fulfils its tasks as an international currency, as a means of payment, store of value and unit of account.[6] Yet, even if the euro is able to perform its substitute currency functions as effectively as the dollar, there are a number of obstacles on the path from dollarization to euroization.

First, replacement of dollars with euros takes time. The demand for euros can be expected to grow gradually along with the ongoing economic integration of EMU countries and their neighbours. Rising trade between EMU participants and CEECs will raise the significance of the euro as an invoicing currency, as well as the transaction demand for the euro.[7] The EU is the main trading partner of the CEECs. This relationship is encouraged not just by physical proximity, but practical measures to promote trade. For example, the export of the Estonian manufactured goods to the EU has been duty-free since 1998.[8]

Risk-related factors also drive euro-based foreign trade between the EMU area and its neighbours. Several EMU neighbours have pegged their exchange rates to the euro. Such official use of the euro as a unit of account decreases the risks of exchange rate volatility and contributes to

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[6] An international currency is one where individuals and institutions in other countries accept or use that currency as a medium of exchange, unit of account or store of value. Traditionally, the tasks of an international currency are separated into private and official tasks as a means of payment, store of value and unit of account. The official tasks refer the use of the foreign currency in interventions, as a peg, and as a reserve currency. The last task relates the use of the international currency as a vehicle currency, an invoicing currency and a banking currency.

[7] For evidence on the impacts of foreign trade on demand for the substitute currency, see Ratti and Jeong (1994), Milner, Mizen and Pentecost (1996), (2000) and deVries (1988).

[8] The share of value in Estonia's 1997 exports to the EU area was 48 %. In 1999, this share had risen to 62.3 %. Sources: *Estonia, Latvia, Lithuania Foreign Trade 1999, Statistikos Lithuania, Vilnius 2000.*

wider private use of euros.[9] The introduction of fiat euro currency in 2002 should further boost the relative importance of the euro as a substitute currency. The monopoly European currency provides wider network externalities and decreases the cost of using European currencies compared to the pre-EMU world with multiple national European currencies.

Exchange rate arrangements may also affect substitution of the substitute currency. The theory of currency substitution posits that, unlike fixed exchange rate systems, a flexible exchange rate regime enlarges the demand for foreign currency balances. The type and the credibility of a peg may also have certain impacts. The demand for foreign currency under the pegged exchange rates may partly reflect the credibility of the peg, as well as other motives for sticking with the international vehicle currency. We assume that speculative demand for foreign currency, due to the imperfect credibility of pegs, is lowest under a currency board arrangement and highest in systems with a unilateral peg.

Estonia reduced its large foreign currency balances by adopting a deutsche-mark-based currency board arrangement in June 1992. Bulgaria used a similar strategy.[10] Lithuania, which adopted a currency board based on a dollar peg in April 1994, has experienced large fluctuations in its for-

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[9] Bosnia and Herzegovina, Bulgaria, and Estonia have pegged their currencies to the euro through *currency board* arrangements. The Bank of Lithuania, which also operates a currency board, has announced plans to abandon its dollar peg and repeg the litas to the euro in February 2002. Cyprus pegs its currency to the euro via *fluctuation bands*. Hungary, Malta and Poland use *currency baskets* with heavy euro weightings. Latvia pegs to the SDR. Slovakia, Slovenia and the Czech Republic use *managed floats* in which the euro acts as an informal reference currency. Macedonia's "managed float" is generally regarded as de facto euro peg. Turkey employs a *managed float with a real exchange rule.* For more on exchange rate arrangements, see *European Central Bank, Monthly Bulletin, August 1999* and *IMF Annual Reports on Exchange Rate Arrangements and Exchange Restrictions.*

[10] Bulgaria adopted a currency board in July 1997 and modestly succeeded in decreasing the rate of dollarization (foreign currency depoists/M3). In July 1997, it was 50.2 %. By December 2000, the dollarization rate had fallen to 34.3 %. See Bulgaria Central Bank, Monetary Survey.

eign currency balances due to the lack of credibility of its currency board.[11]

Peg arrangements can promote the demand for certain foreign currencies. Latvia pegged to the SDR in February 1994. By December 2000 about 89 % of all foreign currency deposits were denominated in US dollars. Similarly, Estonia's currency board arrangement, based earlier on the deutsche mark and now the euro, has contributed to extensive use of euro-related currencies. (See Table 1.)

Ultimately, *currency competition* between the dollar and the euro will determine the relative importance of the dollar and euro as an international currency. Two factors drive demand in a currency competition. The medium-of-exchange role of money drives agents towards use of the monopoly international currency, whereas the store-of-value role of money is in favour of the utility of multiple international currencies. The first factor reflects transaction cost theory, while the latter follows the theory of international portfolio diversification. Under transaction cost theory, e.g. Krugman (1980) and Black (1991), the demand for the *substitute vehicle currency* relates to transaction costs and transaction needs of international trade. This is in favour of the demand for the monopoly foreign currency and the corner solution. The relative importance of portfolio diversification may also decrease due to more trade with the euro zone and the possible home-country bias emerging from it. As a result of currency competition, the euro could account for a large share of the foreign currency balances among the CEECs, unseat the dollar (at least in countries neighbouring the EMU area) or even encourage monetary unification outside EMU.[12]

The dynamics of substitution also deserve analysis. Due to the network externalities provided by the vehicle currency, a shock may be needed to induce a change in the vehicle currency. After the shift, the emergence of the new vehicle currency would be self-reinforcing as those clinging to the

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[11] In Lithuania, foreign currency balances actually increased. In 1993, the share of individuals foreign currency deposits with respect to total deposits was 35.5 %, whereas at the end of 2000 the share was 56.5 %. Similarly, in 1993 the share of foreign currency balances from M2 was 34.7 %, but 45.7 % in 2000. See Lietvos Bankas Quarterly Bulletin 2000/4 and Vetlov (2001).

[12] Vaubel (1990) originally suggested this as a driving force towards monetary union. It could also drive EU aspirants to EMU participation.

old currency would face higher transaction costs. Indeed, a shift in international currencies could be relatively swift once the critical point in transaction costs is exceeded.[13]

As noted by deVries (1988), habits and inertia in the use of substitute currency may play a role in discouraging the shift from one substitute currency into its substitute. However, if a shock is large enough to overcome inertia and exceed the threshold level in currency balances, the change in the composition of foreign currency balances could be immediate.

The persistence in foreign currency balances may be related to the opportunity cost of holding currency. Several studies note hysteresis in dollarization. Ahumada (1992), Kamin and Ericsson (1993), Guidotti and Rodriquez (1992), Mongardini and Mueller (2000), Piterman (1988) all find empirical evidence that dollarization may remain high even when the opportunity cost of holding domestic money has decreased. These findings contradict traditional models of currency substitution, which propose symmetric effects for the changes in the opportunity costs of holding money. Thus, the elasticity of money demand with respect to inflation is higher when inflation is rising than when inflation is falling. These are explained by the fixed costs, which make high level of foreign currency balances irreversible. Dornbusch and Reynoso (1989), Dornbusch, Sturzenegger and Wolf (1990) claim this is due to the high costs of the financial adaptation process which involves sunken costs and "learning by doing." In other words, irreversibility in dollarization relates to transaction costs. Why then is irreversibility mainly detected in time deposits, which serve as a substitute for store of value rather than means of payment? Guidotti and Rodriquez (1992) account for this store-of-value role by pointing out that the irreversibility is related to the inflation band. Above the band limits, dollarization continues as long as inflation is falling. Thus, dollarization

[13] On the other hand, the common currency does not necessarily decrease transaction costs. Hau, Killeen and Moore (2000) indicate that the bid-ask spreads in euro rates have increased compared to pre-euro spreads. Two explanations for this puzzling evidence have been offered. First, the introduction of euro eliminates cross rates, which in turn reduced the intra-temporal risk-sharing capacity of the multi-currency dealership market. Second, the information content of order flow in euro rates relative to previous deutsche mark rates has increased. Thus, the external rates of euro no longer benefit from the spillover from uninformed intra-European order flow.

involves both backward-looking and forward-looking elements. Below the band limits, the level of currency balances is determined based on the past opportunity costs of holding a currency. Above the band, dollarization or "de-dollarization" are forward-looking processes. The irreversibility of dollarization may also depend on the amount of agents using a particular currency. It is costly to transact in foreign currency only if others do not use it. Thus, above a certain level of dollarization, where foreign currency is widely used in all functions of money, changing back to the domestic money becomes costly. Along these lines, Uribe (1997) observes that the cost of transacting in a foreign currency depends on the extent of dollarization.

Inertia in currency substitution between domestic and foreign currency balances has been widely documented, yet there are no studies that specifically seek to detect inertia among substitute foreign currencies. Possible inertia between euro and dollar balances has obvious importance to the dynamics of currency competition between the dollar and euro among CEECs. In principle, currency competition could evolve along several possible paths. First, euro balances in CEECs could gradually increase their relative share in foreign currency balances as a of increased economic integration with EMU. This gradual shift from dollarization to euroization would be supported by economic agents that gradually learn to use the euro. The second scenario is based on the ratchet effect in currency substitution proposed by Guidotti and Rodriquez (1992). The transition from dollar to euro could be quite rapid once euro balances exceeds the critical level needed for efficient transactions.

3 Currency Substitution, Dollarization and Euroization

3.1 Definitions for Currency Substitution and Dollarization

The agent portfolio problem can be broadly characterized as follows.[14] Determination of currency balances occurs sequentially. First, the agent divides his wealth between money (M) and non-monetary assets (B). Second, the allocation between foreign and domestic money is made (3). From his monetary assets, share α is invested in foreign internationalized currency balances (M^f) and (1- α) is invested in domestic money (M^h). Third, bonds are divided into domestic (B^h) and foreign bonds (B^f). The agent then further divides his foreign bond portfolio between dollar-denominated bonds [$B^{USD} = (1-\lambda)B^f$] and euro-denominated bonds [$B^{euro} = \lambda B^f$]. Finally, the agent divides his foreign currency balances between dollars [$M^{USD} = (1-\beta) M^f$] and euros [$M^{euro} = (\beta M^f)$]. In case of β = 0 or β = 1, monopoly foreign currency offers services related to substitute currency and thus no substitutability between foreign currency balances exists.

$$W = B^h + M^h + M^{USD} + M^{euro} + B^{euro} + B^{USD} \quad (1)$$

$$B = B^h + B^f \quad (2)$$

$$B^h = \gamma B;\ B^f = (1-\gamma)B \quad (2.1)$$

$$B^{USD} = (1-\lambda)\ B^f \quad (2.2)$$

$$B^{euro} = \lambda B^f \quad (2.3)$$

$$M = M^h + M^f \quad (3)$$

[14] We only consider demand-determined dollarization, not official dollarization arrangements.

$$M^h = \alpha\, M;\, M^f = (1-\alpha)M \qquad (3.1)$$

$$M^{USD} = (1-\beta)M^f;\, M^{euro} = \beta M^f \qquad (3.2)$$

Traditionally, studies on currency substitution examine determination of currency demand at (3.1). In this study, we endeavour to specify the factors that determine the substitute currency, (3.2).

Currency substitution occurs between domestic and foreign currency balances, Equations (3)-(3.2). Currency substitution between the substitute currencies is related to the optimization problem between foreign currency balances and is thus described by Equation (3.2). Dollarization and euroization, in turn, are broader concepts and include both currency substitution and substitutability between assets (i.e. capital flows). We thus define $(M^{USD} + B^{USD})/W$ to represent the degree of dollarization and $(M^{euro} + B^{euro})/W$ the degree of euroization.[15] $(M^{USD} + M^{euro})/M$ measures the overall level of currency substitution and (M^{euro}/M^{USD}) the substitution between substitute currencies, euro and dollar. The functional difference between dollarization /euroization and currency substitution is in the ability to fulfil the functions of money. Dollarization/euroization refers to situation where foreign money fulfils all the tasks related to money: i.e. store of value, unit of account and means of payment. Currency substitution only relates to the use of foreign currency as a means of payment.[16] *In other words, the concept of dollarization/euroization relates more to the store-of-value role of money, while currency substitution more narrowly relates to substitution between means of payment.* An economy may be highly dollarized or euroized even with little currency substitution. Conceivably, despite large

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[15] This definition does not rule out the possibility that an agent has liabilities denominated in foreign currency, i.e. debt dollarization.

[16] In principle, money (M) consists solely of cash balances held for transaction purposes. Cash balances are not expected to yield any interest. Bonds, in turn, are interest-yielding assets. Interest-yielding currency deposits may serve as a proxy for dollarization/euroization in an economy where the investment in foreign bonds is otherwise impossible.

foreign currency balances, a domestic currency may still be used extensively in transactions.

A further distinction can be made comparing changes in opportunity costs. A change in the opportunity cost of holding money has different impacts on dollarization and currency substitution. Dollarization, which refers to the store-of-value role of foreign currency, is dependent on the real interest rate. Currency substitution is also affected by the nominal interest rate. Thus, a decrease in the interest rate will not effect dollarization if it has no impact on domestic inflation. Currency substitution, however, can be expected to decrease along with decreasing interest rates.[17]

Formal models of dollarization that distinguish between dollarization emerging from foreign bonds and foreign money are scarce. The remarkable Thomas (1985) model is the notable exception.[18] Even rarer are models that make it possible to estimate dollarization emerging from foreign bonds and foreign money. Indeed, even with such a model, there is the problem of data scarcity. Therefore, we must settle for examining euro-dollar substitution with models of currency substitution that do not distinguish between currency substitution and dollarization. On a positive note, the novel advantage of this approach is that it also tests the usefulness of traditional currency substitution models in detecting substitution between substitute currencies.

3.2 Substitution of the Substitute Currency in the Money Service Model

There are slight differences in how various theories of currency substitution explain demand for foreign currency. Models of currency substitution can be broadly categorized by their theoretical underpinnings. One class of models employs money as a pure source of liquidity services without any transaction variables involved. Another class of models explicitly consid-

[17] See Sahay and Végh (1996).

[18] The Thomas (1985) model differs from other models of currency substitution in that it incorporates the possibility for lending. See also Calvo and Végh (1996), Sahay and Végh (1996).

ers the transaction demand for money and includes a separate transaction variable.[19]

The early models of currency substitution, e.g. Calvo and Rodriquez (1977), relate currency substitution to the current account surplus. In these models, foreign money is the only internationally traded asset.[20] Hence, the stock of foreign currency can only be expanded through current account imbalances. Because such models aggregate asset substitutability and currency substitution, they are not useful in describing dollarization where bonds are available. Our main criticism of such models, however, is that they are ill-suited for proper empirical testing.[21]

A popular approach to study currency substitution is based on estimation of money service models.[22] It originates with Chetty's (1969) model for liquidity services provided by money balances. Miles (1978) followed with a seminal work, that since has spawned several studies utilizing this approach in determination of the demand for substitute currency, e.g. Miles and Stewart (1980), Rojas-Suarez (1992). Imrohoroglu (1994), Buffman and Leiderman (1992), (1993) subsequently dynamized this approach for intertemporal contexts. Notable, money service models such as Miles (1978) have not been applied before this study for substitution of the substitute international currencies.

The Miles (1978) model can be applied for the substitution of the substitute currency by following. Let us assume that M^{euro}/P^{euro} of euro bal-

[19] For a categorization of both theoretical and empirical models see e.g. Calvo and Végh (1992), Giovannini and Turtelboom (1994), Mizen and Pentecost (1996).

[20] See also Kouri (1976).

[21] No empirical tests on such models exist. These models all assume currency substitution comprises two effects: a price effect and a quantity effect. Separating these two is impossible, however. First, exchange rate depreciation, which lowers the value of domestic money, leads to higher share of foreign currency balances in the portfolio. Second, exchange rate depreciation leads to trade balance surplus, which accumulates foreign cash in the domestic resident portfolio and further increases the share of foreign currency in the portfolio. For a critique, see Mizen and Pentecost (1996).

[22] Along with the portfolio balance model, it may be regarded as a one of the most widely used in empirical estimation of currency substitution.

ances and M^{USD}/P^{USD} dollar balances produce money services in the CES production function (4).

$$\frac{MS}{P^i} = \left[\alpha_1 \left(\frac{M^{euro}}{P^{euro}} \right)^{-\rho} + \alpha_2 \left(\frac{M^{USD}}{P^{USD}} \right)^{-\rho} \right]^{-(1/\rho)} \qquad (4)$$

MS refers to money services; P^{euro} and P^{USD} are euro and dollar price indices. P^i refers to a country in which dollar and euro are substitutes. While real balances are in goods units, for the purpose of empirical estimation the function is produced for nominal cash balances and exchange rates. α_1 and α_2 reflect the efficiency of euro and dollar balances in producing money services, i.e. all functions provided by money (means of payment, store of value and unit of account). Thus, their relative efficiency is captured by the constant term.

Assuming triangular arbitrage and absolute purchasing power parity (PPP) holds between the Estonian, US and EU economies, we would have $e^i_{US} = P^i/P^{US}$, $e^i_{EU} = P^i/P^{EU}$. Denoting $P^i = 1$, we obtain the following money services function.

$$MS = (\alpha_1\ e^i_{EU} M^{-\rho}_{euro} + \alpha_2\ e^i_{US} M^{-\rho}_{USD})^{-(1/\rho)} \qquad (5)$$

Following Miles (1978) and sequential portfolio selection, agent first decides to hold a level of M^f of foreign cash balances. Second, the agent divides his cash balances between the euro and dollar balances based on the relative costs of holding these currencies and their relative effectiveness to produce services. These asset constraints are expressed as real balances (6) and in terms of nominal balances using PPP (7).

$$\frac{M_0^f}{P^i} = \frac{M^{euro}}{P^{euro}}(1 + i^{euro}) + \frac{M^{USD}}{P^{USD}}(1 + i^{USD}) \qquad (6)$$

$$M_0^f = e^i_{EU} M^{euro}(1 + i^{euro}) + e^i_{US} M^{USD}(1 + i^{USD}) \qquad (7)$$

Accordingly, M^f_0 is the total money asset that must be held to provide the money services of M^{euro} and M^{USD} money assets. Maximization of the production function with subject to the assets constraints produces marginal conditions:

$$\partial MS / \partial M^{euro} = \lambda(1 + i^{euro}) \quad (7.1)$$

$$\partial MS / \partial M^{USD} = \lambda(1 + i^{USD}) \quad (7.2)$$

$$M_0^f = e_{EU}^i M^{euro}(1 + i^{euro}) + e_{US}^i M^{USD}(1 + i^{USD}) \quad (7.3)$$

From the marginal productivity of euro and dollar balances in producing money services (7.1) and (7.2), we obtain the relative marginal productivity (8):

$$\frac{\alpha_1}{\alpha_2}\left(\frac{e_{EU}^i M^{euro}}{e_{US}^i M^{USD}}\right)^{-(1+\rho)} = \frac{1+i^{euro}}{1+i^{USD}} \quad (8)$$

Following Miles (1978), we take logs from the sides and rearrange terms to obtain (9).

$$\log\left(\frac{e_{EU}^i M^{euro}}{e_{US}^i M^{USD}}\right) = \frac{1}{1+\rho}\log(\alpha_1/\alpha_2) + \frac{1}{1+\rho}\log\left(\frac{1+i^{USD}}{1+i^{euro}}\right) + u \quad (9)$$

If Fischer parity does not hold, there could be an additional inflation factor having impact on the substitutability of currencies. Thus, the opportunity cost of holding money can be distinguished as separate factors, i.e. the opportunity cots of holding money due to the interest rate and the opportunity cost of holding money due to relative rates of inflation: $\Delta p^{USD}/\Delta p^{euro}$.

$$\frac{1}{1+\rho}\log\left(\gamma_1\left(\frac{1+i^{USD}}{1+i^{euro}}\right) + \gamma_2\left(\frac{\Delta p^{USD}}{\Delta p^{euro}}\right)\right) \quad (9.1)$$

From (9), we obtain estimates for the elasticity of substitution between dollar and euro balances [($\sigma = (1/1 + \rho)$)] and for the ratio of efficiency of foreign currency balances in providing monetary services α_1/α_2. High substitutability emerges in the model either through the elasticity of substitution or through the ratio of the efficiency coefficients α. Perfect substitutability implies a unit value for α_1/α_2. The value of the elasticity of substitution σ can be directly estimated from the coefficient for the marginal productivity term, while the value for the ratio of coefficients α_1/α_2 is $\alpha_1/\alpha_2 = \exp(C/\sigma)$. The ratio of α_1/α_2 is expected to capture the transaction demand for foreign currency balances and thus regarded as fairly constant.

Asymmetry and the ratchet effect can be introduced by replacing $(1/1 + \rho)[1 + i^{USD}/1 + i^{euro}]$ with the Heaviside indicator function I_t in (9.2).

$$+ I_t \left[\frac{1}{1+\rho} \log\left(\frac{1+i^{USD}}{1+i^{euro}} \right) \right] + I_t \left[\frac{1}{1+\rho} \log\left(\frac{1+i^{USD}}{1+i^{euro}} \right) \right] + u \quad (9.2)$$

$$\text{so that } I = \begin{cases} 1 \textit{ if } \left[(1+i^{USD})/(1+i^{euro}) \right] \geq \tau & (9.2.1) \\ 0 \textit{ if } \left[(1+i^{USD})/(1+i^{euro}) \right] < \tau & (9.2.2) \end{cases}$$

Thus, elasticity of substitution may have different values depending on the type of asymmetry and the value of threshold τ.

Bordo and Choudri (1982), Cuddington (1983), for example, have criticized the money service approach for exaggerating short-term speculation. They point out that it omits the transaction demand for currency while focusing exclusively on liquidity services provided by money balances. Evidence from low and moderate inflation countries indicates that in order to have a proper measure for the dynamics of currency substitution, explicit measures for transaction demand are needed. This criticism is partly avoided by including incomes in the money service model for currency substitution,[23] as well as in modified portfolio balance models of Cuddington (1983) and Branson and Henderson (1985). Portfolio balance models utilize domestic output as a measure of wealth. Transaction technology-based models regard output as a measure for transaction needs for the substitute currency. In any case, these models suggest that Miles-type models need to be augmented with output.

The inference, however, may be inappropriate for an economy where foreign currency balances are not used in domestic transactions. Rather, transaction demand for foreign currency balances emerge because of foreign trade. Ratti and Jeong (1994),[24] deVries (1988), Bergstrand and Bundt (1990), Milner, Mizen and Pentecost (1996), (2000)[25] all note that foreign currency demand is closely related to transaction needs emerging from foreign trade. In those studies foreign trade and transaction demand turn out to be even more important than the opportunity costs for holding money. In

[23] See Bordo and Choudri (1982), Marquez (1987). For substitute foreign currencies, the Bourdo-Chourdi specification would be

$$eM^{euro} / eM^{US} = \delta_0 + \delta_1 \log y + \delta_2 i^{euro} + \delta_3 (i^{US} - i^{euro}).$$

[24] The Ratti and Jeong (1994) model is an intertemporal, shopping cost version of a money service model and avoids the assumption of sequential portfolio selection applied in studies using the Miles (1978) model. Transformed Ratti and Jeong (1994) specification would produce in our case following equation

$$\ln(em^{euro}/em^{USD})_t = \eta_0 + \eta_1 \ln\left[(r^{USD}/r^{euro})(1+\varepsilon)\right] + \eta_2 \ln(eP^{USD}/P^{euro})_t + \eta_3 \ln\left(\frac{(E/I)^{USD}}{(E/I)^{euro}}\right).$$

The expected signs for coefficient are $\eta_1 > 0$; $\eta_2 < 0$; $\eta_3 < 0$. It involves the ratio of exports to imports (E/I) and real exchange rate eP^{USD}/P^{euro} and an interest rate differential adjusted for depreciation of the domestic currency $[r^f (1 + E(de))/r^d]$. If the relative holdings of currency *i* balances are responsive for the real exchange rate, then currency balances in the money service function should be deflated by the currency of country *i*.

[25] Milner, Mizen and Pentecost (2000) draw from Bergstrand and Bundt (1990) and introduced *gross international trade (T)* as a transaction variable. For substitution of the substitute currency the specification would be

$$\ln(em_t^{F,euro} / em_t^{F,USD}) = \eta_0 + \eta_1 r_t^{euro} + \eta_2 r_t^{USD} + \eta_3 \ln(T^{euro} / T^{USD}) + \varepsilon_t.$$

this study, all these aspects of asymmetries, transaction demand and foreign trade for the demand for an internationalized substitute currency are taken into account.

4 Evidence of Substitutability of Dollar and Euro Balances in the Estonian Economy

The share of deposits in foreign currency in Estonia in January 1994 was 7.8 %. By December 2000, the figure had reached 34 %. Hence, Estonia is classed as a dollarized economy. To evaluate substitution between substitute currency in the Estonian economy, we must distinguish dollar deposits and deposits in euro-related currencies. Table 1 shows that most deposits in foreign currency fall into these two categories.

Table 1. Foreign currency deposits in Estonia

	USD	DEM	SEK	FIM	EUR	EUR*	Other
April 1997	*15.3 (70.4)*	*3.8 (17.3)*	*0.4 (1.8)*	*0.8 (3.6)*	-	*4.6 (21.0)*	*1.5 (6.9)*
April 2000	*10.0 (56.7)*	*7.2 (23.5)*	*0.6 (2.0)*	*0.8 (2.7)*	*3.6 (11.8)*	*9.0 (29.4)*	*1.0 (3.2)*

Note: Figures give the percentage share of nominal foreign currency deposits in that particular currency from the total deposits in the Estonian economy. Figures in parenthesis represent the percentage share of foreign currency deposits in that particular currency. EUR* denotes share of deposits in a constructed euro currency, an aggregate of deposits in DEM, FIM and EUR. Deposits include all the client sectors other than credit institutions and include both deposits owned by residents and non-residents. All deposits are converted into Estonian currency at current exchange rates. The data for foreign currency deposits denominated in different currencies is available from April 1997. Source: Bank of Estonia.

Foreign currency deposits were mainly spread between four major currencies: the US dollar (USD), deutsche mark (DEM), Finnish markka (FIM) and Swedish krona (SEK). Among the other significant currencies were the British pound and Latvian lats, neither of which are EMU participants. The share of currencies seemed to be relative stable between April 1997 – April 2000. During the period, the US dollar was the most important foreign currency in Estonian economy, although its relative importance declined in relation to euro-related currencies. [26]

We compose two groups for deposits in foreign currency: currency balances in US dollars and currency balances in euro-based currency. Foreign currency balances in euro and US constitutes demand deposits, savings deposits and time deposits. Thus, the substitutability of foreign currencies in terms of store of value, unit of account and means of payment is explored. As displayed in Table 1, deposits in EMU-related currencies were made mainly in FIM, DEM, and since 1999, in EUR. In effect, the aggregate of currency deposits in DEM, FIM and EUR serve as euro-based deposits and a substitute (FCD^{euro}) for dollar deposits (FCD^{USD}). The bias emerging from the omitted euro-based currencies is insignificant.[27]

The deposit rate (dr) for currency balances is expected to capture the opportunity costs of substitute foreign currencies (dr^{euro}) and (dr^{USD}). We also introduced a second measure for the opportunity cost of holding currency balances, the short-run interest rates differential between euro and dollar in international money markets: (r^{euro}) and (r^{USD}).

Regarding the Bordo-Choudri critique we introduce several transaction variables to capture the transaction demand and assure the validity of a Miles-type of model of foreign currency balances. First, we employ the *sales of Estonian manufactured goods* (Y). This index is expected to capture the overall economic activity in Estonian economy on a monthly basis and serves as a measure for the transaction demand for foreign currency balances. Second, following Ratti and Jeong (1994), deVries (1988), Mil-

[26] As far as liabilities are concerned, the Estonian economy is regarded as euroized. In April 1997, 38 % of the loan stock was denominated in deutsche marks, whereas the dollar share was only 7.5 %. Since then the share of euro-denominated loans has increased while the share of dollar-denominated loans has remained constant. By February 2001, 0.1 % of the loan stock was denominated in Estonian kroons, 9.3 % in dollars and 67 % in euro-zone currencies.

[27] The resulting bias caused by this omission is expected to be very low and of minor importance. The share of the deposits in currencies not mentioned in Table 1 is fairly low. For demand deposits, the figure is about 1 %. For other deposits, the share is around 0.7 % of total foreign currency deposits. Notably, these figures include deposits in currencies of countries not participating in EMU, including the British pound and the Latvian lats.

ner, Mizen and Pentecost (1996), (2000) we employ measures for transaction needs emerging from foreign trade. The relevant studies utilize *the ratio of imports to export* (I/E) as there is a greater incentive to invoice export in home currency and imports in importers' currency. We assume that euro will be the invoicing currency in trade with the EU. We also expect that trade with the rest of the world is invoiced in US dollars. Thus, an increase in the relative share of foreign trade with the EU increases the transaction demand for euros. The third potential measure for transaction demand is a measure for relative *gross trade*, tr(EU/W). Following Ratti and Jeong (1994) we also tested the role of real exchange rate (eP^{USD}/P^{euro}) for the demand of a substitute currency. See Data Appendix for closer exposition of the data.

4.1 Tests for unit roots

The analysis started with the tests for unit roots performed from the general to the specific. This resembles the Hall (1994) approach suggested in Ng and Perron (1995) for determining the lag structure in the ADF. As recommended by Said and Dickey (1984), the upper number of number of lags *(k)* was chosen to be large enough to avoid possible distortions emerging from possible MA components in the time series. Moreover, DeJong et al (1992) indicate that an increase in *k* results modest decrease in power and a substantial decrease in size distortions. Regarding distortions emerging from possible MA components as a more severe problem, AIC and BIC criteria, which generally produce a small number of lags, were not used.

$$\Delta y_t = \alpha + \rho y_{t-1} + \sum_{j=1}^{k} \beta_j \Delta y_{t-j} + \varepsilon_t \qquad (10)$$

Instead, the upper number of truncation lags in the ADF were specified according to the formula suggested by Schwert (1989) so that $k = INT\,[c\,(T/100)^{1/d}]$. Schwert (1989) recommends the of $c = 12$, which specifies ten lags in our analysis as a starting value. The number of truncation lags is then sequentially decreased. The last lag is significant at the 0.05 level of significance. We also test and control for possible autocorrelation in residuals. Where necessary, the number of truncation lags is sequentially increased until the residual non-autocorrelation is saved.

Tests for unit roots in Table 2 suggest that in most cases our data were I(1) processes that had to be differenced once to produce stationarity.

Table 2. Tests for unit roots

Variable	ADF for I(0); lags; s	ADF for I(1); lags; s	ADF for I(2); lags; s
$\ln[FCD^{USD}/FCD^{euro}]$	-2.156; 2 ; s	-6.126; 0; (***)	
$\ln(r^{euro}/r^{USD})$	-1.777; 4; s	-4.488; 0; (***)	
$\ln(dr^{euro}/dr^{USD})$	-2.433; 1; s	-5.721; 0; (***)	
ln [tr(EU/W)]	-1.989; 1; s	-8.278; 0; s (***)	
ln [I(EU/W)]	-1.348;1; s	-8.263; 0; s (***)	
$\ln[eP^f/P]$	1.481;10;	-1.289; 9;	- 4.414; 8; (***)
ln(Y)	-2.069; 5; s	-6.571; 0; s (***)	
$[\Delta p_t^{euro}/\Delta p_t^{USD}]$	-1.080;0;	-9.650; 0; (***)	
$\ln(r^{estonia})$	-1.846; 0;	-3.068, 0; (**)	
$\ln(dr^{estonia})$	-2.135, 5;	-3.989,4; (***)	
$\Delta p_t^{estonia}$	-2.483; 10;	-3.689;0; (***)	

Notes: Sample size April 1997-November 2000. Critical values are from MacKinnon (1991); (*) denotes significance at 10 %, (**) at 5 % and (***) at 1 % risk levels, respectively. Estimation included constants. Seasonal adjustments and time trends were included where significant.

There is an exception. The real exchange rate is an I(2) process. This suggests that PPP between the EMU and the US economy do not hold and not even the change in real exchange rate is stationary. This contrasts with the currency substitution models employing PPP assumptions.[28] There are two obvious reasons for this finding. First, the estimation period is far too short for long-run economic phenomena such as PPP. It may even be too short to yield stationarity for changes in the real exchange rate. Second, irrespective of the data, ADF tests are unanimously regarded as too weak to detect stationarity. The trade variables ln[tr(EU/W)] and ln[I(EU/W)] are also problematic with regard to inferring stationarity. Tests for unit roots suggest nonstationarity in the period April 1997–November 2000. However,

[28] The rejection of PPP is supported by several empirical studies. For surveys, see e.g. Froot and Rogoff (1995) or MacDonald (1995). In any case, the I(2) property for real exchange rate lends no support.

visual inspection, as well tests for unit roots for the period January 1994–November 2000 suggest stationarity. Knowing the low power of tests for unit roots some further analysis for inference was required. The final inference on stationarity was based on tests in cointegrating analysis.

4.2 Evidence from a Miles-type model

Our research strategy for the substitution of the substitute currency involved estimation of several specifications of a Miles-type model for currency substitution. After several tests, an augmented Miles-type model for euro and dollar balances in the Estonian economy was specified.

4.2.1 Specification of cointegrating vectors

Let us define $X_1 = \ln[FCD^{USD}/FCD^{euro}]$ and $X_2 = \ln[(1 + i^{euro})/(1 + i^{USD})] = \ln[dr^{euro}/dr^{USD}]$.
120

$$X_{1t} = a_0 + a_1 X_{1t-1} + a_2 X_{2t} + a_3 X_{2t-1} + \varepsilon_t \qquad (11)$$

This gives different elasticities for the short run (a_2) and long run $(a_2 + a_3)/(1 - a_1)$. We get the long-run elasticity when we set the variables in the dynamic model to their steady-state values (st); $X_{1,\ t+i} = X_1^{st}$, X_2^{st} ,i.e., $\ln[FCD^{USD}/FCD^{euro}]_{t+i} = \ln[FCD^{USD}/FCD^{euro}]^{st}$, $\ln[dr^{euro}/dr^{USD}]^{st}$.

The model can be re-parameterized as follows

$$\Delta X_1 = a_0 + a_2 \Delta X_{21t} - \rho[\ X_{1t-1} - \beta_1 X_{2t-1}\ ] + \eta_t \qquad (12)$$

where $\rho = (1 - a_1)$ and $\beta_1 = [(a_2 + a_3)/(1 - a_1)]$. The model generates a long-run solution, whereby all first differences are set to zero. Now we have a steady state with no deterministic level. $[(X_1 - \beta_1 X_2)]_{t-1,}$ (i.e. μ_t) represents the equilibrium correction, which we designate as *the Error Correction Mechanism* (ECM). If X_1 and X_2 are I(1) and $(\rho=0)$, there is no cointegration and we end up with estimation of the model with differenced data only.

As mentioned, the unit roots tests indicated non-stationarity. We tested for possible cointegration in several ways. First, we used Engle-Granger (1987), Augmented Dickey- Fuller (ADF) and Cointegration Durbin-Watson (CRDW) tests. Next, we employed the VAR approach of Johansen (1988) and Johansen and Juselius (1990) for cointegrating vectors. Third, we tested for threshold cointegration according to the method of Ender and Siklos (2001), which takes into account the asymmetries in the adjustment process. Finally, we applied the ECM for a powerful test for cointegration *(ρ=0)*.[29]

Symmetric cointegration

While the results of the Engle-Granger type of tests were unanimous (see Table 3), the ADF and CRDW tests failed to offer evidence of a long-run relationship in the Miles model of currency substitution. One reason for the inference could be the low power of these residual-based tests.[30] Cointegration was next tested employing the more powerful Johansen (1988), Johansen and Juselius (1990) trace and maximum eigenvalue tests.

Table 3. Engle-Granger type tests for cointegration

Model specification	ADF	CRDW
$ln[FCD^{USD}/FCD^{euro}]= 0.848+ 1.027\ ln(dr^{euro}/dr^{USD})+ \varepsilon_t$	-1.762; 0;	0.329

[29] See Kremers, Ericsson and Dolado (1992).

[30] Campbell and Perron (1991) recommend avoiding CRDW tests. Under the null of no cointegration, the asymptotic distribution of the Durbin Watson statistics depends on the nuisance parameter such as the correlations among the first-differences of the variables included in the regression. Kremer et al (1992) proposes that the weak power is due to ignoring equation dynamics and concentrating on error dynamics, which imposes a common factor restriction. ECM-based tests are thus much more powerful than residual-based tests when common factor restriction does not hold.

Notes: ADF refers to an Augmented Dickey-Fuller Test for cointegration; CRDW refers to Cointegration Durbin Watson test. MacKinnon (1991) critical values for the ADF test for cointegration were 2.953 (0.005) and 3.642 (0.001). The ADF tests for cointegration were specified along the lines of unit root tests for individual time series. The critical values of Engle and Yoo (1987) for CRDW tests for cointegration are 1.000 at 1%, 0.78 at 5% and 0.69 at the 10% level of significance.

The specification of the Johansen VAR for cointegration began with four lags, and subsequently the number of lags was reduced to the minimum to produce the Gaussian error process. Finally, we included two lags for each of the endogenous variables *(s=2)*. The status of the exogenous variables, trend and constant were determined together with the determination of the cointegrating rank.[31]

Table 4. Johansen tests for cointegration; $\ln[FCD^{USD}/FCD^{euro}]$, $\ln[dr^{euro}/dr^{USD}]$

Test	r = 0	r ≤ 1
Trace	18.1	6.39
95 % critical value	25.3	12.3
(T-nm)	16.38	5.78
λ max	11.71	6.39
95% critical value	19.0	12.03
(T-nm)	10.6	5.78
Diagnostics Tests		
Vector Portmanteau, 5 lags	15.647	
Vector AR 1-3	1.1766 [0.3356]	
Vector Norm	7.1556 [0.1279]	
Vector X_i^2	0.4756 [0.9755]	
Vector X_iX_j	0.1422 [1.0000]	

Notes: Critical values are from Osterwald-Lenum (1992), *T-nm* refers to Reimers (1992) small-sample-corrected test statistics. Numbers in parenthesis indicate statistical significance. *Vector Norm* refers to Doornik-Hansen (1993) test for vector normality.

[31] See Pantula (1979), Johansen (1992), Johansen and Juselius (1991).

Estimation started from the most restrictive version and ended with the most general. We stopped at the first specification that did not reject the null, while the rank assumption was kept constant. The constant was entered restricted only in the short-run analysis, while the exogenous time trend was included in the long-run analysis. This specification ruled out quadratic levels and implied that the system has at most a linear trend in levels. The specification also followed the simulations of Doornik, Hendry and Nielsen (1998), whereby even when DGP does not include the trend, its adoption into the cointegration analysis has a low cost. The specification is characterized as a stochastic cointegration, since the trend was included in the cointegration space and an unrestricted constant was included. In the end, neither of the Johansen-type tests rejected the null of no-cointegration (see Table 4).

Table 5 presents the identified cointegrating vector in Johansen VAR, Equation (13).

$$\Delta X_t = \sum_{j=1}^{s-1} \Pi_j \Delta X_{t-j} + \alpha(\beta' X_{t-1}) + Fq_t + v_t \qquad (13)$$

X is a vector of endogenous variables. q_t represents m deterministic variables (seasonals, constant and trend). All the parameters $\Pi_j \ldots \Pi_s$ are variation free. The rank (π) = r < n when $\pi = \alpha'\beta$. α and β are $n \times r$ matrices of rank r and $\beta'X$ comprises r cointegrating relations, $\nu_t \sim IN_n [0, \Omega]$, n dimensional, normal density with mean zero and covariance matrix Ω.

The Johansen procedure seemed to produce slightly more elasticity (1.325) than the static Engle-Granger estimation (1.027). This finding is in line with e.g. Wolters, Teräsvirta and Lütkepohl (1998). Thus, in the long run, an increase in the opportunity cost of holding currency increases the demand for a substitute currency. This supports the standard theory for currency substitution.

Johansen's VAR provided several caveats for this interpretation. The test for a long-run weak exogeneity, $\alpha_i = 0$, proposed that relative interest rates cannot be regarded as weakly exogenous in the long run. It suggests rather that the interest rate adjusts to restore possible long run equilibrium.

This contrasts with the theory of currency substitution and the interpretation of the relationship as a currency demand equation.[32]

We tested several specifications for the currency substitution models and found none were any better at estimating the elasticity of substitution and interpreting the relative currency demand equation. On the other hand, violation of the weak exogeneity should not be exaggerated in the Johansen cointegration. In an unrestricted estimation, the long-run elasticity, βs, becomes accurately estimated independent of the normalization of the cointegrating vector.[33]

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[32] We expect that banks set interest rates. Thus, agent reactions to interest rate levels and the level of balances has no impact on the interest rates themselves.

[33] The long-run specification of the Miles model proved immune to several critiques. *First*, the critique of Bordo and Choudri (1982), Ratti and Jeong (1994), Milner, Mizen and Pentecost (1996), (2000), deVries (1988), Bergstrand and Bundt (1990) regarding the omitted transaction variable was avoided. ln[tr(EU/W)] turned out to be a stationary in the cointegration space, and could thus not be included into the cointegrating vector: $\chi^2(2) = 3.857$ [0.1454]. A similar interpretation was made regarding ln[I(EU/W)]: $\chi^2(2) = 3.7724$ [0.2464]. The Bordo-Choudry critique, in turn, was avoided as, first, the model augmented with *y* did not provide evidence for cointegration, and second, the weak exogeneity of y could not be accepted. Nonetheless, while looking at the parameter value, βs were strongly affected. This provides some evidence for the Bordo-Choudri critique:

$$\ln[FCD^{USD}/FCD^{euro}] = \underset{(0.4691)}{0.517} \ln[dr^{euro}/dr^{USD}] + \underset{(1.6345)}{6.917}\ln(Y) - \underset{(0.0112)}{0.0056}trend$$

Second, the Ratti and Jeong (1994), Milner, Mizen and Pentecost (1996) and (2000) critique about the omitted real exchange rate, $\Delta\ln[eP^f/P]$, was avoided. The test for weak exogeneity of $\Delta\ln[eP^f/P]$ was rejected. This offers us an implausible explanation that the adjustment for disequilibrium in Estonian foreign currency balances occurs through changes in real exchange rate between the dollar and the euro; $\chi^2(2) = 8.7486$ [0.0031]. Nonetheless, $\Delta\ln[eP^f/P]$ increased the elasticity of substitution up to 1.6.

Table 5. Specification of cointegrating vectors

	$ln[FCD^{USD}/FCD^{euro}]$	$ln[dr^{euro}/dr^{USD}]$	*trend*
Standardized Eigenvectors β	1	-1.3247 (0.405)	-0.0049 (0.010)
Standardized Adjustment Coefficient α	0.0604 (0.111)	0.2381 (0.093)	
Tests for weak Exogeneity $\chi^2(1)$	0.12847 [0.7200]	4.7244 [0.0297]	
Tests for Significance: $\beta s\ \chi^2(1)$	5.0625 [0.0244]	4.9748 [0.0261]	

In summary, the evidence from the tests for cointegration (CRDW, ADF and Johansen) did not favour cointegration between relative foreign currency balances and interest rates.[34] Moreover, the Johansen VAR for cointegration did not support the interpretation of the long-run currency demand equation. This does not, however, imply that no long-run relationship exists. Rather, the sample size, 44 monthly observations (three years and eight months) might simply be too short for the long-run relationships between foreign currency balances and interest rates. Moreover, asymmetries in currency substitution may also have impacts.

[34] We also tested to see whether r^{euro}/r^{USD} and FCDs cointegrate. Using the Pantula (1979) principle in specifying the system, we rejected the null of no-cointegration: *Trace* test using *T-nm* 22.41 (**) and λmax using *T-nm* 30.73 (**). The vector included the constant in cointegrating space and allowed nonzero drift.

$ln[FCD^{USD}/FCD^{euro}] = 3.3486 + 2.928\ ln[r^{euro}/r^{USD}] + \varepsilon_t$ and the αs were 0.0040 (cons) and 0.059 $ln[r^{euro}/r^{USD}]$. (0.5627) (0.9325) (0.038) (0.0127)

The specification was rejected since it suggested that the international interest rate for dollar and euro, $ln[r^{euro}/r^{USD}]$, adjusts to attain the equilibrium in the system: ($\alpha_{rr} = 0$); $\chi^2(1) = 97.792[0.0000]$. FCD's in turn, were weakly exogenous to the system ($\alpha_{rr} = 0$); $\chi^2(1) = 00143[0.047]$. Moreover, the ECM with $ln[r^{euro}/r^{USD}]$ performed worse than the ECM with $ln[dr^{euro}/dr^{USD}]$.

Threshold cointegration

Traditional cointegration analysis restricts symmetric adjustment towards the long-run equilibrium. However, inertia, asymmetries and ratchet effects might impair the evidence of cointegration when the tests applying symmetric adjustment are employed. Therefore, we tested for threshold cointegration to determine whether the deviations from the long-run equilibrium were symmetric in the sense that excess holding of dollar balances adjusts to the long-run equilibrium with similar dynamics as excess holding of euro balances. Notably, threshold cointegration has not previously been applied in studies of currency substitution/dollarization.

In principle, threshold cointegration can be applied to a wide variety of cointegration models. Given the existence of one cointegrating vector, an error-correcting model for X_{1t} in case of threshold cointegration can be written as

$$\Delta X_{1t} = \rho_{1,i} I_t \mu_{t-1} + \rho_{2,i}(1-I)\mu_{t-1} + \upsilon_{it} \qquad (14)$$

where $\rho_{1,i}$ and $\rho_{2,i}$ are speed-of-adjustment coefficients for ΔX_{1t} and μ_t is (X_{1t} - $\beta_1 X_2$). In effect, the model considers processes of adjustment, $\rho_{1,i}$ and $\rho_{2,i}$, depending on the sign of the deviation from the long-run equilibrium.[35] This asymmetry in cointgration can be tested using a *Threshold Autoregressive* (TAR) model. Let us now denote the residual from the first step of Engle-Granger cointegration regression by μ_t. The TAR model can be written as

$$\Delta \mu_t = I_t \rho_1 \mu_{t-1} + (1-I_t)\rho_2 \mu_{t-1} + \varepsilon_t \qquad (15)$$

where I_t is the Heaveside indicator function. ε_t is a sequence of zero-mean, constant variance iid random variable such that ε_t is independent of μ_j, $j < t$, and τ is the value of the threshold. The TAR could also be augmented to capture the dynamic adjustment of $\Delta\mu_t$.

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[35] An alternative form of threshold cointegration relates to deviations from equilibrium. For large deviations, a mean reverting process exists, while inside the range, a unit root process exists. See Balke and Fomby (1997).

$$\Delta\mu_t = I_t \rho_1 \mu_{t-1} + (1 - I_t)\rho_2 \mu_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta\mu_{t-1} + \varepsilon_t \qquad (16)$$

$$I_t = \begin{cases} 1 \ if \ \mu_{t-1} \geq \tau \\ 0 \ if \ \mu_{t-1} < \tau \end{cases} \qquad (16.1)$$

An alternative specification for Heaveside function is one where the threshold depends on the previous period change in μ_t, which Enders and Granger (1998) refer to as a *Momentum-Threshold Autoregressive* model (M-TAR). In M-TAR models, the μ_t series exhibits momentum in one direction.

$$I_t = \begin{cases} 1 \ if \ \Delta\mu_{t-1} \geq \tau \\ 0 \ if \ \Delta\mu_{t-1} < \tau \end{cases} \qquad (16.2)$$

M-TAR adjustment is able to capture shocks in dynamics if, e.g., there is a greater adjustment for increases rather than decreases from the equilibrium.

The necessary and sufficient conditions for stationarity of the μ_t both in TAR and M-TAR models is that $\rho_1 < 0$, $\rho_2 < 0$ and $(1 + \rho_1)(1 + \rho_2) < 1$ for any value of τ. Thus, if these conditions are satisfied, $\mu_t = 0$ is the long-run equilibrium value in the system in a sense that $X_{1t} = \beta_1 X_{2\ t-1}$. Indeed, Engle-Granger cointegration is actually a special case of (14) since it assumes that adjustment is symmetric, i.e. $\rho_1 = \rho_2 = \rho$. In general, without any prior information, the value of τ is generally unknown and has to be estimated along with values of ρ_1 and ρ_2.

Table 6 Threshold cointegration.

Threshold	$I_t \mu_{t-1}$	$(1-I_t) \mu_{t-1}$	*Φ*-test	*t-Max*	$\rho_1 = \rho_2$
TAR (τ = 0)	-0.291 (-2.350)	-0.1118 (-1.022)	F(2,41) = 3.2835	-1.022	$\chi^2(1)$ = 1.1779 [0.2778]
M-TAR (τ = 0)	-0.1994 (-1.689)	-0.1815 (-1.549)	F(2,41) = 2.6259	-1.549	$\chi^2(1)$ = 0.0117 [0.9140]
TAR*(τ = -0.035)	-0.354 (-3.035)	-0.0476 (-0.437)	F(2,41)= 4.7008	-0.437	$\chi^2(1)$= 3.6914 [0.0547]
M-TAR*(τ = 0.1067)	-0.281 (-2.080)	-0.137 (-1.313)	F(2,41)= 3.0257	-1.313	$\chi^2(1)$=0.72073 [0.3959]

Note: For TAR adjustment and for unknown threshold critical values for *Φ*-test are 5.09, 6.20 and 8.78 and for the t-Max test –1.89, -2.12 and -2.58. For M-TAR adjustment and the *Φ*-test 5.59, 6.73 and 9.50 and for the t-Max test: -1.79, -2.04, -2.53. For known threshold (*), the critical values for TAR* adjustment and the *Φ** -test are 6.05, 7.24 and for t-Max* test –1.62, -1.92 and –2.44 for. Critical values for M-TAR* adjustment and the *Φ**-test are 5.97, 7.12 and 9.96 and for the t-Max* test -1.65, -1.92, -2.44.

The empirical estimation of threshold autoregression, TAR and M-TAR, involves several steps. First, the Engle-Granger-type cointegrating regression is estimated and then the type of asymmetry is decided. We tested both TAR and M-TAR specifications. We assumed $\tau = 0$. Enders and Siklos (2001) present three tests for threshold adjustment in cointegration: *t-Max, t-Min* and *Φ*. *Φ* is based for the null $\rho_1 = \rho_2 = 0$. Since the necessary condition for convergence are ρ_1 and ρ_2 to be negative, the t-Max is a direct test of these conditions. The *Φ*-test, in turn, can lead to a rejection of the null only when one of the values is negative. The usefulness of this test is in its power. In contrast, *t-Min* statistics suffer from lack of power and is hence avoided.

Results for threshold cointegration are presented in Table 6. Since there was no evidence for residual autocorrelation in any of our cases, Equation (15) was estimated. Results for TAR and M-TAR did not favour asymmetric cointegration when the value of threshold was zero ($\tau = 0$). The *Φ*-test and *t-Max* test yielded values far below the level of statistical significance. Moreover, the adjustment coefficients were quite close to each other such that an assumption of asymmetric adjustment can be rejected.

We next estimated the threshold value and applied it in tests for threshold cointegration, a TAR*-type test. Following Chan (1993) in the estimation of the threshold value, the residuals were sorted in ascending order: $\mu_1^\tau < \mu_2^\tau \ldots \mu_T^\tau$. The largest and the smallest 15 % of the values were discarded. Each of the remaining 70 % of values was considered as a possible threshold value. For each possible threshold value, Equations (15) and (16) were estimated. The estimated threshold having the lowest residual sum of squares was then selected as the appropriate value. For TAR* adjustment, the estimated threshold value was -0.035 (τ = -0.035). For known threshold values, we had stronger evidence on asymmetric adjustment. Adjustment was over seven times stronger when the disequilibrium exceeded the threshold. We were further able to reject the equality of the adjustment below and above the threshold. When the value of τ is known, standard t intervals should work well enough for the inference. Thus, the t-test for $\rho_1 = \rho_2$ had the value of –1.649 suggesting that the equality of adjustment could be rejected at the 0.010 level of significance. A similar inference was possible with the Wald test, whereby $\chi^2(1)$= 3.6914[0.0547]. This suggests that for excess dollar balances there is a more rapid adjustment towards the long-run equilibrium than for excess euro balances. However, neither the *Φ*-test nor the *t-Max* test favoured threshold cointegration at the traditional levels of significance.

We also tested the possible M-TAR cointegration for known threshold (M-TAR*). Following Chan (1993), we estimated that the value of threshold for $\Delta\mu_t$ is 0.1067 (τ = 0.1067). The final choice between the TAR and M-TAR models was made based on the residual sum of squares of the equation (15), (16). It turned out that TAR* (τ = -0.035) outperformed M-TAR* (τ = 0.1067). Thus, if threshold cointegration existed, it would be a TAR with a threshold value of –0.035.

In summary, there was no evidence of threshold cointegration at conventional levels of significance. This might be related to the lack of power of these tests since the excess parameter in the estimation implies a loss of power.[36] If the adjustment process is not too asymmetric, it is preferable to use tests that assume symmetric adjustment for long-run equilibrium.

[36] See Enders and Siklos (2001).

4.2.2 Specification of the Miles model

Our research strategy is, in principle, characterized as an attempt to test the extent to which theories and dynamic specifications of currency substitution explain the determination of the substitution between foreign currency balances. We started with the Miles model and tested it against several specifications and proposals presented in subsequent studies.

Several specifications of Miles model for currency substitution are presented in Table 7. *Miles0* refers to the model, which employs international euro and dollar interest rates. The results for the Estonian economy do not support this model. The elasticity of substitution was zero and the model had no predicting power. We could interpret that the demand for constructed euro and dollar balances is not driven by international euro-dollar interest rates and expectations of euro-dollar exchange rate changes. Alternatively, considering the composition of the constructed euro balance, it could be that interest rates of EMU-member currencies rather than euro interest rates during the period were important in determining the demand for the substitute currencies in the short run. This latter explanation was tested next.

The second version of the Miles model, Model I, introduced relative deposit rates of US dollar (dr^{USD}) and euro (dr^{euro}) balances.[37] Here, deposit rates reflect the opportunity cost of holding dollar or euro balances. This model had considerable explaining power. The short-run elasticity of substitution had the value of 0.5.[38] The value of the constant is nearly zero. According to Miles, the constant term offers the extra interpretation of the substitutability of currency balances: $\alpha_1/\alpha_2 = exp(C/\sigma)$. Thus, if the euro and dollar are perfect substitutes, the ratio between the efficiency of dollar and euro balances (α_1/α_2) in providing money services should equal one. The value of $exp(C/\sigma)$ turns out to be 0.96, which suggests that euro and dollar balances have been relatively close substitutes in the short term in producing money services in Estonian economy. The diagnostics, however,

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[37] Miles (1978) uses short-run treasury bills rates to capture the costs of borrowing money.

[38] The value is about ten times less than the long-run elasticities noted in the Miles study.

offered evidence of misspecification, i.e. heteroskedasticity due to X_i^2 and X_iX_j tests, as well as nonlinearity as indicated by the RESET test.

Since these might be due to ratchet effects and non-symmetries in the changes in the opportunity costs of holding money, two tests were applied. First, we introduced the maximum value of the opportunity cost variable along the lines of Piterman (1988), Kamin and Ericsson (1993), Mongardini and Mueller (2000), whereby $max\ ln(dr^{euro}/dr^{USD})$. Neither the change in the maximum value $\Delta max\ ln(dr^{euro}/dr^{USD})$, F(1,39) = 0.222551 [0.6375], nor the maximum value $max\ ln(dr^{euro}/dr^{USD})$, F(1,39) = 0.1058 [0.7468], were significant. Second, along the lines of Ahumada (1992) the model was re-specified to consider the case of different elasticities for increasing and decreasing opportunity costs. In effect, two opportunity costs were considered. The first, (D1), captures increasing relative interest rates; $\Delta ln(dr^{euro}/dr^{USD}) \geq 0$. The second, (D2), captures decreasing relative interest rates; $\Delta ln(dr^{euro}/dr^{USD}) < 0$. In terms of Heaviside indicator function, we write

$$I\left[\ \gamma_3 \Delta \ln(dr^{euro}/dr^{US})\ \right] + (1-I)\left[\ \gamma_2 \Delta \ln(dr^{euro}/dr^{US})\right] \quad (17)$$

$$\text{where } I = \begin{cases} 1\ if\ \left[\ \Delta \ln(dr^{euro}/dr^{US})\ \right] \geq 0\ ;\ D1 & (17.1) \\ 0\ if\ \left[\ \Delta \ln(dr^{euro}/dr^{US})\ \right] < 0\ ;\ D2 & (17.2) \end{cases}$$

The elasticities were different. Restriction for $\gamma_2 - \gamma_3 = 0$ was rejected: $\chi^2(1) = 4.839$ [0.00278]. The elasticity equal to 0.5 was clearly rejected for γ_2, $\chi^2(1) = 19.009$ [0.0000], but accepted for γ_3, $\chi^2(1) = 0.6354$ [0.0000]. This suggests that when the relative US dollar interest rate is increasing, the short-run elasticity of substitution between the euro and the dollar is higher. In an opposite case, however, when the relative euro interest rate is increasing, the short-run elasticity of substitution between dollar and euro balances is lower and not different from zero.

Finally, we estimated a more parsimonious Specification III, which turned out to be acceptable in the statistical sense: The model passed through the diagnostics and its forecasting ability was acceptable. The substitution between the euro and the dollar was supported from the elasticity parameters and from the rate of efficiency of currency balances in producing money services: $\alpha_1/\alpha_2 = exp(C/\sigma) = 1.018$. However, substitution turned out to be strongly asymmetric.

4.2.3 Augmented Miles-type models

Although we were unable to reject the null of no-cointegration in the case of symmetric (Engle-Granger, Johansen and Juselius) and asymmetric cointegration (TAR, M-TAR), we ended up estimating the ECM. There are several reasons for this. First, as noted by Kremers et al (1992), the ECM tests for cointegration. Second, as noted by Urbain (1992), the ECM offers additional ways to test the validity of long- and short-run weak exogeneity assumptions. Third, restricted ECMs provide relatively robust estimates with respect to the parameter of interest even when long-run weak exogeneity assumptions are not met. As Metin (1995) notes, the bias emerging from lacking weak exogeneity may be small when an efficient analysis is in any case impossible due to data limitations. We evaluated the impacts of the omitted long-run relationships on the short-run elasticity parameter in several ECMs. We ended up with specification of Miles IV, which resembles the specification of Miles III with an EC term, i.e. $[ln(FCD^{USD}/FCD^{euro}) - 0.848 - 1.027\ ln(dr^{euro}/dr^{USD})]$. The ECT had only a minor impact on the short-run elasticity parameter and was reduced by about 1.8 %.

Table 7 Estimates of the Miles models for Currency Substitution.

Variable	Miles	Miles I	Miles II	Miles III	Miles IV	Miles V
Constant	*-0.0161 (0.885)*	*-0.020 (1.280)*	*0.008 (0.396)*	*0.0162 (0.949)*	*0.0106 (0.631)*	*0.0107 (0.574)*
$\Delta ln[(r^{euro}/r^{USD})]$	*- 0.135 (0.0434)*			-		-
$\Delta ln[(dr^{euro}/dr^{USD})]$	-	*0.512 (4.078)*		-		-
$D1*\Delta ln(dr^{euro}/dr^{USD})$	-		*0.160 (0.797)*	-		-
$D2*\Delta ln(dr^{euro}/dr^{USD})$			*0.850 (4.360)*	*0.891 (2.127)*	*0.847 (4.734)*	*0.906 (4.890)*
ECT_{-4}					*-0.135 (2.090)*	*-0.165 (2.521)*
Seasonal – 3	-	*0.119 (1.911)*	*0.129 (2.171)*	*0.126 (2.127)*	*0.116 (2.069)*	*0.120 (2.155)*
$\Delta ln[\Delta p^{euro}/ \Delta p^{USD}]_{-2}$						*0.4232 (1.936)*
DIAGNOSTICS						
R^2	0.046	0.306	0.382	0.372	0.453	0.543
DW	2.17	2.12	2.32	2.37	2.51	2.53
F	F(1,41)= 0.18828 [0.6666]	F(2,40)= 8.8025 [0.0007]	F(3,39)= 8.0445 [0.0003]	F(2,40)= 11.857 [0.0001]	F(3.36)= 9.9447 [0.0001]	F(4,29)= 8.6022 [0.0001]
AR1-3	F(3,38)= 0.5782 [0.6377]	F(3,37)= 1.1905 [0.3267]	F(3,36)= 2.2878 [0.0951]	F(3,37)= 2.3996 [0.0834]	F(3,33)= 2.264 [0.0993]	F(3,26)= 1.3911 [0.2677]
ARCH 3	F(3,35)= 0.8804 [0.4607]	F(3,34)= 0.8381 [0.4824]	F(3,33)= 1.26 [0.3041]	F(3,34)= 0.8785 [0.4619]	F(3,30)= 0.77586 [0.5167]	F(3,23)= 0.61033 [0.6151]
Norm $\chi^2(2)$	9.636 ** [0.0081]	0.90695 [0.6354]	1.3762 [0.5025]	1.6029 [0.4487]	0.51930 [0.7713]	1.7257 [0.4220]
X_i^2	F(2,38)= 0.27074 [0.8139]	F(3,36)= 4.5888** [0.0081]	F(5,33)= 1.775 [0.1492]	F(3,36)= 2.7306* [0.0581]	F(5,3)= 2.5816 * [0.0467]	F(7,21)= 1.336 [0.2828]
X_iX_j	F(2,38)= 0.20704 [0.8139]	F(3,36)= 3.4201* [0.0184]	F(6,32)= 1.4276 [0.2348]	F(4,35)= 1.996 [0.1166]	F(8,27)= 2.6961* [0.0255]	F(12,16) = 1.437 [0.2453]
RESET	F(1,40)= 0.35017 [0.5573]	F(1,38)= 5.0398* [0.0398]	F(1,38)= 3.2345 [0.0801]	F(1,39)= 2.8674 [0.0984]	F(1,35)= 1.6358 [0.2093]	F(1,28)= 2.4112 [0.1317]
Forecast CHOW	F(6,24)= 1.0378 [0.4258]	F(6,34)= 0.4428 [0.8449]	F(6,33)= 0.40815 [0.8683]	F(6,34)= 0.39768 [0.8753]	F(6,30)= 0.72776 [0.6306]	F(6,29)= 0.66929 [0.6751]

Notes: ECT refers to the term $[\ln(FCD^{USD}/FCD^{euro}) – 0.84 - 1.027 \ln(dr^{euro}/dr^{USD})]$

The ECT suggested a relatively slow error (equilibrium) correction mechanism and its statistical evidence for cointegration is controversial.[39] Nevertheless, we interpreted the results as slight evidence in favour of symmetric long run mean reverting process towards the equilibrium.[40] In the short run, however, irreversibility and the ratchet effect were essential to the dynamics for foreign currency balances.[41]

After finding an acceptable specification, we tested the relevance of the Miles model critique and the assumption behind the model. As far as the latter is concerned, a central assumption was a sequential portfolio selection with the composition of currency balances decided independently from other investment decisions. This suggests that an inclusion of the opportunity cost of holding domestic money should be insignificant.[42] This assumption turned out to be valid. Estonian interest rates were first included with four lags, none of which proved significant. As an example, an LM test of adding either the contemporaneous weighted average of Estonian deposit rate $\Delta ln(dr^{estonia})$, F(1,29) = 0.1334 [0.7176] or Estonian money market rate did not reject $\Delta ln(r^{estonia})$, F(1,29) = 0.02801 [0.8681].

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39 In effect, the standard statistical distribution does not apply for the ECT (Error Correction Term) under the null of no-cointegration. Kremers (1992) et al suggest that the standard t-test produces a too high level of significance and that the critical values produced by ADF test statistics such as MacKinnon (1991) should be used. Under the alternative hypothesis, the t-value is asymptotically normally distributed.

40 The asymmetric adjustment in the ECM was tested. We were not able to reject $\rho_1 = \rho_2$ neither for TAR* (τ = -0.035) adjustment, $\chi^2(1)$ = 0.17241 [0.6780] or for M-TAR* (τ = 0.1057) adjustment, $\chi^2(1)$ = 0.036176 [0.8492]. We also accepted $\rho_1 = \rho_2 = \rho = -0.153$, in Equation (18); M-TAR* $\chi^2(2)$ = 0.036533 [0.9819], TAR* $\chi^2(2)$ = 0.17275 [0.9172]. Moreover, the ECM with threshold cointegration performed worse with the extra parameters estimated.

41 This resembles the findings of the dynamics of substitution between high inflation domestic currency and foreign currency balances. See e.g. Ahumada (1992).

42 The series for *money market interest rate* (r) for Estonia used the following. From January 1994 to December 1999, the money market interest rates are from International Financial Statistics. From 1996 to November 2000 the 3-month Talibor interest rate is used (source: *Bank of Estonia*). *Interest rate for deposits* in Estonian currency (dr) is the weighted average of interest rates paid on demand, savings and time deposits (Source: Bank of Estonia). Table 2 indicates both were I(1) processes.

Moreover, the inflation rate gave further support for the sequential portfolio selection.[43] At first, four lags of Estonia inflation rates were included. None turned out to be significant and e.g. the test for adding contemporaneous Estonian inflation $\Delta(\Delta p^{estonia})$, F(1,33) = 0.22344 [0.6395] did not reject.

Inflation

Most theories of currency substitution hold that dollarization should depend on real interest rates rather than nominal interest rates. Accordingly, we augmented the model with relative rates of inflation. Relative rates of inflation had a significant impact on the demand for foreign currency balances, which was seen as evidence of substitution between dollarization and euroization. An increase in EU inflation decreases the demand for euro balances in proportion to the loss of store-of-value services relative to the US balances. Relative inflation rates had an impact only in the second lag $\Delta[\Delta p^{euro}/\ \Delta p^{USD}]_{-2}$, F(1,35) = 4.3431 [0.00445], which offers evidence on the dynamics of inflation expectations on currency demand (see specification V, Table 7).

We also considered the possibility for asymmetric impacts of the relative rates of inflation. We specified two possible estimates for inflation, $D1*\Delta(\Delta p^{euro}/\Delta p^{USD})$ for increasing and $D2*\ \Delta(\Delta p^{euro}/\Delta p^{USD})$ for decreasing relative rates of inflation, c.f. Equation (17). It turned out that $D1*\ \Delta(\Delta p^{euro}/\Delta p^{USD})_{-2}$ was practically equalled zero; elasticity had a value of –0.240 with significance F(1,34) = 0.9824 [0.3246]. $D2*\Delta(\Delta p^{euro}/\Delta p^{USD})_{-2}$ in turn, proved significant: F(1,35) = 5.1977 [0.0288] with the parameter estimate of 0.47. Some further evidence for the differences in elasticity was provided. First, they could not be regarded as equal. The LM test for equal elasticities for $D1*\Delta(\Delta p^{euro}/\Delta p^{USD})_{-2}$ and $D2*\Delta(\Delta p^{euro}/\Delta p^{USD})_{-2}$ was rejected; $\chi^2(1)$ = 5.4206 [0.0199]. Second, the elasticities of $D2*\Delta(\Delta p^{euro}/\Delta p^{USD})_{-2}$ and $\Delta(\Delta p^{euro}/\Delta p^{USD})_{-2}$ were not equal; $\chi^2(1)$ = 4.3431 [0.0372]. The final decision to include only $D2*\Delta(\Delta p^{euro}/\Delta p^{USD})$ into the model was based on the slight increase in the F value for the entire model.

[43] Estonian inflation is percentage change in the CPI comprising all items compared with the same month in previous year (Source: *Statistics Estonia*).

Real exchange rate

The specification of the Miles model assumed an instantaneous PPP. However, the tests for unit roots did not favour this. Instead, $ln[eP^f/P]$ was regarded as an I(2) process, which was likely related to the short time-span of our data. Concerning the evidence in studies on real exchange rates, the I(1) property of the data might be more appropriate. $\Delta ln[eP^f/P]$ was a significant factor affecting the demand for relative currency balances with the second and third lags. The coefficients were equal but opposite in signs; $\Delta ln[eP^f/P]_{-2} = - \Delta ln[eP^f/P]_{-3}$ with the significance of $\chi^2(1) = 0.0999$ [0.7519]. Ultimately, we included $\Delta\Delta ln[eP^f/P]_{-2}$ with the significance of F(1,34) = 11.197 [0.0020]. The sign of the estimate was along the lines of Ratti and Jeong (1994) suggesting that foreign money should enter the money service production function deflated by the foreign price level. In general, the real exchange rate seemed to have an impact on substitutability. The short-run elasticity of substitution slightly increased, while the inflation elasticity was essentially unaffected.

Transaction demand

As noted by Bordo and Choudhri (1982), Miles-type models have been widely criticized for their misspecification. Our model seemed to avoid this. An LM test for the omitted domestic transaction demand of ΔlnY turned out to be insignificant when four lags and a contemporaneous value were included, i.e. F(5, 29) = 0.64413 [0.6680]. None were separately significant.

Later, Ratti and Jeong (1994), Milner, Mizen and Pentecost (1996), (2000), deVries (1988) all observed that foreign currency demand is closely related to the transaction needs emerging from foreign trade. It seems that our specification for Miles model was somewhat immune to these. Our model postulates that the transaction demand is captured by a constant that measures all the services provided by money balances. Foreign trade variables, $ln[I(EU/W)]$ and $ln[tr(EU/W)]$, supported this interpretation.[44] They appeared stationary based on tests for unit roots in the

[44] Descriptive tests supported our inference. For $ln[I(EU/W)]$ LM test for γ_{0*}const. = 0; F(1,32) = 230.2 [0.0000] and for $ln[tr(EU/W)]$; F(1,33) = 79.428 [0.0000].

VAR for cointegration and on visual inspection of time series. Thus, we ended up with the specification in which the constant term captured the long-run transaction service for foreign trade. An obvious explanation for this is the relatively short time period, three years and three months, in which the data were taken. We further tested the short-run impact of foreign trade on the relative currency balances. Although some evidence of transaction demand was obtained, we essentially avoided the criticisms of Ratti and Jeong (1994), Milner, Mizen and Pentecost (1996), (2000), deVries (1988). The highest impacts of transaction demand were recorded with two lags. The signs for coefficients were as expected but both of the trade variables were insignificant.[45] In summary, we inferred that transaction demands had little impact on dollar-euro dynamics in the Estonian economy.

There are several potential explanations for the insignificance of the transaction demand. First, our measure for foreign currency consists mainly of balances in foreign currency savings accounts, which have little relation to the transaction demand for currency. Mainly, they serve the store-of-value function. In December 1997, the percentage of euro-related demand deposits was about 64.5 % of total euro balances. In December 1999, the figure was only 37 %. Although the composition of dollar balances seemed more stable, in December 1997 demand deposits accounted for 64.5 % of the dollar deposits, in December 1999 the figure was 63.8 %. Second, our foreign trade variable might be far too broad to capture the transaction demand for dollars and euros. The EU aggregate includes all EU member countries, including countries not participating in EMU. Our result could imply that the national currencies outside EMU still play an important part in Estonian foreign trade. In any case, neither the US dollar nor the euro offer such high network externalities that only those two currencies would be used as vehicle currencies in international trade. The euro will increase its share as a transaction currency if the trade be-

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Tests were based on: $ln[I(EU/W)] = \underset{(9.912)}{-0.626} + seasonal + \varepsilon$; $R^2 = 0.148$ and $ln[tr(EU/W)] = \underset{(15.176)}{-0.667} + seasonal + \varepsilon$; $R^2 = 0.386$.

[45] $\Delta ln[tr(EU/W)]_{-2}$ had the value of –0.260 with the significance of F(1,339) = 2.0536 [0.1613], whereas $\Delta ln[I(EU/W)]_{-2}$ yielded a coefficient of –0.269 with the significance of F(1, 33) = 3.1644 [0.00845].

tween Estonia and EMU increases or if the number of countries in EMU increases.

4.3 Substituting the substitute currency in Estonia

In summary, we end up with the following parsimonious equation for the substitutability of the substitute currencies in Estonian economy during August 1997-November 2000, less six observations for forecast The forecast period runs from June 2000 to November 2000.

$$\Delta ln[FCD^{USA}/FCD^{euro}] = \underset{(1.951)}{0.035} + \underset{(3.339)}{0.163}\, Seasonal3 + \underset{(6.250)}{1.242}\, [D2 * \Delta ln(dr^{euro}/dr^{USD})]$$

$$- \underset{(-2.779)}{0.153}[ln(FCD^{USA}/FCD^{euro}) - 0.848 - 1.027\, ln(dr^{euro}/dr^{USD})]_{-4}$$

$$+ \underset{(2.393)}{0.424}\, [D2*\Delta(\Delta p^{euro}/\Delta p^{USD})]_{-2} \underset{(-4.009)}{-2.2412}\, \Delta\Delta ln[eP^{USD}/P^{euro}]_{-2} + \varepsilon_t \quad (18)$$

Diagnostics

R^2 = 0.682, F(5, 28) = 12.034 [0.0000], DW = 2.30, AR 1-3; F(3,25) = 0.54582 [0.6555], ARCH 3; F(3,22) = 0.31002 [0.8179], Norm $\chi^2(2)$ = 5.0225 [0.0812], Xi^2; F(9,18) = 0.5841 [0.7933], X_iX_j; F(17,10) = 1.9707 [0.1380], RESET; (1,27) = 2.541 [0.1226],CHOW; F(6,28) = 1.4875 [0.2186].

Weak exogeneity

The Johansen test for cointegration indicated that an interpretation of the relationship as demand equation for relative currency balances might not be valid after all because of the rejected long-run weak exogeneity.[46] We

[46] All the tests for weak, strong and superexogeneity were also performed for symmetric elasticity parameter $*\Delta ln(dr^{euro}/dr^{USD})$. The inference on these tests was unaffected. Results are available upon request.

tested this again in the ECM framework. Urbain (1992) pointed out that if $D2*\Delta ln(dr^{euro}/dr^{USD})$ was weakly exogenous, it would not be dependent on disequilibrium changes represented by the ECT. The ECT turned out to be insignificant in the ECM for $D2*\Delta ln(dr^{euro}/dr^{USD})$ and that the assumption of weak exogeneity of interest rate variable was saved; i.e. F(1,31) = 2.2109 [0.1471].[47] This finding contrasted with the inference drawn from the Johansen-Juselius test. Thus, in the conditional model, in which the ECM was normalized as a currency demand equation, the long-run weak exogeneity may be saved. This is in line with the findings of Juselius, (1992), Durevall (1998) and Metin (1995), (1998) that, even without weak exogeneity, single equation modelling may be feasible by treating the system estimates of the cointegrating vector as given.

A further analysis for weak exogeneity was made following the Hausman (1978) and Engle (1992) LM tests. The method estimates the instrumental regression for the variables in question and tests the significance of *the predicted values in conditional model*. We interpret this as a test for short-term weak exogeneity, since the test does not involve long-run parameters of interests, i.e. the ECT. The LM tests for adding the projected values μ did not reject. The test for adding $\mu D2*\Delta ln(dr^{euro}/dr^{USD})$ yielded F(1,33) = 2.7791 [0.1050], so weak exogeneity was clearly accepted.[48]

Strong exogeneity and causality

Granger causality tests for strong exogeneity. Weak exogeneity and Granger causality defines the concept of strong exogeneity and if present,

[47] The model for $D2*\Delta ln(dr^{euro}/dr^{USD})$ had the following form:

$$D2*\Delta ln(dr^{euro}/dr^{USD}) = \underset{(-3.923)}{-0.041}\ cons + \underset{(1.631)}{0.0728}\ ECT_{-4} + \underset{(4.251)}{0.387}\Delta ln[FCD^{USD}/FCD^{euro}]$$

$$+ \underset{(2.713)}{1.174}\Delta\Delta\ ln[eP^{USD}/P^{euro}]_{-2} + \varepsilon_t$$

R^2 = 0.408, F(3,30) = 6.8956 [0.0011], DW = 2.55, AR1-3 F(3,27) = 2.2689 [0.1032], ARCH F(3,24) = 0.61706 [0.6107], Norm. $\chi^2(2)$ = 6.3885 [0.0410], Xi^2 F(6.23) = 0.27972 [0.9407] X_iX_j;F(9,20) = 0.31983 [0.9586], RESET F(1,29) = 3.312 [0.0791], CHOW F(6,30) = 0.76604 [0.6024].

[48] See Engle and Hendry (1993), p.130. The marginal models are estimated in Table 1, Appendix 2. Fitted values are adopted from the type (II) models.

validates the model for policy simulations. $D2*\Delta ln(dr^{euro}/dr^{USD})$ would be strong exogenous with respect to $\Delta ln(FCD^{USD}/FCD^{euro})$ if it is weakly exogenous and Granger causes $\Delta ln(FCD^{USD}/FCD^{euro})$.

As pointed out by Granger (1988) in the ECM, ΔX_{2t} or ΔX_{1t} or both must be Granger caused by ECT, which is a linear combination of X_{2t} and X_{1t}. Later Ericksson, Hendry and Mizon (1998) observe that if X_{1t} Granger causes X_{2t}, then γ_{22i} and α are not equal to zero. Thus, we tested for $\gamma_{22i} = \alpha_2 = 0$ and $\gamma_{11i} = \alpha_1 = 0$.

$$\Delta X_{1t} = \gamma_{11i}(L_i)\Delta X_{1t-i} + \gamma_{12i}(L_i)\Delta X_{2t-i} + \alpha_1 ECT_{t-k} + \varepsilon_{1t} \qquad (19.1)$$

$$\Delta X_{2t} = \gamma_{21i}(L_i)\Delta X_{1t-i} + \gamma_{22i}(L_i)\Delta X_{2t-i} + \alpha_2 ECT_{t-k} + \varepsilon_{2t} \qquad (19.2)$$

Appendix 1 displays the tests for Granger causality. The ECT, i.e. $[ln(FCD^{USD}/FCD^{euro}) - 0.848 - 1.027\ ln(dr^{euro}/dr^{USD})]_{-4}$, seemed to magnify the Granger causality from $D2*\ \Delta ln(dr^{euro}/dr^{USD})$ to $\Delta ln(FCD^{USD}/FCD^{euro})$ in a VAR (2) specification. In effect, there is a causal relationship from the interest rate to the composition of foreign currency balances.

On the other hand, when we considered short-run causality only, placing no restrictions on αs, the results also favoured the causality running from $\Delta ln(FCD^{USD}/FCD^{euro})$ to $D2*\Delta ln(dr^{euro}/dr^{USD})$. We further tested for possible long-run causality in accordance with Granger and Lin (1995), and Bruneau and Jondeau (1999). When the lagged ECT only influences ΔX_{2t} ($\alpha_1 = 0$), then X_2 should not be causal prior for X_1. The long-term non-causality from $D2*\Delta ln(dr^{euro}/dr^{USD})$ to $\Delta ln(FCD^{USD}/FCD^{euro})$ was rejected, F(1,33) = 4.2556 [0.0471], while the long run non-causality from $\Delta ln(FCD^{USD}/FCD^{euro})$ to $\Delta ln(dr^{euro}/dr^{USD})$ was accepted, i.e. F(1,33) = 0.1989 [0.6585]. We inferred the evidence favoured the causality running from interest rates to currency balances. This is in accordance with our normalization of the cointegrating vector and our assumptions behind the ECM.

In summary, tests for Granger causality indicate causal relationships in both directions. However, we ultimately inferred that the causality is stronger from the relative interest rate to the foreign currency balances. Regarding strong exogeneity, we inferred that it could prevail, especially in the long run. Our model turned out to be suitable for model simulation, but for policy evaluations an extra requirement for superexogeneity must be fulfilled.

Stability tests and superexogeneity

Superexogeneity implies that the Lucas critique does not hold for the relevant class of interventions. An implied testable hypothesis for this is that the parameters of the conditional model remain constant even while those of the marginal model change.[49] One way to test for superexogeneity is to test whether a marginal model is non-constant. In effect, superexogeneity of $\Delta \ln(dr^{euro}/dr^{USD})$ involves indication of the non-constancy of the marginal model and a proof of the constancy of the conditional model.

The stability of the conditional and marginal models was examined applying a Lin-Teräsvirta (1994) test for linearity/non-linearity. This smooth transition regression (STR) model, with $z = t$, is suitable for testing parameter constancy in dynamic linear models.[50] It tracks both the gradual and rapid changes in parameters and thus enables us to detect both gradual and rapid shifts from dollarization to euroization.[51] Jansen and Teräsvirta (1996), Lütkepohl, Teräsvirta and Wolters (1995), Wolters, Lütkepohl and Teräsvirta (1998) have also applied the STR as a diagnostic test.

When k =3, the LM type tests for stability are labelled as LM(1), LM(2) and LM(3), respectively, for k = 1,2,3.[52] Table 1 in Appendix 2 presents the estimated marginal processes and Table 2 in Appendix 2 the re-

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[49] See Hendry (1988), and Favero and Hendry (1992).

[50] See Granger and Teräsvirta (1993). The STR for y_t can be characterized as $y_t = x'_t \pi_1 + x'_t \pi_2 F(z_t) + u_t$ where $F(z_t)$ is a transition function allowing the model to change from $E(y_t| x_t) = x'_t\pi_1$ to $E(y_t | x_t) = x'_t (\pi_1 + \pi_2)$ with z_t. $x_t = (1, y_{t-1}, \ldots, y_{t-p}, x_{1t},\ldots, x_{qn})'$ in an $m \times 1$ vector, $m = p+1+q$, $\pi_1 =(\pi_{11}, \ldots \pi_{1m})'$, $\pi_2 =(\pi_{21}, \ldots \pi_{2m})'$, are $m \times 1$ parameters vectors and u_t is an error term with $Eu_t = 0$, $Ez_tu_t = 0$.

[51] The STR-based tests not only have a considerable amount of power compared with CUSUM or Nyblom-type tests for constancy, they also detect smooth changes in parameters.

[52] If the non-constancy or linearity is rejected, parameters of the STR can be estimated indicating both the break point and the pattern of change. See Teräsvirta and Lin. (1994). While we were only interested in stability of the conditional and marginal models, we did not specify the actual transition function.

sults from the LM3, LM2 and LM1 tests for stability respectively. The tests for superexogeneity were performed in such a way that, first, simple AR models *(I-version)* for marginal processes were estimated and the stability and non-constancy were tested. Second, the models were augmented with zero-one dummies such that the constancy of model was accepted *(II-version).*

The I-version proposes that the constancy of the marginal model may be rejected. This is interpreted as an evidence for superexogeneity. This interpretation was supported in other tests. For example, Engle and Hendry (1993) note that the determinants of non-constancy may be used as a test for superexogeneity. If relative interest rates were superexogenous in the conditional model, then the determinants of the marginal processes' non-constancy should be statistically insignificant if added to the conditional model. All the dummies D97M11, D98M10, D99M5, D20M9 were insignificant in the conditional model separately and jointly; LM for D00M9 F(1,33) = 2.5431 [0.1203]; LM for D99M5 F(1,32) = 0.2082 [0.6512]; LM for D98M10 F(1,32) = 2.6451 [0.1137]; LM for D97M11 F(1,32) = 0.00113 [0.9159]; LM for jointly (D00M9 = D97M11=D99M5=D98M10) = 0; F(4,30) = 1.6577 [0.1858]. In sum up, we interpreted this as an evidence for superexogeneity of the relative interest rate for foreign currency balance in our conditional model.[53]

Moreover, the STR can be used in testing the linearity/nonlinearity emerging from the parameter vectors; see Granger and Teräsvirta (1993), Teräsvirta (1994), which constitutes a test against both LSTR (Logistic Smooth Transition Regression Model) and ESTAR (Exponential Smooth Transition Regression Model). Thus, it offers us an extra test for the non-irreversibility and asymmetry in currency substitution. First, we tested the possible non-linearity/non-constancy of the interest rate variable $\Delta ln(dr^{euro}/dr^{USD})$ in a conditional model, which ruled out the asymmetry. This involved the LM test for h_t; $h_t = \Delta ln(dr^{euro}/dr^{USD})$, see Table 3 in Appendix 2. It turned out that the constancy of $\Delta ln(dr^{euro}/dr^{USD})$ was strongly

[53] Further tests for weak exogeneity confirmed our previous inference. We tested the significance of the residuals $\eta_t D2*\Delta ln(dr^{euro}/dr^{USD})$ from the type II marginal models in the conditional model as suggested by Engle and Hendry (1993). The t value for adding the $\eta_t D2*\Delta ln(dr^{euro}/dr^{USD})$ in the conditional model had a value of 0.317. Accordingly, our inference of weak exogeneity was robust.

rejected F(1,33) = 8.3836 [0.0067]. However, while $h_t = \Delta ln(dr^{euro}/dr^{USD})$ was included in conditional model (18) the STR/ESTR test did not reject; F(1,33) = 0.012271 [0.9125].[54] Neither there was evidence on non-constancy in other variables. Hence, we have evidence that our conditional model (18) captured the asymmetry in substitution between dollar and euro. Accordingly, a topic for further research could involve the modelling of asymmetry using STAR/ESTAR. Notable, there are no applications of these models for currency substitution yet.

5 Conclusions

The present study evaluated the possibility that the euro would overcome the US dollar as a substitute currency in international financial markets. The consequences for the substitution of euroization for dollarization were also highlighted. It turned out that there are two principal factors working in opposite directions in the demand for an international substitute currency. The international demand for vehicle currency favours a single international currency. The risk-related factors, in turn, favour of diversified monetary portfolios and suggest demand for several international currencies. Two possible paths are suggested by the dynamics for the substitution between the euro and dollar. In the first, the switch for the dollar to the euro is smooth and symmetric. The switch in the second is rapid and characterized by asymmetric substitution.

Estimates on substitution of a substitute currency, i.e. euros for dollars, were performed for a representative dollarized CEEC, Estonia, which has experienced strong economic integration with the EU. To solve these puzzles, we applied traditional models for currency substitution for insights into whether new theories are called for and to estimate the substitutability of the euro for the dollar as an international currency.

[54] Similarly, we made an LM test for symmetric inflation elasticity $\Delta(\Delta p^{euro}/\Delta p^{USD})]_{-2}$. In this case, no evidence for significant non-linearity was found; F(1,33) = 1.346 [0.2543].

In principle, our results favoured substitution between dollar and euro-related balances. Traditional currency substitution model turned out to be capable of explaining substitution between substitute international foreign currencies. Several findings deserve notice.

First, the transaction demand did not play a significant role in explaining the dynamics of the relative foreign currency balances. This may be because our balances measured the money demand in all functions of money, i.e. store of value, unit of account and means of payment. To detect only the latter, the demand for money balances more narrowly related to transaction demand should be estimated. There could also be strong inertia in the use of currency in international trade and our data (which covers only three years and three months) is too short to detect these changes.

Second, there was strong irreversibility in the demand for balances of substitute currencies in the short run. Thus, the elasticity of substitution rose whenever there was an increase in the dollar's relative interest rate. Notably, in the opposite case, the elasticity of substitution turned out to be zero. This irreversibility was solely a short-run phenomenon. We found no evidence for long-run asymmetry and threshold cointegration.

Third, the Miles model for currency substitution proved capable of explaining the dynamics of substitute currencies. Nevertheless, the final specification was augmented with inflation and changes in purchasing power parity. The first change drew on theories for dollarization while the latter stressed differences in purchasing power of monies and invalid assumptions behind the model.

As far as the international role of euro and dollar is concerned, our results favoured substitutability. In the long run, substitution was symmetric. In the short run, the euro was only a viable dollar substitute when the opportunity cost of holding dollars increased. This may be interpreted as evidence on significant fixed costs related to the use of dollar, instead the euro-related currencies in the Estonian economy. It would be interesting to find out whether these dynamics prevail throughout the CEECs and how much is attributable to the exchange rate regime such as Estonia's currency board.

In summary, our specification provided new insights about the dynamics of euro and dollar balances as a substitute currency. The dynamics turned out to be a complex and variable over time. In the long run, no asymmetries were detected. In the short run, there was evidence of a ratchet effect favouring the euro. The non-irreversibility of foreign currency balances in this study was detected using dummies. This could be seen as an important first step, but more advanced methods will surely prove beneficial. Nevertheless, we may well conclude that we succeeded in explaining the dynamics of the substitute currencies, euro and dollar, in a rather acceptable manner.

Data Appendix

Foreign currency deposits

Foreign currency deposits are constructed aggregating the demand (D), savings (S) and time (T) deposits in US dollars (FCD^{USD}) and euro related currencies (FCD^{euro}). Source: *Bank of Estonia*.

$$FCD^{euro} = \left[D^{euro} + S^{euro} + T^{euro}\right] \quad (A.1)$$

$$FCD^{USD} = \left[D^{USD} + S^{USD} + T^{USD}\right] \quad (A.2)$$

Interest rates

The *deposit rate* (dr) for currency balances is constructed as the weighted average of deposit rates in different currencies (k) across different deposits and different maturities (j), i.e. demand deposits, time deposits and savings deposits. The interest rate for dollar deposits (dr^{USD}) is the weighted average of annual interest rates for deposits in US dollars (i_j^{USD}). The series for euro deposit interest rates (dr^{euro}) is constructed as the weighted average of annual nominal interest rates in different deposits with different maturities (j) across different euro currencies (k), i.e. DEM, FIM and EUR. Source: *Bank of Estonia.*

$$dr^{USD} = \sum_{j=1}^{n} \alpha_j i_j^{USD} \quad (A.3) \qquad \sum_{j=1}^{n} \alpha_j = 1 \quad (A.3.1)$$

$$dr^{euro} = \sum_{k=1,}^{c} \alpha_k \sum_{j=1}^{n} \alpha_j i_{k,j}^{euro} \quad (A.4) \quad \sum_{k=1}^{c} \alpha_k = 1 \quad (A.4.1) \quad \sum_{j=1}^{n} \alpha_j = 1 \quad (A.4.2)$$

The money-market interest rate for the euro is the 3-month *Euribor rate* (r^{euro}) and the interest rate for the US dollar (r^{USD}) is the 3-month *eurodollar rate*. Source: *OECD Main Economic Indicators*.

Transaction variables

Y, The sales of Estonian manufactured goods (GNP/P). Source: *Statistical Office of Estonia data.*

$$Y_i = GNP_i / P_i \qquad (A.5)$$

I(EU/W), *The relative share of imports from the European union (EU) with respect to total imports (W)* in the Estonian economy is produced from *the ratio of imports to export* (I/E) for the Estonian economy *i* with respect to the EU and the world W.

$$[\ I / E\ ]_i^{EU} = \frac{I_i^{EU} / P_i}{E_i^{EU} / P_i} \quad (A.6.1) \qquad [\ I / E\ ]_i^{W} = \frac{I_i^{W} / P_i}{E_i^{W} / P_i} \quad (A.6.2)$$

The relative share of imports from the European union (EU) with respect to total (W) imports in the Estonian economy is then

$$I(EU / W) = \frac{[\ I\ ]_i^{EU}}{[\ I\ ]_i^{W}} = \frac{[I / P_i\ ]_i^{EU}}{[I / P_i\ ]_i^{W}} \quad (A.6.3)$$

Source: *Statistical Office of Estonia data. Imports (I) are c.i.f. and exports (E) f.o.b.*

tr(EU/W), *Gross international trade*. Gross trade (TR) is divided into gross trade with the EU, TR_i^{EU} , and gross trade with the rest of the world, W, TR_i^{W}.

$$TR_i^{EU} = [I_i^{EU} / P_i\ ] + [E_i^{EU}\ / P_i\ ] \quad (A.7.1)$$

$$TR_i^{W} = [I_i^{W} / P_i^{W}\ ] + [E_i^{W}\ / P_i^{W}\ ] \quad (A.7.2)$$

This provides a measure for relative gross trade $TR_{W,i}^{EU,i}$, i.e., tr(EU/W).

$$tr(EU/W) = [\ TR\ ]_{W,i}^{EU,i} = \frac{TR_i^{EU}}{TR_i^{W}} = [\ \frac{I_i^{EU} + E_i^{EU}}{I_i^{W} + E_i^{E}}\ ] \quad (A.7.3)$$

Source*: Statistical Office of Estonia data. Imports (I) are c.i.f. and exports (E) f.o.b.*

Inflation

Annual inflation figures for the US and EMU participants were based on consumer price indices (CPI) comprising all items. Euro inflation is based on the CPIs of the original eleven EMU members. Annual inflation rates are given as a percentage, i.e. $\Delta p_t^{USD,12} = 100 * [\Delta ln(CPI_t - CPI_{t-12})]^{USD}$; $\Delta p_t^{euro,12} = 100 * \Delta ln[CPI_t - CPI_{t-12}]^{euro}$. Source: *OECD Main Economic Indicators.*

Real exchange rate

Real exchange rate are based on CPI (P^{USD},P^{euro}), which consists of all items.

$$eP^f / P = \frac{e^{euro/USD} * P^{USD}}{P^{euro}} \qquad (A.8)$$

Exchange rate *e* is the nominal exchange rate between the euro and US dollar. Source: *OECD Main Economic Indicators.*

Appendix 1

Table 1. Tests for Granger Causality

ΔX_{1t}	$\gamma_{12i}\ \Delta X_{2t-i} = 0$	$\alpha_1 ECM_{t-i} = 0$	$\gamma_{1t-1}\ \Delta X_{2t} = \alpha_{11} ECM_{t-i} = 0$
$\Delta ln(FCD^{USD}/FCD^{euro})$	$D2*\Delta ln(dr^{euro}/dr^{USD})$; $F(3,33) = 5.0343$ [0.0055]	$F(1,33) = 4.2556$ [0.0471]	$D2*\Delta ln(dr^{euro}/dr^{USD})$; $F(4,33) = 5.0886$ [0.0026]
$D2*\Delta ln(dr^{euro}/dr^{USD})$	$\Delta ln(FCD^{US}/FCD^{euro})$; $F(3,33) = 5.1514$ [0.0050]	$F(1,33) = 0.1989$ [0.6585]	$\Delta ln(FCD^{US}/FCD^{euro})$; $F(4,33) = 3.9325$ [0.0102]

Appendix 2

Table 1. Marginal processes

	D2 (I)	*D2(II)*
	$D2 * \Delta ln(dr^{euro}/dr^{USD})$	$D2 * \Delta ln(dr^{euro}/dr^{USD})$
Cons	-0.0330 (-2.946)	-0.0219 (-2.768)
y-1	-	-
y-3	-0.232 (-1.578)	-0.128 (-1.504)
Seasonal 3	0.0724 (-1.892)	-0.0931 (-4.245)
Seasonal 8	-0.078 (-2.354)	-0.1314 (-6.115)
Seasonal 9		
D97M11	-	-0.128 (-3.549)
D98M10	-	-0.229 (-6.301)
D99M5	-	-0.154 (-4.248)
D00M9	-	0.149 (3.632)
Diagnostics		
R^2	0.257	0.786
DW	1.95	2.21
F	F(3,36) = 4.1616 [0.0125]	F(7,32)= 16.127 [0.000]
AR(1-3)	F(3,33) = 0.7311 [0.5409]	F(3,29) = 2.127 [0.1184]
ARCH 3	F(3,30)= 0.54754 [0.6536]	F(3,26)= 0.1853 [0.9054]
Norm χ^2	16.902 [0.0002]	22.437 [0.0000]
X_i^2	F(4,31) = 0.5475 [0.6536]	F(7,25)= 1.0152 [0.4447]
X_iX_j	F(5,39) = 0.41955 [0.8314]	F(8,24)= 0.8528 [0.5675]
RESET	F(1,35) = 0.0531 [0.8191]	F(1,32) = 0.5167 [0.4776]

Table 2. Tests for stability of the conditional model and marginal models

	LM(1)t	LM(2)t	LM(3)t
$\Delta ln(FCD^{USD}/FCD^{EURO})$	F(1,27) = 0.66814 [0.4209]	F(1,27) = 0.71775 [0.4043]	F(1,27) = 0.7552 [0.3925]
$D2*\Delta ln(dr^{euro}/dr^{USD})(I)$	F(1,34) = 3.7134 [0.0624]	F(1,34) = 4.2408 [0.0472] *	F(1,34) = 4.744 [0.0364] *
$D2*\Delta ln(dr^{euro}/dr^{USD})(II)$	F(1,31) = 2.2173 [0.1466]	F(1,31)= 2.4359 [0.1287]	F(1,31)= 2.6161 [0.1152]
$\Delta ln(dr^{euro}/dr^{USD})$ (I)	F(1,33)= 5.4557 [0.0257] *	F(1,33) = 5.11381 [0.0301] *	F(1.33) = 4.7414 [0.0357] *
$\Delta ln(dr^{euro}/dr^{USD})$ (II)	F(1,29) = 2.3783 [0.1339]	F(1, 29) = 2.3188 [0.1386]	F(1,29) = 2.2104 [0.1479]

Notes: (I) refers to marginal models without dummies. (II) Denotes marginal models with the necessary number of dummies included to produce stability. In the STR model, z=t and k=3;

$$F(t) = F(t,\gamma) = (1 + \exp(-\gamma(t^k + \alpha_1 t^{k-1} + ... + \alpha_{k-1} t + \alpha_k)))^{-1}, k = 1,3 \ .$$

See Teräsvirta and Lin (1994).

Table 3. LM-type test for linearity against the STR

Transition variable	*$D2*\Delta ln(dr^{euro}/dr^{USD})$*	ECT_{-4}	*$\Delta\Delta\, ln[eP^{USD}/P^{euro}]_{-2}$*	*$D2*\Delta(\Delta p^{euro}/\Delta p^{USD})]_{-2}$*
Test Statistics	F(1,33) = 0.0123 [0.9125]	F(1.33) = 0.27246 [0.6052]	F(1,33) = 0.27616 [0.6027]	F(1,33) = 0.025323 [0.8745]

See for Granger and Teräsvirta (1993), Teräsvirta (1994) for testing H_0; $\delta_1 = \delta_2 = \delta_3 = 0$ in an auxiliary regression:

$$y_t = x'\pi_1 + \delta_0'\pi_{1,t} + \delta'_1 \pi_{1,t} h_t + \delta'_2 \pi_{1,t} h_t^2 + \delta'_3 \pi_{1,2} h_t^3 + v_t .$$

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