

International currency substitution and the demand for money in the euro area

Miguel Lebre DE Freitas

Nova School of Business and Economics, Rua da Holanda 1, 2775-405, Carcavelos. Portugal

ARTICLE INFO

JEL classification:

E41
F41
F42
G11

Keywords:

Euro area
Money demand
Capital flows
Portfolio theory
International currency substitution

ABSTRACT

Using quarterly data for the period from 1983:Q1 until 2019:Q4, we identify a stable money demand relationship for the euro area M3, with the US long-term interest rate as a regressor, together with the domestic interest rate and income. This specification is consistent with the open economy liquidity services approach to money demand, in light of which the ownership of money is separate from portfolio decisions. Our results suggest international currency substitution, pointing to interdependency of monetary policies, even in a context of floating exchange rates. In the short-run analysis, we find that excess liquidity helps predict nominal money but not the price level. In general, our findings cast doubt on the usefulness of the information content of M3 to analyse prospective inflation in the euro area.

1. Introduction

When the euro was launched in January 1999 the European Central Bank (ECB) elected money as the nominal anchor of the Euro area (EA) and the *First Pillar* of its monetary strategy (European Central Bank, 1999a). The “prominent role for money” was to be signalled by the yearly announcement of a medium-term reference value for the growth rate of the monetary aggregate M3. In May 2003, however, the Governing Council decided to discontinue its earlier practice of reviewing the reference value for M3 on an annual basis (European Central Bank, 2003). That move marked a first shift in the focus of the ECB assessment criteria toward the “economic analysis” pillar (a general assessment of risks to price stability based on a wide range of indicators), with the “monetary analysis” pillar being downgraded to a secondary, cross-checking role. In July 2021 the ECB monetary strategy was revised again in response to the changing economic environment. In the analytical framework that now supports the ECB’s monetary policy deliberations, the inflation outlook is assessed basically through the economic analysis lenses, while the cross-checking role of the monetary analysis is discontinued. Monetary developments are monitored in the scope of the “monetary and financial analysis”, emphasising the transmission of monetary policy and the interaction between monetary policy and financial stability (European Central Bank, 2021, p.14).

Money lost its prominent role in the ECB monetary strategy

formulation because its relationship with the price level became increasingly difficult to establish. As pointed out by Constâncio (2018), since 2001 the growth rate of M3 started to accelerate to values well above 4.5%, suggesting significant risks to inflation that the behaviour of prices did not show. In the research arena, the previous empirical findings based on constructed pre-EMU monetary aggregates pointing to a stable money demand relationship in a future EA (Funke, 2001; Coenen and Vega, 2001; Calza et al., 2001; Brand and Cassola, 2004, among others) revealed to be fragile when the data were extended to the period following the launch of the euro (Carstensen, 2006; Alves et al., 2006; Beyer, 2009; De Santis et al., 2013). These developments cast doubt on the usefulness of a reference value for the growth rate of the monetary aggregate M3 to support the ECB monetary policy decisions.

The difficulty in identifying a long-run relationship involving the EA M3 and the conventional determinants of money demand led some authors to experiment with less usual money demand specifications. Dreger and Wolters (2010a, 2010b) identified a stable money demand relationship in which the opportunity cost of holding money is captured by consumer price inflation instead of by the nominal interest rate. Jawadi and Sousa (2013) used a non-linear estimation approach to identify a money demand function for the EA in which a domestic interest rate and the inflation rate enter simultaneously as regressors. Beyer (2009) specified a money demand function in which the opportunity cost of holding money was captured by the growth rate of housing

E-mail address: afreitas@novasbe.pt.

<https://doi.org/10.1016/j.econmod.2022.106064>

Received 31 March 2021; Received in revised form 14 August 2022; Accepted 24 September 2022

Available online 29 September 2022

0264-9993/© 2022 The Author. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

wealth. Carstensen (2006) augmented the money demand function with equity returns to capture a possible substitutability between money and shares. De Santis et al. (2013) extended this last model to the context of an open economy, including the equity returns and the long-term interest rate in the EA and in the United States (US).

A common feature in this literature is that the demand for money is set to depend positively on one or two scale variables (income and/or wealth), and negatively on a range of asset returns. This specification is in line with the portfolio model of money demand, the roots of which reside in the works of Metzler (1951) and Tobin (1969). A limitation of the portfolio model is that money is considered as a simple asset that is a gross substitute of all other assets, without any distinctive characteristic that makes it any different from non-monetary assets. The model is incapable of explaining why money is held in the portfolio, despite being dominated as a store of value by interest-bearing bonds (Barro and Fisher, 1976). In contrast, models that account for the distinct function of money in the provision of liquidity services (Sidrauski, 1967; Clower, 1967; Saving, 1971) usually deliver optimal money demands that are independent of portfolio considerations (Kouri, 1977; Lucas, 1982; Thomas, 1985; Boyle, 1990; Greiber and Lemke, 2005).

In this paper we propose a specification for the EA money demand based on the open economy version of the liquidity services model, in which international currency substitution is accounted for (Thomas, 1985; Bergstrand and Bundt, 1990; Mizen and Pentecost, 1994). To motivate our approach we use a microeconomic model based on Thomas (1985) in which an infinitely lived consumer decides on the allocation of wealth among monetary and non-monetary assets, taking into account that monetary assets reduce the costs of transacting in the goods market. The range of available assets is extended, however, to include a real asset offering protection against nominal risks. In this setup we are able to distinguish three types of decisions regarding the asset composition of the agent's portfolio: speculation, which refers to the allocation of part of an agent's wealth away from the safe asset toward nominal assets (Merton, 1969); asset substitution, which refers to the switching from nominal assets denominated in domestic currency to nominal assets denominated in foreign currency; and direct currency substitution, which refers to the switching across monetary assets with different denominations. We show that the presence of a real asset does not make the demand for domestic money dependent on the inflation rate. Currency substitution may, however, open a channel through which changes in the foreign interest rate affect the domestic money demand.

The claim that domestic monetary aggregates in advanced countries may be destabilized by agents' ability to shift the location and the currency denomination of their assets holdings, making national monetary aggregates less reliable to forecast inflation, goes back to Brittain (1981). The author provided evidence that money velocities in Germany and the US were influenced by the interest rate differential between Dollar and Deutsche Mark bonds. McKinnon (1982) contended that international currency substitution could be a source of monetary instability, even under floating exchange rates. Along this reasoning, shocks affecting the relative demand for international bonds denominated in different currencies impact the respective bond yields asymmetrically and then transmit asymmetrically to national money markets – a mechanism that the author coined as “indirect currency substitution”. However, using a sample of seven advanced economies, Joines (1985) found little evidence that international currency substitution destabilized the respective domestic money markets from 1957 until 1980.

We contend that it may be worth revisiting the argument in the context of the EA. In the last few years a consistent body of evidence has been put forward suggesting that the EA M3 has been destabilized by cross-border financial flows. Carvalho and Fidora (2015) argue that as the EA becomes an important supplier of euro denominated bonds to global investors, it is also becoming as exposed to shifts in global savings (with an impact on the domestic interest rates) as the US has been (Bernanke, 2005). The authors document that by mid-2005 foreign ownership of debt securities issued by EA residents amounted to 26.5%

of total outstanding debt securities (corresponding to 31.1% of GDP), which compared to 23% (35.5%) in the US. Using monthly data the authors find that the increase in foreign holdings of EA bonds from 2000 to 2006 is associated with a reduction in the EA long-term interest rate of around 1.55 percentage points. The European Central Bank (2008) reported a tight co-movement between M3 and cross border portfolio investment flows since 1999. Aguilar et al. (2020) report that since the beginning of the euro changes in net external assets of monetary institutions have contributed to the growth rate of EA M3 in a range from minus 5 to plus 5 percentage points. De Santis et al. (2013), argue that the breakdown of traditional money demand specifications in the EA coincides with large net inflows of portfolio investment, starting in the early 2000s.¹

Using quarterly data from 1983 until 2019 we identify a stable money demand relationship for the EA consistent with the open economy liquidity services model. In particular, we identify a money demand equation in which income, the ten-year government bond yields in the EA, and the ten-year government bond yields in the US enter as arguments. We find that this specification delivers estimated coefficients with expected signs, in contrast to specifications that account only for domestic variables. We then test whether the difference between the observed real money balances and the estimated equilibrium real money balances (excess liquidity) help to predict the price level and nominal money in the short run. We find that excess liquidity helps predict nominal money, but not the price level. In general, our evidence supports the recent ECB decision to discontinue the cross-checking role of the monetary analysis in assessing the EA's medium-term inflation outlook.

This paper contributes to the debate on the stability of the EA money demand in several ways. First, our money demand specification is derived from a theoretical model in which the distinctive feature of money is taken into account. With this model we show that the presence of a real asset in the agent portfolio does not necessarily warrant considering the inflation rate as an opportunity cost of holding money. Although this result may be seen as a mere corollary of the well-established proposition that in the presence of nominal bonds the ownership of money is separate from portfolio considerations, we believe that it is worth demonstrating it in the context of the debate at hand, as a number of studies have proposed the inflation rate as an opportunity cost of money. A theoretical model provides a framework to interpret our estimated money demand relationship. Second, our results lend support to De Santis et al. (2013), who found a positive and significant influence of the US dollar long-term interest rate on the EA money demand for the period from 1980 until 2009. Our formulation is more parsimonious, however, as we do not control for equity returns – consistent with the principle of separability between money demand and portfolio decisions. Third, we interpret the positive influence of the US dollar interest rate on the EA money demand as evidence of international currency substitution. This hypothesis implies that shocks affecting the US dollar bond yield transmit to the money market in the EA, even in a context of flexible exchange rates.² Finally, the finding that

¹ Other recent investigations addressing the transmission of monetary disturbances include Carvalho (2019), who provides evidence that cross-border capital flows correlate significantly with broad money in a sample of countries under floating exchange rates; and Cetorelli and Goldberg (2012), who present evidence that global banks that manage liquidity on a global scale are a source of international propagation of liquidity shocks. Benchimol and Ivashchenko (2021) estimate a two-country DSGE model for the US and the EA to assess the influence of volatility shocks and nonlinearities on economic and financial flows, and bond reallocations in particular.

² Evidence of currency substitution between the euro and the dollar is suggested in a number of empirical works using constructed pre-EMU monetary aggregates (see Lebre de Freitas, 2006; Artis and Beyer, 2004; Artis, 1996, and the references therein). To our knowledge, this avenue has not been subject to empirical scrutiny using post-EMU data.

excess liquidity helps predict nominal money but not the price level casts doubt on the usefulness of the monetary aggregate M3 to analyse prospective inflation in the EA.

The remainder of this paper is organized as follows. In Section 2 we present the theoretical model that underlies our proposed specification for the EA money demand. In Section 3 we present the data and data sources. In Section 4 we investigate the stability of alternative specifications for the EA money demand using the Johansen (1988) multivariate cointegrating procedure. In the same section we assess the extent to which deviations from the equilibrium relationship (excess liquidity) help predict the price level in the EA. In Section 5 we conclude.

2. An open economy liquidity services model of money demand

In this section we present an open economy version of the liquidity services model to motivate the money demand specification used in estimation. As is well known, in this model the presence of nominal bonds dominating money as a store of value implies the separation between ownership of money and portfolio decisions. We extend the model proposed by Thomas (1985) accounting for the role of a real asset in the agent portfolio, to argue that the inflation rate is a poor candidate for opportunity cost of money demand when nominal bonds are available. The model combines the optimal choice between a safe asset and risky assets (Merton, 1969) with the open economy shopping costs model proposed by Thomas (1985). In related exercises Boyle (1990) and Greiber and Lemke (2005) extended the closed economy money-in-utility model accounting for the presence of an equity claim, to derive an optimal demand for money in the context of the portfolio choice between bonds and shares. In both cases separation between the ownership of money and portfolio decisions holds.

2.1. The model

We consider an infinitely lived agent endowed with a constant flow of real income, denoted by y . Purchases of the single consumption good (c) imply a transaction cost (τ) proportional to consumption. The agent's portfolio comprises five assets: domestic money (M), foreign money defined in units of foreign currency (M^*), bonds denominated in domestic currency (B), bonds denominated in foreign currency (B^*), and a real asset (a). Amongst the various assets, only domestic money and foreign money provide liquidity services. The agent decides the allocation of wealth amongst monetary and non-monetary assets taking into account that holding monetary assets reduces the amount of real income spent in transacting.³

The agent maximizes the expected value of a discounted sum of instantaneous utility functions of the form:

$$E \int_0^\infty e^{-\beta t} \frac{c_t^{1-\varphi}}{1-\varphi} dt, \tag{1}$$

where c_t denotes real consumption at time t , β is the subjective discount rate, and $\varphi > 0$ is the Arrow-Pratt measure of relative risk aversion (or the inverse of the intertemporal elasticity of substitution). The agent's real wealth is given by:

$$w = m + m^* + b + b^* + a, \tag{2}$$

where $m = M/P$, $m^* = EM^*/P$, $b = B/P$, $b^* = EB^*/P$, P is the domestic price of the consumption good, and E is the nominal exchange rate (price of foreign currency in units of domestic currency).

³ With this formulation we abstract from consumption-leisure decisions. Alternatively, one could define transaction costs in terms of units of time and set leisure as an argument of the utility function (Saving, 1971), or include money directly in the utility function (Patinkin, 1956). Feenstra (1986) showed that these alternative approaches are functionally equivalent.

We assume that purchases of the consumption good imply a proportional transaction cost (τ) that depends negatively on real money holdings in both denominations. We use the following transactions technology proposed by Végh (1989):

$$\tau = cv \left[\frac{m}{c}, \frac{m^*}{c} \right], \tag{3}$$

with $v(\cdot) > 0$, $v_j < 0$, $v_{jk} \geq 0$, $k, l = 1, 2$, and $\Delta = v_{11}v_{22} - v_{12}^2 > 0$, where a subscript j, k to the function $v(\cdot)$ denotes partial differentiation with respect to the j, k argument. The function $v(\cdot) > 0$ represents the transaction cost per unit of consumption and is assumed continuous and twice differentiable. In light of this specification, transaction costs are a decreasing function of real balances in both currencies, with diminishing returns. That is, additional holdings of money reduce transaction costs at a decreasing rate. The assumption $\Delta > 0$ ensures strict convexity of the transactions' technology and hence the verification of the second-order conditions in the maximization problem and well behaved money demand functions. Currency substitutability in the production of liquidity services (direct currency substitution) occurs when the marginal contribution of money denominated in a given currency to the reduction in transaction costs decreases with the ownership of money denominated in the other currency (v_{12} is positive).

Money holdings earn zero nominal returns. Domestic and foreign bonds have certain nominal returns, represented by i and i^* , respectively. The real return on the safe asset is equal to r . Holdings of nominal assets are risky because they are decided upon based on forecasts about the price level and the exchange rate, the future realizations of which are unknown. To model the agent decision under risk we assume the following stochastic processes for the percentage changes of prices and of the exchange rate⁴:

$$\frac{dP}{P} = \pi dt + \sigma dZ, \tag{4}$$

and

$$\frac{dE}{E} = \varepsilon dt + \gamma dX, \tag{5}$$

where π and ε are the mean inflation and exchange rate depreciation rates, σ and γ are the standard deviations, and dZ and dX are standard Wiener processes. To capture the fact that the nominal exchange rate and the price level tend to move together, we assume a positive but less than unitary instantaneous correlation between the two stochastic processes, $R = (dZ \cdot dX) / dt = \rho / \sigma\gamma < 1$, where ρ is the covariance.

Using Ito's lemma to obtain the real returns to nominal assets, and replacing in the consumer's flow budget constraint, we obtain:

$$dw = \Phi dt + (b^* + m^*)\gamma dX - \sigma(w - a)dZ, \tag{6}$$

with $\Phi = r_m m + r_{m^*} m^* + r_b b + r_{b^*} b^* + sr + y - c[1 + v(\cdot)]$, where $r_b = i + \sigma^2 - \pi$, $r_m = \sigma^2 - \pi$, $r_{b^*} = i^* + \varepsilon + \sigma^2 - \pi - \rho$ and $r_{m^*} = \varepsilon + \sigma^2 - \pi - \rho$ denote the mean returns of domestic bonds, domestic money, foreign bonds, and foreign money, respectively.

The consumer maximizes (1), subject to (6). From the envelope and first-order conditions of the maximization problem we obtain the following optimal conditions (see Appendix A for the mathematical details):

$$1 - \frac{a}{w} = \frac{(r_b - r)\gamma^2 + (r_{b^*} - r_{b^*})\rho}{\varphi(\sigma^2\gamma^2 - \rho^2)}, \tag{7}$$

⁴ By decision under risk, we mean the case in which the agent can assign (objective or subjective) probabilities to random events (Knight, 1921). In what follows we refer to the size of the second moments in the stochastic processes as measuring "uncertainty" (Bloom, 2009).

$$\frac{b^* + m^*}{w} = \left(1 - \frac{a}{w}\right) \left(\frac{\rho}{\gamma^2}\right) + \left(\frac{r_{b^*} - r_b}{\rho\gamma^2}\right), \quad (8)$$

$$i + v_1 \left(\frac{m}{c}, \frac{m^*}{c}\right) = 0, \quad (9)$$

$$i^* + v_2 \left(\frac{m}{c}, \frac{m^*}{c}\right) = 0. \quad (10)$$

2.2. Optimal portfolio

In this model the optimal currency denomination of the portfolio is embedded in the choice between the real (safe) asset and nominal (risky) assets. Equation (7) is a version of the Merton (1969) formula, capturing the speculative demand for risky assets⁵: it states that the agent is induced to allocate part of her wealth away from the safe asset toward risky assets, depending on the degree of risk aversion, uncertainty, and the expected return differential (adjusted for the presence of a domestic and a foreign bond).

Equation (8) corresponds to the international investor portfolio rule (Branson and Henderson, 1985) in this specific context of asset availability: it states that the optimal currency denomination of the portfolio depends on a hedging component (first term), and a speculative component (second term). According to (8), the consumer is induced to move away from the denomination structure that minimizes the portfolio purchasing power risk by the expected return differential of investing in foreign assets, and the magnitude of the move depends on the degree of risk aversion, ρ .

2.3. Money demand functions

Equations (9) and (10) implicitly define the money demand functions. Totally differentiating (9) and (10), and solving together, the following properties are obtained for the money demand functions in each denomination:

$$\frac{m}{c} = L^m(i, i^*) \text{ with } L_i^m = -\frac{v_{22}}{\Delta} < 0 \text{ and } L_{i^*}^m = \frac{v_{12}}{\Delta} \geq 0, \quad (11)$$

$$\frac{m^*}{c} = L^f(i, i^*) \text{ with } L_i^f = \frac{v_{12}}{\Delta} \geq 0 \text{ and } L_{i^*}^f = -\frac{v_{11}}{\Delta} < 0. \quad (12)$$

Notably, the optimal money demands do not depend on expected inflation or on second moments. For instance, when expected inflation increases, there will be an overall portfolio reallocation away from nominal bonds to the real asset, but money holdings remain unchanged for each level of consumption and nominal interest rates.⁶ By the same token, an increase in exchange rate volatility will induce a portfolio reallocation away from foreign bonds toward the real asset and the domestic bond, but money holdings in each denomination remain unchanged, conditional on interest rates and on consumption. Even though

monetary assets must be held before use – exposing the household to inflation and exchange rate risks – the opportunity to trade bonds allows the agent to optimally manage these risks.⁷ The optimal demand for money in each denomination involves only a comparison between the respective marginal productivities in the production of liquidity services and holding costs (the domestic and the foreign interest rates). Unless substitutability of domestic money by foreign money in the provision of liquidity services is zero, the demand for domestic money will depend positively on the foreign interest rate (Thomas, 1985). Finally, money demands depend on the level of consumption, not on current wealth. There is an influence of the household's life-time wealth on money demands that is mediated by current consumption, but the household's instantaneous asset position plays no role in the demand for money.⁸

2.4. Separation

In this model the investor can be viewed as making his portfolio allocation in three steps: first the agent decides the amounts of money it desires in each denomination for transaction purposes: equations (9) and (10); then it borrows or lends in both denominations to achieve the optimal currency composition of its nominal portfolio: equation (8); and finally it decides on the optimal proportion between risky assets and the safe asset: equation (7). Together, these conditions imply that the proportion of risky assets and the denomination structure of the portfolio are independent of money holdings. There is a separation between the ownership of money and portfolio decisions. The main reason underlying this result is that domestic and foreign money are dominated as a store of value by interest-bearing assets. Since money bears the same risk characteristics as bonds and earns a lower return, it is not demanded for the speculative and risk-diversification reasons that underlie the demand for financial assets in general.⁹

Arguably, the assumption that the consumer is able to borrow and lend in any currency denomination is a strong one. In recent years there has been an increasing recognition that financial market frictions and

⁷ In the extreme case in which the degree of risk aversion is infinite, implying that the agent wants all its wealth to be held in the form of the safe asset ($a = w$), the agent hires liabilities in domestic and foreign bonds to exactly match its like-denominated monetary holdings (that is, $b + m = 0$ and $b^* + m^* = 0$). In any case, money demands are determined by interest rates and transaction services only, and the optimal partition between real assets and nominal assets is independent of monetary holdings.

⁸ In (9) and (10) the scale variable is the level of consumption because the model focuses on the decision of a representative household. In a more general setup in which liquidity services applied to other types of transactions, including financial trade (as proposed by Grilli and Roubini, 1992), a broader transactions demand for money would apply. For empirical purposes, since real GDP tends to be highly correlated with economic activity in general, it is a natural candidate to proxy the volume of transactions.

⁹ Some authors have found a negative correlation between real money balances and indexes of economic sentiment or of stock market volatility, suggestive of a relationship between macroeconomic uncertainty and liquidity preference (see, for instance, Greiber and Lemke, 2005; Carstensen, 2006; De Bondt, 2010; Mera et al., 2020). Greiber and Lemke (2005) discuss the theoretical difficulty in modelling a relationship between uncertainty and money demand distinct from the one that is already reflected in the nominal interest rate and consumption. The authors conjecture that broader concept of uncertainty, such as "pessimism", might affect preferences directly. The authors therefore allow for exogenous shifts in the relative weight of money in utility (i. e., shifts in the transactions technology) that translate into shifts in the money demand. In a related approach, Benchimol (2014) proposes a DSGE model in which the coefficient of relative risk aversion in respect to consumption is allowed to vary over time, opening a channel through which the changing attitude of the public toward risk ("micro uncertainty shocks") affects consumption and money velocity. As shown below, we do not need to control for macroeconomic uncertainty or to account for structural breaks to identify a stable money demand relationship in the EA.

⁵ In (7), $R < 1$ ensures that the denominator is positive.

⁶ Some authors using the liquidity services approach focus on the indirect link between third variables and money demand, mediated by the nominal interest rate. Along this avenue, Boyle (1990) establishes a link between money velocity and stock prices on the grounds that higher nominal interest rates leading to an increase in money velocity also induce substitution away from stocks into bonds, driving stock prices down. Benchimol and Qureshi (2020) use the consumer steady state Euler equation relating the nominal interest rate to trend inflation to establish the long-run relationship between money velocity and inflation. In this paper we stick to a partial equilibrium model, so the basic properties of the money demand are obtained independently of how other aspects of the economy might be modelled.

absence of collateralizable wealth are driving a substantial fraction of households out of the credit market (Kiyotaki, and Moore, 1997; Bernanke et al., 1996). In the New Keynesian literature a new generation of models has arisen in which the assumption of a representative agent has been replaced by that of heterogeneous agents facing uninsurable risks (Kaplan et al., 2016)¹⁰. In the event that money, or a substitute for it, is not dominated as a store of value, its demand may become influenced by portfolio considerations (Choi and Oh, 2003; Lebre de Freitas and Veiga, 2006). Choi and Oh (2003) proposed a model in which nominal bonds are available but money competes with liquidity services provided by accumulated investments in financial innovation, which are real in nature. That substitutability opens a channel through which risk-return considerations affecting real investment transmits to the money demand. In Lebre de Freitas and Veiga (2006) domestic money is also dominated by a nominal bond, but foreign money is not, because the agent is constrained on foreign bond holdings. In that case, substitutability between the domestic and foreign money in the provision of liquidity services opens a channel through which variables influencing the portfolio demand for foreign money influence the demand for domestic money. For instance, an increase in the expected exchange rate depreciation (or a decrease in exchange rate volatility) will induce a higher demand for foreign money as store of value, and then a lower demand for domestic money via currency substitution (a brief explanation in Appendix B).

When domestic money is not dominated by like-denominated bonds, it becomes demanded for portfolio reasons, regardless of currency substitution. To see this in a simple manner, consider the case in which the household is not allowed to hold foreign assets at all and is constrained on domestic bond holdings, at $b = \bar{b}$. In that case, the agent can only decide the proportions of wealth to be allocated to the real asset or to domestic money. The optimal demand for domestic money is (Appendix B):

$$\frac{m + \bar{b}}{w} = \frac{r_m - v_1 - r}{\phi \sigma^2}. \quad (9a)$$

Equation (9a) is another version of the Merton (1969) formula, stating that the optimal proportion of the portfolio allocated to money (risky asset) depends on the degree of risk aversion, uncertainty, and the return differential *vis-à-vis* the safe asset (adjusted for the transactional role of money). In this case, the demand for domestic money becomes a negative function of expected inflation.

Arguably, in a world where some fraction of the population is constrained in the access to nominal assets other than domestic money, a negative influence of inflation on money demand would be expected. As shown below, however, our evidence is not favourable to the inclusion of the inflation rate among the regressors in a money demand equation for the EA. This is not to say that perfect capital mobility holds exactly in the EA. We simply contend that a stable money demand relationship for the EA M3 can be identified that is consistent with the open economy liquidity services model of money demand, in light of which the ownership of money is separate from portfolio decisions.

2.5. Implications for the monetary aggregate M3

The distinctive feature of money in the model above is that it

¹⁰ The difficulty in accounting for individual heterogeneity using analytical methods has motivated a research stream that proposes the use of computer algorithms to simulate the decision processes of adaptive, learning individuals having different beliefs and goals, the outcomes of which are then aggregated to represent complex non-linear systems and markets. The departure from ordinal concepts of utility allows the construction of measures of individual well-being that can be aggregated to quantify the impact of shocks and policy changes (for a review of agent-based modelling in finance, see LeBaron, 2000; on the construction of measures of aggregate well-being, see Polyzos et al., 2020, 2021).

provides liquidity services while bonds do not. In practice the distinction is not that clear, because some financial assets have a high degree of price certainty and are so liquid that they can be easily held along with cash and demand deposits to support transactions. For this reason, central banks usually define and monitor alternative monetary aggregates that differ with respect to the degree of moneyness of the assets included. Arguably, the monetary aggregate that best serves the purpose of the central bank in each particular environment is a matter of empirical analysis. In the ECB framework the broad monetary aggregate M3 was elected as the main reference because it revealed more favourable properties than narrow definitions, in terms of both stability and information content, to predict price developments (European Central Bank, 1999b). This monetary aggregate includes mainly residents' holdings of currency and demand deposits (68.8% of the total in December 2019), bank deposits with maturities of up to two years or redeemable at notice of up to three months (26.4%), and marketable instruments issued by resident monetary and financial institutions (4.8%). Although some of these components may depart from what is traditionally considered to be money, a high degree of liquidity and price certainty make them close substitutes for cash and demand deposits.¹¹ Thus, for instance, when the central bank increases the official interest rates, the demand for interest-bearing bank deposits is expected to rise and for cash and demand deposits to fall. To the extent that these substitution effects cancel out in the aggregate, M3 will be more stable (though less controllable by the monetary authority) than narrower definitions of money (European Central Bank, 1999b).¹²

A different question has to do with the currency denomination and the location of monetary assets. Equations (11) and (12) describe the total demands for money in each denomination, regardless of their location inside or outside country borders. In practice, however, monetary authorities typically target monetary aggregates that are held within countries' borders. In the case of the EA, the reference monetary aggregate M3 accounts for foreign currency deposits held by non-bank residents in bank accounts located in the EA but excludes monetary assets in any denomination held abroad. To obtain a feel for the possible magnitudes, we consider the data on domestic bank deposits published by the European Central Bank (Statistics Bulletin, Table 2.7.1), and data on cross-border deposits published by the Bank of International Settlements (Locational Banking Statistics). According to the European Central Bank, in December 2018 deposits in domestic banks held by non-bank EA residents amounted to €1264.5bn, of which 96% were denominated in euros. According to the Bank of International

¹¹ Our estimation exercises reveal the same qualitative findings when the narrow monetary aggregate M1 is used instead of M3 (regarding the signs and significance of the coefficients in the long-run relationships, as well as the conclusions of the short-term model), but cointegration rank tests are generally less conclusive. These results are available upon request.

¹² In rigour, substitution effects arising from changes in the relative user costs of the different components inside M3 do not exactly cancel out because the different components in M3 do not substitute perfectly for one another in the provision of liquidity services (otherwise there would be no demand for non-interest-bearing components, such as banknotes and coins). This observation points to some inconsistency between the choice of M3 for the statistical analysis and the model assumption of a single monetary asset in each denomination. Formally, the conciliation would involve extending the transactions technology (3) to account for monetary assets in each denomination with different degrees of liquidity and user costs, and then constructing a monetary aggregate corresponding to M3 using the methodology of index-numbers. As pointed out by Barnett (1980), monetary aggregates constructed in that way (Divisa money) are likely to measure the flow of monetary services demanded by households more accurately (and hence are expected to be more stable) than simple-sum aggregates like M3 (for a recent investigation focusing on the US, see Belongia and Ireland, 2019). Sticking to M3 in the empirical analysis below we inherit some measurement error, but we keep our results comparable to most of the literature on the EA money demand, as M3 has been by far the aggregate that has been more subject to statistical scrutiny.

Settlements, the outstanding amount of cross-border deposits belonging to EA residents was \$5.118bn, of which 1.650bn were held by private sector non-banks, and of which 55% were denominated in euros. Using the year-end exchange rate, we obtain cross-border deposits held by non-bank EA residents amounting to €1439bn, of which €643bn was denominated in foreign currency. Putting the pieces together, and ignoring cash holdings, we obtain an estimate of 94% for the proportion of monetary holdings denominated in domestic currency held at home and 57% for the proportion of monetary assets denominated in foreign currency held abroad. Thus, although some currency substitution is internalized, there is still considerable scope for M3 to be destabilized by changes in relative user costs of domestic and foreign currency.

A positive influence of a foreign interest rate in the demand for domestic money may also arise because of indirect currency substitution, which is more likely to affect international currencies (McKinnon, 1982). With this reasoning in mind, suppose that some exogenous event induces global investors to shift their desired portfolio away from bonds denominated in euros to bonds denominated in US dollars. In that case there will be pressure for euro-bond yields to rise and for US dollar bond yields to fall. Changes in bond yields are then transmitted asymmetrically to money markets, with money holders in each denomination switching in opposite directions between monetary and nonmonetary assets. The demand for money would then contract in the EA and would expand in the US, consistently with equation (11), even if no agent were switching across monetary assets with different denominations.

3. Variables and data used

3.1. Variables used

In this section we investigate whether a semi-log specification in line with the liquidity services approach under financial openness delivers a stable money demand function for the EA. Our baseline specification consists of a money demand system containing four variables: the log of the (seasonally adjusted) real M3 in the EA (m), the log of real GDP in the EA (y), the yields of ten-year government bonds in the EA (i) and the yields of ten-year government bonds in the US (i^*).¹³

In our experiments we also consider the annualized quarterly change in the EA consumer price index (π) and the 3-month money market interest rate in the EA (s). The inflation rate has been found to be significant in a number of studies and interpreted as capturing either substitutability between money and goods or a price homogeneity restriction in the demand for money (Coenen and Vega, 2001; Dreger and Wolters, 2010a, 2010b, 2014). The EA money market rate has also been found to be significant in many studies, either with a negative sign when the long-term rate is not included, playing the role of opportunity cost (Funke, 2001; Calza et al., 2001), or with a positive sign when the long-term interest rate is included, suggesting that this variable may act as a proxy for money's own return (Coenen and Vega, 2001; Dreger and Wolters, 2010a; 2014; De Santis et al., 2013). In the following, we experiment with alternative VAR systems, changing the variables in each system.

3.2. Data and unit roots tests

Because the time series after the launch of the EMU is still too short, the empirical investigation on the EA money demand has relied on constructed monetary aggregates for the period before 1999. The ECB publishes data on M3 from January 1980, but recent studies have

¹³ In line with De Santis et al. (2013), we consider the US dollar as the foreign currency. According to the above-mentioned sources, in December 2018 US dollar deposits accounted for 71.1% of the foreign currency deposits located in the EA, and for 71.2% of the foreign currency deposits held by EA residents abroad.

adopted 1983 as the starting year, responding to reported excess sensitivity to the aggregation method in the first years of the sample (Dreger and Wolters, 2014). We set the sample window to end just before the current pandemic crisis. Accordingly, our sample consists of quarterly data from 1983:Q1 to 2019:Q4.

Nominal money balances (M3) and the quarterly change in the Harmonized Consumer Price Index (π) are taken from the ECB and refer to seasonally adjusted values. Data on government bond yields (i , i^*), money market interest rate (s), seasonally adjusted real GDP (y), and the corresponding deflator (P) are from the Federal Reserve Economic Data. The series on the money market interest rate, GDP and corresponding price deflator are extended backwards from 1995:1, using the Fagan et al. (2005) database. All variables are in logs except the interest rates and the inflation rate.

Unit root tests in Table 1 confirm that all these variables are integrated of order one, except the quarterly inflation rate, which is stationary. Hence, all variables but the inflation rate are eligible for cointegration analysis. Nevertheless, in the exercise that follows we report the results of one system in which the inflation rate is included, for comparative purposes.

At the bottom of Table 1 we show the results of unit root tests on differences between variables. These are: income minus real money (velocity); the nominal interest rate minus the inflation rate (the long-term real interest rate); the long-term interest rate minus the money market interest rate (the slope of the yield curve); and the difference between the domestic and the foreign interest rates (a proxy for the expected exchange rate depreciation). Notably, all variables except the term premium are found to be non-stationary. The stationarity of the term-premium opens the window for the identification of a relationship orthogonal to the money demand, capturing the slope of the yield curve (as in Brand and Cassola, 2004; Coenen and Vega, 2001). Absence of cointegration between the domestic and foreign interest rate is also verified in the case in which a non-unit coefficient is allowed for (result available upon request). This means that the domestic and foreign bond yields are free to enter together in the long-run money demand relationship, without forming a co-integrating vector apart.

4. Empirical results

Because the main regressors are integrated of order one, the analysis follows the Johansen (1988) multivariate procedure. Tables 2 and 3 report the estimation results for different VAR systems, arranged in columns, corresponding to different combinations of variables.

The upper panels of Tables 2 and 3 identify the various systems, numbered from (i) to (vi), the variables entering in each system, the number of lags used in estimation, and the number of observations. In each system we first estimate an unrestricted VAR, experimenting with differing numbers of lags. The number of lags is then chosen in light of the parsimonious Schwarz information criterion. Panel I shows the results of the cointegrating rank test. To account for a linear deterministic trend in the data and to control for the units of measurement, intercepts are included in the co-integrating space and in the adjustment dynamics. We use the trace test statistics with the critical significance set at the conventional 5% level. Panel II describes the identification procedure, namely the number of cointegrating vectors and the LM test on over-identifying restrictions, when applicable. Panels III and IV display, respectively, the coefficients and standard errors of the identified cointegrating vectors and of the loading factor in the equation describing the short-run dynamics of real money. In panel V we report the coefficient and the standard error of the coefficient on money obtained normalizing the (first) cointegrating vector to income. The aim is to obtain a t-ratio assessing the significance of real money in the corresponding long-run relationship.

Table 1

Unit root tests (1983:Q1-2019:Q4).

Variables	Description	Level	First difference
m	Real M3 in the euro area	-0.24	-4.98***
y	GDP in the euro area	-2.28	-7.54***
i	Government bond yields	-1.69	-7.01***
i*	Government bond yields US	-1.84	-6.01***
s	Money market interest rate	-1.53	-6.94***
π	CPI Quarterly Inflation Rate	-3.57***	
y-m	Money velocity	0.45	-5.78***
i- π	Long-run real interest rate	-0.09	-6.41***
i-s	Slope of the yield curve	-3.46**	
i-i*	Interest rate differential	-1.94	-5.85***

Notes: The data display the t-statistic of the lag dependent. In each equation, the number of lags is determined by the Aikake information criterion, with a maximum lag-length equal to 12. Significance is assessed using the Mackinnon (1996) critical values. The long-run real interest rate is computed as the difference between the 10-year bond yields and the current inflation rate.

4.1. Closed economy specifications

Columns (i)-(iii) of Table 2 present the estimation results for closed economy specifications when the money demand includes only a scale variable and a proxy for the opportunity cost. The null of no-cointegration is rejected at 5% significance in systems (i) and (ii), in which the opportunity cost of holding money is measured by the long-term interest rate and by the money market rate, respectively. When the opportunity cost of holding money is measured by inflation rate (system iii) the trace test rejects the non-cointegration null with 1% significance, but this is not a valid test because the inflation rate is stationary. The information in column (iii) is displayed for comparative purposes only.

In Panel III we observe that all coefficients in the identified money demand equations in systems (i), (ii), and (iii) are significant, but some signs are at odds with the theory: in systems (i) and (ii) the income elasticity is negative; in system (iii) the semi-elasticity of the inflation rate with respect to income is positive.¹⁴ Notably, in both systems (i) and (ii) money is not significant in the cointegrating vector normalized to income (panel V). This evidence confirms the failure to identify a money demand function for the EA with the conventional determinants (income and an interest rate). The similarity of results in systems (i) and (ii) is consistent with the evidence reported in Table 1, that the difference between the long-term and short-term interest rates is stationary.

In column (iv) a more complex system is specified, including both the short-term and the long-term domestic interest rates. The trace test in Panel I points to two stable relationships involving the four variables at 5% significance. This is an expected result in light of our preliminary tests in Table 1. We therefore identify two vectors, one consisting of a money demand in which the long-run interest rate enters as opportunity cost, and a second vector capturing the relationship between the short-term and long-term interest rates, following Brand and Cassola (2004), and Coenen and Vega (2001). In Panel II, the LR test on the identifying restrictions indicates a p-value of 8.3%, pointing to rejection at 10% significance, even though we are not imposing a unit coefficient in the short-term interest rate in the second cointegrating vector (with this further restriction the p-value falls to less than 1%). More important, enriching the model to account for the two interest rates does not alter the main problem in the earlier systems, that the estimated income elasticity of money demand is negative, at odds with any money demand theory.

¹⁴ A positive semi-elasticity of inflation in the EA money demand, at odds with the portfolio balance model, is also reported in Jawadi and Sousa (2013).

4.2. Open economy specification

In Table 3 column (v) we depart from closed economy specifications, allowing the demand for domestic money to depend on the foreign interest rate, i^* . In Panel I, the trace statistics reject the non-cointegration null with a p-value of 1.6%. In Panel III all coefficients are significant and with signs in accordance with the theoretical model. Comparing to the model in column (i), we observe that augmenting the system with the US dollar interest rate substantially improves the quality of the fit: the coefficient on income becomes positive, money becomes significant in the long-run relationship (Panel V), and the loading factor of real money in the short-term model also becomes significant (Panel IV). This finding is in line with De Santis et al. (2013), who also found a positive and significant influence of the US dollar long-term interest rate on the EA money demand for the period from 1980 until 2009. Our formulation is more parsimonious, however, as we do not control for equity returns.¹⁵

So far, system (v) is the only one delivering a stable and sensible money demand relationship, and this result is obtained without imposing any dummy variable.¹⁶ The deviations from the equilibrium relationship in model (v) are plotted in Fig. 1 with the name "Excess liquidity in system (v)".

For robustness check we next investigate how the quality of the fit changes when we augment the open economy model to include the money market rate (s). The corresponding results are reported in column (vi). The cointegration test rejects the null of at most one cointegrating vector with a p-value of 4.6%. Proceeding as in system (iv), we then identify two orthogonal relationships: a money demand equation and a second relationship capturing the term premium in the long-run interest rate. The p-value of the overidentifying restrictions is now 40%, which is an improvement relative to (iv). Comparing to (iv), we also observe that accounting for the US dollar interest rate makes the coefficient on income in the money demand equation positive. Comparing systems (v) and (vi), we observe that the coefficient on the US bond yield remains positive and significant, pointing to robustness of our baseline specification. In the column (vi)-Restricted, we test the hypothesis of a stable term premium, imposing a further restriction of equal and symmetric coefficients on the two domestic rates. Although the implied LR statistic rejects this specification at 10% significance, all other results remain qualitatively unchanged. In Fig. 1 the deviations from the equilibrium relationships in systems (vi) and (vi)-Restricted are plotted together with that of system (v). Comparing the various series, we observe that the implied measures of excess liquidity behave similarly.

4.3. Short-run dynamics

In panels IV of Tables 2 and 3 we observe that the loading factors of real money on excess liquidity in systems (v) and (vi) are all significant, pointing to convergence of real money balances to the equilibrium relationship. Yet whether this adjustment is driven by changes in nominal money or by changes in the price level is a different question. As pointed out by Gerlash (2004), in a context of slow price adjustment,

¹⁵ Notably, the coefficients of equity returns in the money demand equation estimated by De Santis et al. (2013, p. 385, eq. (3)) are not significant, suggesting that a specification identical to ours could have been identified in their sample.

¹⁶ Dreger and Wolters (2010a) reported a break in money velocity in 2002, which the authors controlled for by using a step dummy equal to 1 starting in 2002Q1. In our sample we observe that accounting for this dummy in systems (i)-(iv) affects the estimated income elasticities, but it does not rescue any of these models from the above-mentioned inconsistencies. In system (v) the results are qualitatively identical. This evidence (available upon request) suggests that some of the shift in money velocity reported by Dreger and Wolters (2010a, 2014) might be accounted for by movements in the US government bond yields.

Table 2
Closed economy specifications (1983:Q1-2019:Q4).

System	(i)	(ii)	(iii)	(iv)
Variables	m, y, i	m, y, s	m, y, π	m, y, i, s
Lags (SIC)	2	2	2	2
Observations	148	148	148	148
I. Trace tests for reduced rank:				
$r = 0$	33.69**	35.66**	116.78***	62.20***
$r \leq 1$	15.45*	16.68*	15.16*	32.76**
$r \leq 2$				12.63
II. Identification				
Number of cointegrating vectors (r)	1	1	1	2
Test on the overidentifying restrictions imposed on cointegrating vectors				
LR statistic (X^2)	–	–	–	3.01*
d.f.	–	–	–	1
p-value	–	–	–	8.3%
III. Estimates of long-run coefficients in the money demand equation				
	$\beta 1$	$\beta 1$	$\beta 1$	$\beta 1$ $\beta 2$
m- real money ($\beta 11$)	–1	–1	–1	–1
y - real income ($\beta 12$)	–18.8*** (4.90)	–34.26*** (8.80)	3.56*** (0.26)	–1.99*** (0.88)
i - euro area bond yield ($\beta r3$)	–1.01*** (0.27)			–0.18*** (0.05)
s - Money market interest rate ($\beta r4$)		–1.33*** (0.40)		0.82*** (0.04)
π - euro area inflation rate ($\beta r5$)			0.28*** (0.02)	
IV. Loading factors				
d(m) - real money ($\alpha 11$)	0.000 (0.0005)	0.000 (0.0002)	0.001 (0.0011)	0.001 (0.002)
V. Memo: significance of the coefficient on money				
y - real income ($\beta 12$)	–1	–1	–1	–1
m- real money ($\beta 11$)	–0.05 (0.12)	–0.03 (0.12)	0.28*** (0.04)	–0.50*** (0.20)

Notes: ***, **, *: denote significance at 1%, 5%, and 10%, respectively. Standard errors in parentheses. Each column corresponds to the estimation results with the system including the variables described in the upper panel. The lag-length is chosen based on the Schwarz criterion and is set equal to 2 throughout the analysis. Panel I presents the Trace statistics testing for reduced rank. Panel II describes the number of cointegrating vectors assumed in estimation, as well as the LM statistics for the overidentifying restriction imposed on cointegration vectors, when applicable. Panel III displays the estimated coefficients in the long-run relationships, as well as the corresponding standard errors. Panel IV displays the error correction coefficient in the short-term equation describing the change in money demand. Panel V shows the significance of the coefficient on money when the long-run relationship is normalized to income.

money being too high relative to prices might well lead to lower money growth in the future. To investigate this, in Table 4 we run three single equation error correction models, whereby the quarterly changes of real M3, nominal M3, and the price level are regressed in their own lags and on the measure of error correction term (excess liquidity) obtained from model (v). The number of lags of the dependent variable is chosen according to the Akaike information criterion with a maximum of 12 lags, whereas excess liquidity enters with only one lag.¹⁷

As shown in the table, the endogeneity of real money with respect to excess liquidity (reported in the first column) reflects the adjustment of nominal money balances to excess liquidity (second column), not of the price level (third column). This finding is robust to the inclusion of other variables in the model and does not change when the residuals of system (vi) are used instead.

The finding that nominal money is endogenous with regard to the long-run relationship has a natural interpretation: it suggests that the non-monetary sector finds ways of adjusting the quantity of currency and bank deposits according to the desired demand for money – for instance, borrowing from banks or paying off old loans – before the price level comes into operation to clear the money market. This evidence can be interpreted as a natural consequence of the policy regime in force: in a context in which the short-term interest rate is the monetary policy

instrument, money becomes an endogenous variable, with the central bank supplying whatever quantity of money that is demanded, given its determinants (Svensson, 1999).

The main result in this section is that excess liquidity is not significant in predicting the price level in the short run (a similar conclusion regarding the EA in Benchimol and Fourçans, 2017). This finding has important policy implications: for money to be a useful device to assess future price developments, not only is a stable money demand relationship required, but also the resulting measure of excess liquidity must contain information that is useful to predict the price level. Our results do not support the second condition. Thus, while our evidence is consistent with the view that money matters for price formation in the long run, it casts doubt on its usefulness to predict short-run movements of the price level around the long-term relationship with money.

5. Conclusions

In this paper we show that adding the US dollar ten-year bond yield to an otherwise conventional closed economy money demand specification rescues the EA monetary aggregate M3 from its apparent instability. Using quarterly data for the period from 1983:Q1 until 2019:Q4, and maintaining the discipline of not using dummies or other econometric techniques to smooth the data, we find that the US dollar long-term interest rate is not only significant and with a positive sign, it is also essential to identify a stable money demand relationship with the expected signs in the other key money demand coefficients. The positive coefficient found for the US dollar interest rate has a natural interpretation in line with the open-economy liquidity services model, according to which the ownership of money is separate from portfolio decisions.

¹⁷ Residual non-normality occurs in all three equations. Although in the first two equations, residual non-normality could be eliminated by adding the two impulse dummies proposed by Dreger and Wolters (2010b) – capturing the impact of German Unification in 1990:2 and instability in the stock market in 2001:1 – that would come at the cost of other estimation problems, without changing qualitatively the main findings reported above.

Table 3
Open economy specifications (1983:Q1-2019:Q4).

System	(v)	(vi)	(vi)-Restricted		
Variables	m, y, i, i*	m, y, i, i*, s			
Lags (SIC)	2	2			
Observations	148	148			
I. Trace tests for reduced rank:					
r = 0	52.80**	84.04***			
r ≤ 1	29.27*	48.22**			
r ≤ 2	12.05	28.43*			
II. Identification					
Number of cointegrating vectors (r)	1	2	2		
Test on the overidentifying restrictions imposed on cointegrating vectors			$\beta_{23} + \beta_{24} = 0$		
LR statistic (X ²)	–	1.81	– 7.35*		
d.f.	–	2	– 3		
p-value	–	40.4%	– 6.2%		
III. Estimates of long-run coefficients in the money demand equation					
	β_1	β_1	β_2	β_1	β_2
m-real money (β_{11})	–1	–1	–1	–1	–1
y - real income (β_{12})	2.00*** (0.57)	1.23*** (0.51)	1.42*** (0.48)	1.42*** (0.48)	1.42*** (0.48)
i - euro area bond yield (β_{r3})	–0.12*** (0.03)	–0.12*** (0.03)	–1	–0.13*** (0.03)	–1
s - Money market interest rate (β_{r4})			0.84*** (0.04)		1
i* - US bond yield (β_{16})	0.16*** (0.04)	0.13*** –0.04		0.13*** –0.03	
IV. Loading factors					
d(m) - real money (α_{11})	0.010*** (0.004)	0.009*** (0.004)		0.012*** (0.004)	
V. Memo: significance of the coefficient on money					
y - real income (β_{12})	–1	–1		–1	
m-real money (β_{11})	0.50*** (0.12)	0.82*** (0.18)		0.71*** (0.14)	

Notes: same as in Table 2.

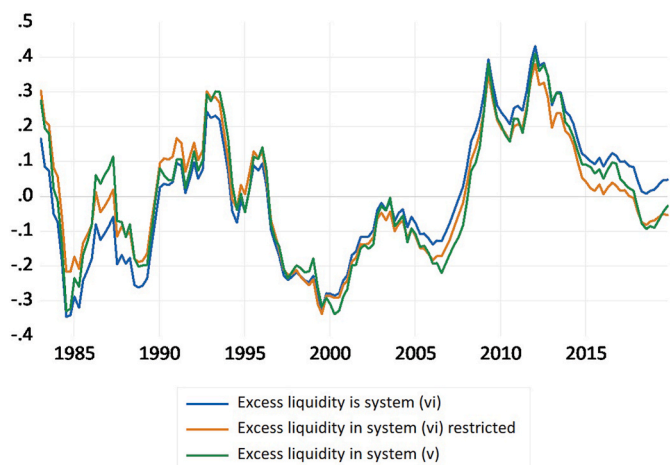


Fig. 1. Estimated excess liquidity in systems (v), (vi), and (vi)-Restricted.

Our model therefore differs from most of the recent empirical investigations on the stability of the EA M3, which have relied on the portfolio-balance model of money demand.

The fact that we are able to identify a stable relationship involving the EA M3 with the expected coefficients does not necessarily imply that monetary developments contain useful information to predict the price

Table 4
Conditional models for real M3, nominal M3, and the price level (1983:Q1-2019:Q4).

	Dependent Variable		
	D(m)	D(M)	D(P)
Method:	OLS	OLS	OLS
Lags on dependent (AIC, maxlag = 12)	2	3	9
Models evaluated	12	12	12
Included observations:	148	148	148
Excess liquidity in system (v)	–0.011*** (0.003)	–0.0102*** (0.0032)	–0.0010 (0.0011)
Adjusted R-squared	0.284	0.429	0.767
Durbin-Watson stat	2.01	1.98	1.97
LM(1)	0.27	0.35	0.45
LM(4)	3.25***	1.63	0.54
ARCH (1)	0.15	0.06	3.81*
ARCH (4)	0.08	0.12	1.65
Jarque-Bera	177.6***	428.4***	7.18**
RESET F (1)	1.16	0.97	0.12
RESET F (2)	0.58	0.72	0.06
Bai Perron Multiple breakpoint test (< 5)	No break	No break	No break

Notes: ***, **, *: denote significance at 1%, 5%, and 10%, respectively. Standard errors in parentheses. In each system, the lag-length is chosen based on the Akaike criterion, with a maximum of 12 lags.

level. Our estimates of the short-term dynamics of prices and nominal money using an error correction specification reveal that excess liquidity helps predict nominal money, but not the price level. This result suggests that non-bank residents have been able to adjust the composition of their balance sheets to achieve the desired demand for money before changes in the price level come into operation to clear the money market. Endogeneity of money is a natural outcome in a context where the central bank sets the interest rate in the conduct of monetary policy.

These findings have important policy implications. First, if the demand for domestic money is influenced by the US dollar bond yields, which are not under the control of the ECB, a medium-term reference value for the growth rate of M3 can hardly provide a reliable anchor for price stability. Second, our evidence that excess liquidity helps predict nominal money but not the price level implies that even if the demand for real money were predictable, it would probably not be informative enough regarding the medium-term inflation outlook in the EA. In general, our results support the recent ECB decision to discontinue the cross-checking role of monetary analysis in the revised analytical framework that now supports its monetary policy deliberations.

Third, our results indicate that monetary and financial developments abroad are transmitted to the money market in the EA even under floating exchange rates. As recently argued by [Carvalho and Fidoro \(2015\)](#), because the euro is an attractive denomination for securities to be supplied in the global economy, the EA is exposed to shifts in global savings, thereby affecting domestic interest rates. Our results add another dimension to this argument: the EA is exposed not only to shocks affecting the total demand for international assets, but also to shocks in the relative demand for international assets, which transmit to money markets asymmetrically. One such a shock might have occurred at the outset of the global financial crisis, for example, when some European financial institutions that had accumulated short-term dollar liabilities to finance acquisitions of long-term asset-backed securities suddenly faced a severe shortage of funding. In response, in December 2007 an emergency dollar-swap line was created involving the Federal Reserve and the European Central Bank, allowing the former to indirectly provide dollar liquidity to European financial institutions. Coincidentally, the EA M3 decelerated sharply, from an annual growth rate of +10.8% in December 2007 to a minimum of –2.1% in December 2010. This episode suggests that an increased substitutability between the euro and the dollar as international currencies is pushing for new policy solutions. As rightly put by [Cetorelli and Goldberg \(2012, p. 1841\)](#), globalization and the international transmission of shocks are

confronting central banks “with a diminished effectiveness of their standard policy tools and with a renewed and expanded need for broader international coordination”. Whether more permanent and institutionalized mechanisms to help manage the international liquidity globally will develop in the next few years is an open question.

Data availability

Supplementary materials include a workbook with data and an

views file with the codes

Acknowledgements

We thank two anonymous referees, Paulo Rodrigues, André Silva, and Daniel Carvalho for helpful comments and suggestions. We acknowledge support from FCT – Portuguese Foundation for Science and Technology under project UIDB/03182/2020.

Appendix A

The consumer maximizes (1), subject to (6). The Hamilton-Jacobi-Bellman equation of the corresponding quasi-stationary problem is:

$$\beta V(w) = \max_{c,m^*,b,b^*} \left\{ \frac{c^{1-\varphi}}{1-\varphi} + V'(w)\Phi + \frac{1}{2}V''(w)[\gamma^2(b^* + m^*)^2 + \sigma^2(w - a)^2 - 2\sigma\rho(w - a)(b^* + m^*)] \right\},$$

where $V(w)$ is the optimal value function. The first-order conditions with respect to b^* , b , m^* , and m imply:

$$V'(w)[r_{b^*} - r] + V'(w)[(\gamma^2 - \rho)(b^* + m^*) + (\sigma^2 - \rho)(w - a)] = 0, \tag{a1}$$

$$V'(w)[r_b - r] + V'(w)[\sigma^2(w - a) - \rho(b^* + m^*)] = 0, \tag{a2}$$

$$V'(w)[r_{m^*} - v_2 - r] + V'(w)[(\gamma^2 - \rho)(b^* + m^*) + (\sigma^2 - \rho)(w - a)] = 0, \tag{a3}$$

$$V'(w)[r_m - v_1 - r] + V'(w)[\sigma^2(w - a) - \rho(b^* + m^*)] = 0. \tag{a4}$$

Using the envelope condition $\varphi = -V''(w)w/V'(w)$ in (a1) to (a4), one obtains, respectively:

$$\frac{r_{b^*} - r}{\varphi} = (\sigma^2 - \rho)\left(1 - \frac{a}{w}\right) + (\gamma^2 - \rho)\left(\frac{b^* + m^*}{w}\right), \tag{a5}$$

$$\frac{r_b - r}{\varphi} = \sigma^2\left(1 - \frac{a}{w}\right) - \rho\left(\frac{b^* + m^*}{w}\right), \tag{a6}$$

$$\frac{r_{m^*} - v_2 - r}{\varphi} = (\sigma^2 - \rho)\left(1 - \frac{a}{w}\right) + (\gamma^2 - \rho)\left(\frac{b^* + m^*}{w}\right), \tag{a7}$$

$$\frac{r_m - v_1 - r}{\varphi} = \sigma^2\left(1 - \frac{a}{w}\right) - \rho\left(\frac{b^* + m^*}{w}\right). \tag{a8}$$

Subtracting (a6) from (a5) and after some manipulation, conditions (7) and (8) are obtained. Subtracting (a4) from (a2) and (a3) from (a1), one obtains (9) and (10).

Appendix B

In terms of our model, the case in which the household is constrained on foreign bond holdings corresponds to imposing the binding condition $b^* = \bar{b}$. In that case, condition (a1) no longer holds. Thus, while (a2) and (a4) can still be solved together to deliver equation (9), the demand for foreign assets becomes uniquely determined by (a7), given the admissible quantity of foreign bonds. Solving together (a6) and (a7), one obtains the following condition, which extends Lebre de Freitas and Veiga (2006) to the case in which a real asset is available:

$$\frac{\bar{b}^* + m^*}{w} = \frac{\sigma^2(r_{m^*} - v_2 - r_b) + \rho(r_b - r)}{\varphi(\gamma^2\sigma^2 - \rho^2)}. \tag{10a}$$

This condition replaces (8) and (10) and implies a portfolio demand for foreign money, in addition to the transactions motive. Although in this case there is no portfolio demand for domestic money – condition (9) still holds – substitutability between the domestic and foreign money in the provision of liquidity services opens a channel through which variables influencing the portfolio demand for foreign money in (10a) affect the demand for domestic money.

A pure portfolio demand for domestic currency arises when the agent faces a binding restriction on domestic bond holdings, $b = \bar{b}$. In that case, condition (a2) does not hold and thus cannot be combined with (a4) to obtain a separate money demand function of the form (9). If in addition the agent faces binding restrictions in foreign money and bond holdings, then the only relevant first-order condition is (a4), which solves to (a8). Equation (9a) corresponds to (a8) in the particular case in which $b^* = m^* = 0$.

Appendix C. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.econmod.2022.106064>.

References

- Aguilar, C., Soares, R., Adalid, R., 2020. Revisiting the monetary presentation of the euro area balance of payments. ECB Occasional Paper N° 238. European Central Bank. February.
- Alves, N., Marques, C., Sousa, J., 2006. Some issues concerning the use of M3 for monetary policy analysis in the euro area. Bank of Portugal Economic Bulletin, Summer 41–55.
- Artis, M., 1996. Currency substitution in European financial markets. In: Mizen, P., Pentecost, E. (Eds.), *The Macroeconomics of International Currencies: Theory, Policy and Evidence*. Edward Elgar, Cheltenham, UK, pp. 139–154.
- Artis, M., Beyer, 2004. Issues in money demand: the case of Europe. *J. Common. Mark. Stud.* 42, 717–736.
- Barnett, W., 1980. Economic monetary aggregates: an implication of index number of aggregation theory. *J. Econom.* 14, 11–48.
- Barro, R., Fisher, S., 1976. Recent developments in monetary theory. *J. Monetary Econ.* 2, 133–167.
- Belongia, M., Ireland, P., 2019. The demand for divisia money: theory and evidence. *J. Macroecon.* 61, 103–128.
- Benchimol, J., 2014. Risk aversion in the eurozone. *Res. Econ.* 68 (1), 39–56.
- Benchimol, J., Ivashchenko, S., 2021. Switching volatility in a nonlinear open economy. *J. Int. Money Finance* 110 (C), 1–31.
- Benchimol, J., Qureshi, I., 2020. Time-varying money demand and real balance effects. *Econ. Modell.* 87 (C), 197–211.
- Benchimol, J., Fourçans, A., 2017. Money and monetary policy in the Eurozone: an empirical analysis during crises. *Macroecon. Dyn.* 21 (3), 677–707.
- Bernanke, B., 2005. The global savings glut and the U.S. Current account deficit. In: *Speech Delivered at the Sandridge Lecture*. Virginia Association of Economists, Richmond, Va. March 10.
- Bernanke, B., Gertler, M., Gilchrist, S., 1996. The financial accelerator and the flight to quality. *Rev. Econ. Stat.* 78 (1), 1–15.
- Bergstrand, J., Bundt, T., 1990. Currency substitution and monetary autonomy: the foreign demand for US deposits. *J. Int. Money Finance* 9 (3), 325–334.
- Beyer, A., 2009. A stable model for euro area money demand. Revisiting the role of wealth. ECB working paper 1111. European Central Bank.
- Bloom, N., 2009. The impact of uncertainty shocks. *Econometrica* 77 (3), 623–685.
- Boyle, G., 1990. Money demand and the stock market in a general equilibrium model with variable velocity. *J. Polit. Econ.* 98 (5), 1039–1053.
- Brand, C., Cassola, N., 2004. A money demand system for euro area M3. *Appl. Econ.* 36 (8), 817–838.
- Branson, W.H., Henderson, D., 1985. The specification and influence of asset markets. In: Jones, R., Kenen, P. (Eds.), *Handbook of International Economics*, vol. II. North Holland, Amsterdam, pp. 749–805.
- Brittain, B., 1981. International Currency Substitution and the apparent instability of velocity in some Western European economies and in the United States. *J. Money Credit Bank* 13 (2), 135–155.
- Calza, A., Gerdesmeire, D., Levy, J., 2001. Euro Area Money Demand: Measuring the Opportunity Costs Appropriately. International Monetary Funds, Washington DC. IMF Working Paper 01/179.
- Carstensen, K., 2006. Stock market downswing and the stability of European Monetary Union money demand. *J. Bus. Econ. Stat.* 24, 395–402.
- Carvalho, D., 2019. Financial integration and the great leveraging. *Int. J. Finance Econ.* 24 (1), 54–79.
- Carvalho, D., Fidora, M., 2015. Capital Inflows and euro area long-term interest rates. *J. Int. Money Finance* 54, 186–204.
- Cetorelli, N., Goldberg, L., 2012. Banking, globalization, and monetary transmission. *J. Finance* LXVII (5), 1811–1843.
- Choi, G., Oh, S., 2003. A money demand function with output uncertainty, monetary uncertainty, and financial innovations. *J. Money Credit Bank.* 35 (5), 685–709.
- Coenen, G., Vega, J., 2001. The demand for M3 in the euro area. *J. Appl. Econom.* 16 (6), 727–748.
- Constância, V., 2018. Past and future of the European Central Bank monetary policy. In: *Speech at the Conference on “Central Banks in Historical Perspective: What Changed After the Financial Crisis?”*. Central Bank of Malta, Valletta. May 4.
- Clower, B., 1967. A reconsideration of the microeconomic foundations of monetary theory. *West. Econ. J.* 6, 1–8.
- De Bondt, G., 2010. New evidence on the motives for holding euro area money. *Manch. Sch.* 78 (3), 259–278.
- De Santis, R., Favero, C., Roffia, B., 2013. Euro area money demand and international portfolio allocation: a contribution to assessing risks to price stability. *J. Int. Money Finance* 32, 377–404.
- Dreger, C., Wolters, J., 2010a. M3 money demand and excess liquidity in the euro area. *Publ. Choice* 144, 459–472.
- Dreger, C., Wolters, J., 2010b. Investigating M3 money demand in the euro area. *J. Int. Money Finance* 29, 111–122.
- Dreger, C., Wolters, J., 2014. Money demand and the role of monetary indicators in forecasting euro area inflation. *Int. J. Forecast.* 30, 303–312.
- European Central Bank, 1999a. The stability oriented monetary policy strategy of the Eurosystem. ECB Monthly Bulletin, January 41–53.
- European Central Bank, 1999b. Euro area monetary aggregates and their policy role in the Eurosystem’s monetary policy strategy. ECB Monthly Bulletin, February 29–46.
- European Central Bank, 2003. The outcome of the ECB’s evaluation of its monetary policy strategy. ECB Monthly Bulletin, June 79–92.
- European Central Bank, 2008. The external dimension of monetary analysis. ECB Monthly Bulletin, August 71–84.
- European Central Bank, 2021. An Overview of the ECB’s Monetary Policy Strategy. European Central Bank. July.
- Fagan, G., Henry, J., Mestre, R., 2005. An area-wide model for the euro area. *Econ. Modell.* 22, 39–59.
- Feenstra, R., 1986. Functional equivalence between liquidity costs and the utility of money. *J. Monetary Econ.* 17 (2), 271–291. Elsevier.
- Funke, Michael, 2001. Money demand in euroland. *J. Int. Money Finance* 20 (5), 701–713.
- Gerlach, S., 2004. The pillars of the ECB. *Econ. Pol.* 19, 389–439.
- Greiber, C., Lemke, W., 2005. Money demand and macroeconomic uncertainty. Bundesbank Discussion Paper Series: Economic Studies, N 26.
- Grilli, V., Roubini, N., 1992. Liquidity and exchange rates. *J. Int. Econ.* 32, 339–352.
- Jawadi, F., Sousa, R., 2013. Money demand in the euro area, the US and the UK: assessing the role of nonlinearity. *Econ. Modell.* 32, 507–515.
- Johansen, S., 1988. Statistical analysis of cointegration vectors. *J. Econ. Dynam. Control* 12, 231–254.
- Joines, D., 1985. International currency substitution and the income velocity of money. *J. Int. Money Finance* 4, 303–316.
- Kaplan, G., Moll, B., Violante, G., 2016. Monetary policy according to HANK. *Am. Econ. Rev.* 108 (3), 697–743.
- Kiyotaki, N., Moore, J., 1997. Credit cycles. *J. Polit. Econ.* 105 (2), 211–248.
- Knight, F., 1921. *Risk, Uncertainty and Profit*. Houghton Mifflin, Boston, MA.
- Kouri, P., 1977. International investment and interest rate linkages under flexible exchange rates. In: Aliber, R.Z. (Ed.), *The Political Economy of Monetary Reform*. Macmillan, London, pp. 74–96.
- LeBaron, B., 2000. Agent-based computational finance: suggested readings and early research. *J. Econ. Dynam. Control* 24 (5–7), 679–702.
- Lebre de Freitas, M., 2006. Currency substitution and money demand in euroland. *Atl. Econ. J.* 34 (3), 275–287.
- Lebre de Freitas, M., Veiga, F., 2006. Currency substitution, portfolio diversification and the money demand. *Can. J. Econ.* 39 (3), 719–743.
- Lucas, R., 1982. Interest rates and currency prices in a two-country world. *J. Monetary Econ.* 10, 335–359.
- Mackinnon, J., 1996. Numerical distribution functions for unit root and cointegration test. *J. Appl. Econom.* 11 (6), 1979–1990.
- McKinnon, R., 1982. Currency substitution and instability in the world dollar standard. *Am. Econ. Rev.* 72 (3), 320–333.
- Mera, V., Silaghi, M., Turcu, C., 2020. Economic Sentiments and money demand stability in the CEECs. *Open Econ. Rev.* 31, 343–369.
- Merton, R., 1969. Lifetime portfolio selection under uncertainty: the continuous time case. *Rev. Econ. Stat.* 51, 247–257.
- Metzler, L., 1951. Wealth, savings, and the rate of interest. *J. Polit. Econ.* 59, 93–116.
- Mizen, P., Pentecost, E., 1994. Evaluating the empirical evidence for currency substitution: a case study of the demand for sterling in europe. *Econ. J.* 104, 1057–1069.
- Patinkin, D., 1956. *Money, Interest and Prices*, second ed. Harper and Row, New York. 1965.
- Polyzos, S., Samitas, A., Katsaiti, M.S., 2020. Who is unhappy for Brexit? A machine-learning, agent-based study on financial instability. *Int. Rev. Financ. Anal.* 72, 101590.
- Polyzos, S., Abdulrahman, K., Dandu, J., 2021. Effects of financial instability on subjective well-being: a preference-based approach. *Int. J. Soc. Econ.* 48 (7), 982–998.
- Saving, T.R., 1971. Transaction costs and the demand for money. *Am. Econ. Rev.* 61, 407–420.
- Sidrauski, M., 1967. Rational Choice and Patterns of growth in a monetary economy. *Am. Econ. Rev.* 57, 534–544.
- Svensson, L., 1999. Inflation targeting as a monetary policy rule. *J. Monetary Econ.* 43, 607–654.
- Thomas, L., 1985. Portfolio theory and currency substitution. *J. Money Credit Bank.* 17 (2), 347–357.
- Tobin, J., 1969. A general equilibrium approach to monetary theory. *J. Money Credit Bank.* 1, 15–29.
- Végh, C., 1989. Currency Substitution and the optimal inflation tax. *J. Monetary Econ.* 24, 139–146.