Ostbayerische Technische Hochschule
Amberg-Weiden

OTH
Amberg-Weiden

im Dialog

Weidener Diskussionspapiere

Cash Holdings in Germany and the Demand for „German“ Banknotes: What role for cashless payments?

Nikolaus Bartzsch
Prof. Dr. Franz Seitz

Diskussionspapier Nr. 51
Juni 2015

Impressum

Herausgeber Prof. Dr. Franz Seitz und Prof. Dr. Horst Rottmann

Ostbayerische Technische Hochschule Amberg-Weiden
University of Applied Sciences, Abt. Weiden
Hetzenrichter Weg 15, D-92637 Weiden
Telefon: +49 961 382-0
Telefax: +49 961 382-2991
e-mail: weiden@oth-aw.de
Internet: www.oth-aw.de

Druck Hausdruck

Die Beiträge der Reihe "OTH im Dialog: Weidener Diskussionspapiere" erscheinen in unregelmäßigen Abständen.

Bestellungen schriftlich erbeten an:
Ostbayerische Technische Hochschule Amberg-Weiden
Abt. Weiden, Bibliothek, Hetzenrichter Weg 15, D-92637 Weiden
Die Diskussionsbeiträge können elektronisch unter www.oth-aw.de abgerufen werden.

ISBN 978-3-937804-53-8

Cash Holdings in Germany and the Demand for "German" Banknotes: What role for cashless payments?

Nikolaus Bartzsch, Deutsche Bundesbank, Cash Department, Germany

Franz Seitz, Weiden Technical University of Applied Sciences, Germany

June 2015

Abstract

This paper models the demand for banknotes issued in Germany. It highlights that all motives for holding banknotes are present in this case. Inter alia, special attention is paid to the role of card payments. For small and large denomination notes we are able to establish meaningful vector error correction models (VECM). The results suggest that the long-run demand for German small denomination notes is mainly driven by domestic transactions and demand from outside the euro area. The transaction motive in the rest of the euro area and non-cash payments are part of the short-term dynamics. The long-run demand for German large denomination notes is mainly driven by foreign demand both from the rest of the euro area and outside the EMU. The global financial crisis led to a one-time increase in the (real) demand for these notes. Our results are in line with estimates according to which the level and dynamics of banknote demand are largely determined by foreign demand. It was not possible to setup a VECM for medium denominations for which we resort to a single-equation approach. Card payments do not play any role for the medium and large denomination categories.

JEL Classification: C22, C32, E41

Keywords: banknotes, vector error correction, card payments

Deutscher Abstract

Das vorliegende Papier modelliert die Nachfrage nach Euro-Banknoten, die von der Deutschen Bundesbank emittiert wurden. Dabei wird offensichtlich, dass alle Motive der Bargeldhaltung in diesem Fall relevant sind. Ein spezielles Augenmerk wird darauf gerichtet, welche Rolle bargeldlose Zahlungen in Form von Kartenzahlungen spielen. Für große und kleine Stückelungen gelingt es, aussagekräftige Vektorfehlerkorrekturmodelle (VECM) mir ökonomischem Gehalt aufzustellen. Langfristig wird die Nachfrage nach kleinen Stückelungen vor allem getrieben von inländischen Transaktionen und der Nachfrage außerhalb des Euro-Währungsgebietes. Das Transaktionsmotiv in den anderen Euro-Ländern und Kartenzahlungen treiben die Kurzfristdynamik. Die langfristige Nachfrage nach großen Stückelungen wird dagegen hauptsächlich von der Auslandsnachfrage innerhalb und außerhalb des Euro-Währungsgebiets getrieben. Die globale Finanzkrise führte dabei zu einem einmaligen Sprung in der realen Nachfrage nach diesen Noten. Für die mittleren Stückelungen konnte kein VECM aufgestellt werden. Deshalb musste auf einen Einzelgleichungsansatz zurückgegriffen werden. Kartenzahlungen beeinflussen weder die Nachfrage nach großen noch nach mittleren Stückelungen.

1 Introduction*

Generally speaking, all euro-area national central banks issue euro banknotes. Following the introduction of euro cash at the start of 2002, the cumulated net issuance of euro notes by the Deutsche Bundesbank ("German" euro notes) increased from an initial €73 billion to €508 billion at the end of 2014. Figure 1 shows that the volume of these German euro banknotes outstanding has grown very much faster than could have been expected on the basis of earlier growth rates of D-Mark currency. For the first two years after the launch of euro cash, this strong growth could be explained by the need to replenish stocks of hoarded banknotes both inside and outside the euro area after the currency changeover. However, this should have ceased to have an effect at the end of 2003 when the volume of German banknotes outstanding returned to the hypothetical level that would have been reached had euro cash not been introduced. Nevertheless, the pace of growth in the volume of banknotes outstanding continued to be much more dynamic than in the D-Mark era in the 1990s. As shown in Bartzsch et al (2011a), this huge surge is due to foreign demand for euro banknotes. They find that, at the end of 2009, around 70% of the cumulated net issuance was held outside Germany. Of this, the lion's share (roughly 50%) was in non-euro-area countries, with the remainder in other euro-area countries. This also means that only a relatively small share – approximately 30% – was used for transaction purposes and hoarding in Germany.[1] In their opinion, 20% is a realistic figure for banknotes hoarded in Germany. Consequently, only around 10% were used for transaction purposes in Germany. This was equivalent to around €430 *per capita* at the end of 2009.

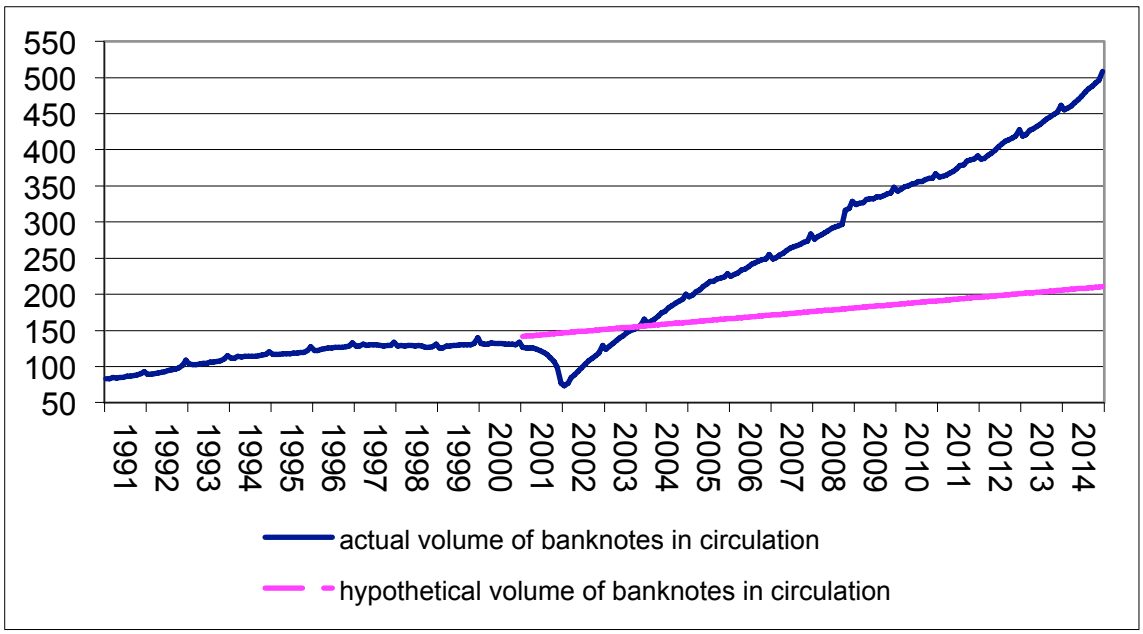
While Bartzsch et al (2011a, b) have split up the cumulated net issuance of euro notes by the Deutsche Bundesbank into its components (transaction balance, hoarding and foreign demand), we want to further analyse the role of these underlying motives of banknote demand. These should differ for the individual denominations. Therefore, we estimate models of banknote demand for small, medium and large German euro banknotes. In these structural models, the demand for banknotes is explained by proxy variables for the motives of holding banknotes. Amongst others, we estimate the interest (semi-)elasticities of banknote demand. This allows us to answer the question whether portfolio shifts from short-term bank deposits

* The authors thank E Gladisch and R Setzer for their helpful comments. We are particularly grateful to S Arz for his valuable contribution. The opinions expressed in this paper do not necessarily reflect those of the Deutsche Bundesbank.

[1] Although the results of the indirect approaches are slightly higher than the figures obtained in the direct approaches (see Bartzsch et al, 2011b), the latter are largely confirmed. An update of the estimates in Bartzsch et al (2011b) is presented in section 3.

into cash are to be expected owing to the very low level of interest rates. Moreover and specifically, we ask what role cashless payment media play in the evolution of the demand for banknotes. Our paper is closely related to Seitz and Setzer (2009) who also estimate structural models of the demand for German banknotes. With data available only up until the end of 2007 they use a mixed D-Mark/euro series from 1991 to 2007. By contrast, our models are estimated for the euro era only with data ranging from 2002 to 2011.

Figure 1: German banknotes in circulation (€ billion)



Note: The actual volume of banknotes in circulation in the period from January 1991 to December 2001 corresponds to the volume of D-Mark banknotes outstanding (converted to euros with the irrevocably fixed exchange rates of 1 January 1999) and, following the introduction of euro cash in January 2002, the volume of Bundesbank-issued euro banknotes outstanding. For the sake of simplicity, the volume of D-Mark banknotes outstanding in the period from January 1991 to December 2000, extrapolated using its linear trend, is taken as the hypothetical volume of banknotes in circulation as of January 2001.

Sources: Deutsche Bundesbank and the authors' own calculations.

The paper is structured as follows. Chapter 2 contains a literature survey on banknote demand models with special emphasis on Germany and the role of card payments. In chapter 3, some stylised facts are presented concerning the development and composition of banknotes in circulation in Germany and the rest of the euro area as well as some figures on cashless payments. The data we use to estimate banknote demand models are described in chapter 4. In chapter 5, we estimate structural models of banknote demand for the three denomination categories. The results are summarised together with other conclusions in chapter 6.

2 Literature review

The following literature survey focuses on more recent work since the beginning of the 2000s. For an overview of older papers on currency demand, see Boeschoten (1992, subsection 1.4.2).

Doyle (2000) estimates foreign demand for US, German and Swiss currency. He obtains higher foreign shares than in previous studies. His results are based on currency demand equations within a cointegration framework. Doyle obtains different results when he splits up currency into large and small-value denominations. The signs and significance of the coefficients are unchanged with just large denomination notes. By contrast, when only small-denomination notes are used, those same coefficients tend to be insignificant or have the wrong signs. These smaller notes are the ones that Doyle expects will more likely be used in the legitimate US economy. Therefore, he concludes that this result might indicate an invalidation of traditional explanations of currency demand or simply movements away from small to large notes (in real terms), or from cash to other payment instruments.

Khamis and Leone (2001) find strong evidence that real currency demand in Mexico remained stable throughout and after the financial crisis in Mexico which started at the end of 1994. They find a strong cointegration relationship between currency balances, private consumption expenditures and the interest rate. The sample period from 1983 to 1997 includes the inflationary debt crisis period, the stabilisation period under the 1987 stabilisation plan, the ensuing financial crisis in December 1994 and the recovery period thereafter. The paper concludes that the significant reduction in currency demand in the course of the financial crisis can be appropriately explained by a change in the variables that historically explain cash demand in Mexico quite well.

Akinci (2003) models currency in circulation in Turkey using data between 1987 and 2003. Cointegration analysis reveals that there is a long-run relationship between currency issued, private consumption, interest rates and a bilateral exchange rate. The results reveal that economic agents are more sensitive to interest rate movements than to exchange rate movements in the long run. The exchange rate elasticity is more effective in the short run. This indicates that the exchange rate might be a powerful indicator in terms of capturing the dynamics of the demand for cash. Moreover, this implies the existence of currency substitution in Turkey. In the long run, however, real income and the interest rate variables appear to be the main determinants of the demand for cash balances.

Amromin and Chakravorti (2009) analyse cash demand for 13 advanced economies from 1988 to 2003 with panel regressions by separating cash into three denomination categories to disentangle its store of value and payment functions. They isolate the transactional role of cash by focusing on the small denomination class, which they define as banknotes (including coins) that are lower in value than those which are commonly dispensed by ATMs. Amromin and Chakravorti econometrically test a money demand equation where the currency-to-GDP ratio is a function of alternative payment infrastructure, cash infrastructure, proportion of small merchants, and the opportunity cost of cash. They also report results for the aggregate currency-to-GDP ratio. The substitution effects with respect to electronic payments are largely confined to the demand for small denominations. Moreover, they find that the demand for small denomination currency is not affected by changes in the interest rate. By contrast, the demand for high denomination notes decreases as interest rates rise but is unaffected by changes in debit card usage. The interest rate sensitivity of demand for high-denomination notes is especially high in countries that do not have significant proportions of their currency stock circulating outside their borders. This suggests a persistent role for cash as a store of wealth.

Nachane et al (2013) identify various factors influencing currency demand in India from 1989 to 2011 in a vector error correction framework for aggregate currency demand as well as for various currency sub-groups. They argue that the homogeneity postulate with respect to prices might be too restrictive. Hence, they model currency in nominal terms, using wholesale prices as price measure. The trends in currency in circulation at the individual denomination level show considerable fluctuations, in particular, which renders econometric modelling a complex task. However, there exists a cointegrating relationship between (total) currency circulation, real GDP, prices and deposit rates. The income elasticity of currency is found to be somewhat higher than is observed in similar studies for advanced countries.

Cusbert and Rohling (2013) analyse the strong increase in the demand for currency in Australia which began in mid-October 2008, around one month after the collapse of Lehman Brothers and concurrently with policy responses of the Reserve Bank of Australia and the Federal Government. They attempt to capture the effects of the global financial crisis on currency demand in three ways. First, they add dummy variables for the last quarter of 2008 until the second quarter of 2009 to their baseline model. Second, they introduce confidence, financial market and wealth variables to their model. They expect increases in the stock of currency to be associated with declines in confidence and wealth and rises in financial

volatility. Finally, they examine whether these variables retain any explanatory power in the presence of dummy variables. In their baseline model, currency in circulation is modelled in a single equation error correction framework to exploit the possible cointegration between currency holdings, nominal GDP and interest rates. They also include ATMs, EFTPOS terminals, bank branches per capita and the ratio of self-employed to total employment in the long-run relationship. They estimate the model using data from 1993 to 2011 and find that only around 20% of the rise in Australian currency demand during the financial crisis can be attributed to the normal response of currency holdings to the lowering of interest rates and to the increase in income from the government stimulus. The remaining 80% may be due to an increase in precautionary holdings in response to financial market uncertainty, which is consistent with the larger increase in demand for high-denomination banknotes. In addition, Cusbert and Rohling estimate separate models of currency demand of the bank and non-bank sector for different denominations. The interest coefficients are broadly consistent with the idea that demand for larger denominations should be more interest sensitive. The insignificance of the financial crisis dummy variables in the low-denomination regression confirms that only larger denominations were behaving unusually in this period.

Besides these time series models there is one paper which estimates currency demand using micro data. Briglevics and Schuh (2014) investigate US consumer demand for cash using panel micro data for 2008–2010 with a special emphasis on the role of low interest rates and different kinds of credit cards. They find that cash demand by consumers using credit cards for convenience is much more interest elastic than those using credit cards to borrow. These findings may have implications for the welfare cost of inflation because consumers who revolve credit card debt are less likely to switch from cash to credit.

There are only three papers which concentrate on the euro area. Fischer et al (2004) analyse currency in circulation in the euro area since the beginning of the 1980s. They develop a theoretical model which extends traditional money demand models to also incorporate arguments for the informal economy and foreign demand for specific currencies. In the empirical part, they estimate the total demand for euro legacy currencies and for small and large denominations within a vector error correction framework. They find significant differences between the determinants of holdings of small and large denominations as well as overall currency demand. While the long-run demand for small-value banknotes is mainly driven by domestic transactions, the demand for large-value banknotes in the cointegrating relation depends on a short-term interest rate, the exchange rate of the euro as a proxy for

foreign demand and inflation variability. Therefore, large value banknotes seem to be used to a large extent as a store of value both domestically and abroad.

An approach similar to that of Fischer et al (2004) is taken by Seitz and Setzer (2009). They estimate the demand for small, medium and large denominations of German banknotes in a vector error correction framework for the period from the first quarter of 1991 to the fourth quarter of 2007. These comprise D-Mark banknotes and euro banknotes which were put into circulation by the Deutsche Bundesbank. They include the DM period, as the time series for the euro era alone was too short at that time. In the case of small and medium denominations, what stands out in the results is the obvious impact of the transaction volume. The large denominations, by contrast, appear to be unaffected by this. In their case, however, non-resident motives are important: first, via a long-term impact of the house prices in the euro area, whose dynamics are determined mainly by the real estate market outside Germany, and second, via private consumption in the euro area excluding Germany. Additionally, demand from non-euro-area countries is important for all denominations. Moreover, an influence of the shadow economy on banknote demand cannot be ruled out for any of the three banknote categories. Finally, opportunity costs in the form of interest rates seem to be of relevance only for the small denominations. Alternative means of payment (especially card payments) evidently influence only the small denominations, too. The error correction term indicates the fastest adjustment for the small denominations and the longest for the large denominations.

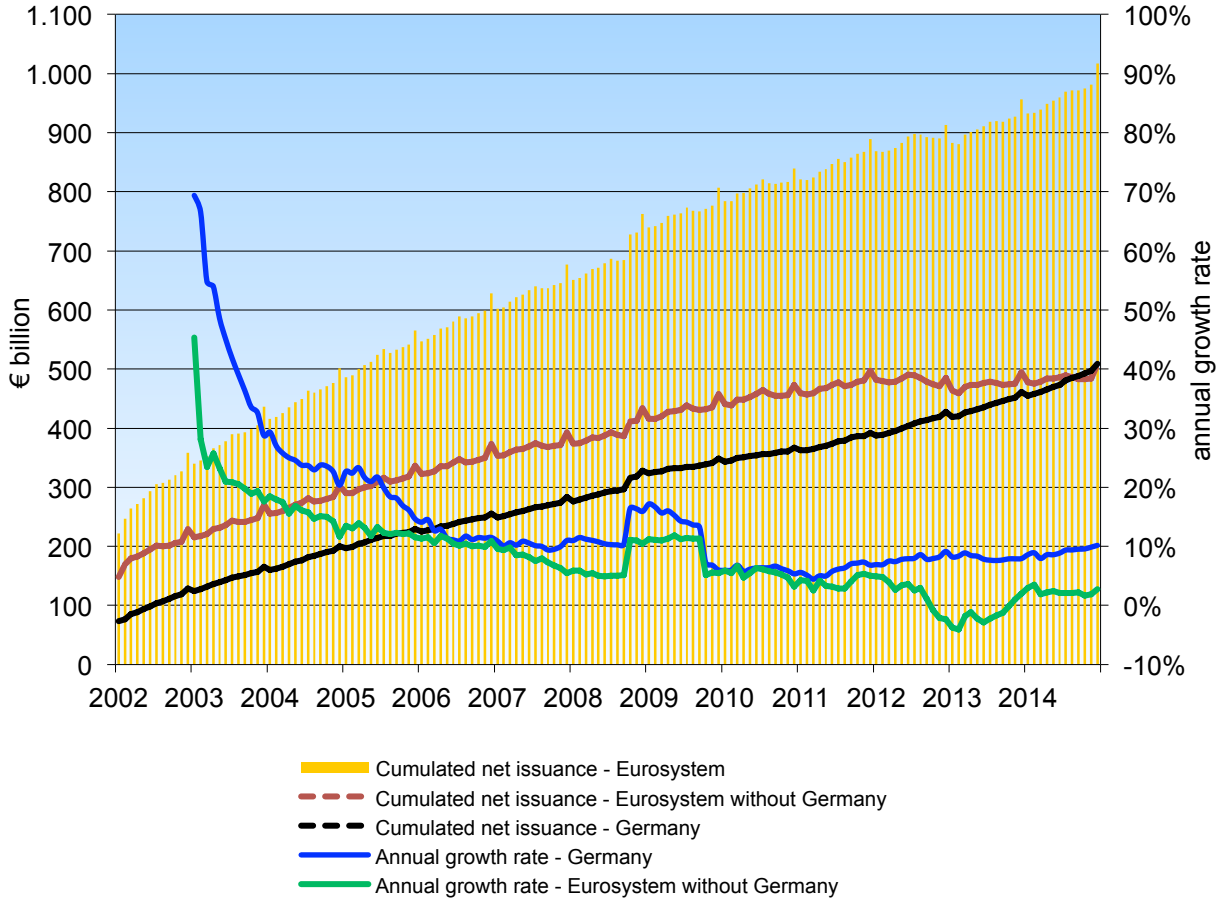
Bartzsch et al (2015) take Seitz and Setzer (2009) as starting point, but concentrate on genuine euro area data. Their models reveal a strong foreign influence on the demand for "German" banknotes, but no significant repercussions from card payments as alternatives to cash. This might be attributed to the poor quality of their proxy variable, the number (value) of card payments published by the Deutsche Bundesbank in its payments statistics. Due to redefinitions, this series exhibits a counterintuitive and unexplained downward shift in 2007 (see section 3 for details). In contrast, in Seitz and Setzer (2009), who use a similar framework with data before the redefinition, this variable exerted a significant influence on small denomination notes.

Our paper analyses cash demand using also genuine euro data since 2002. As regards card payments, we take another data series into account which does not suffer from the statistical break.

3 Stylised facts

In this section we present a number of stylised facts about the cumulated net issuance of euro banknotes by the Deutsche Bundesbank ("German" euro banknotes in circulation) and the Eurosystem as well as the role of cashless payments in Germany. The development of euro banknotes in circulation is shown in figure 2. After the euro cash changeover at the beginning of 2002, the cumulated net issuance of German euro banknotes increased from an initial €73 billion to €508 billion (10.7 billion notes) at the end of 2014. This corresponds to an average annual growth rate of more than 16%. In the euro area, banknotes in circulation increased during the same period from an initial €221 billion to €1,017 billion (17.5 billion notes). Thus, the German share in the value of the cumulated net issuance of euro banknotes has increased from 33% to 50% since the euro cash changeover. This share is clearly above Germany's share in the ECB capital of 25.7%, which is determined on the basis of the size of its population and its GDP.

Figure 2: Euro banknotes in circulation



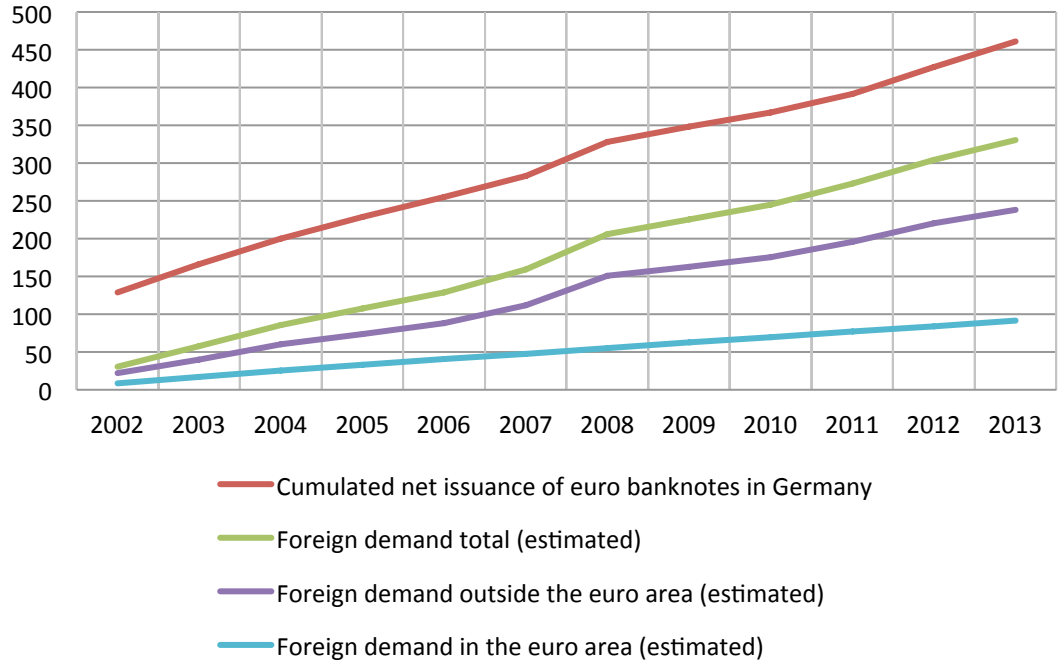
Note: Left scale: Cumulated net issuance; right scale: annual growth rate.

Sources: Deutsche Bundesbank and ECB.

The vast growth in German euro banknotes in circulation up until the end of 2003 can be attributed to the replenishment of stocks of hoarded banknotes both inside and outside the euro area (see figure 1). From 2004, the growth rates of banknotes in circulation began to decline steadily. In 2006, they stabilised at a level of about 10%. In the wake of the financial crisis, German households made considerable shifts in their financial investment in the fourth quarter of 2008 (see Deutsche Bundesbank 2009, p 52 f). This led to sharp inflows into liquid and (relatively) secure short-term types of investment, which also boosted the demand for cash. As a result, the German net issuance of banknotes rose by €16 billion in October 2008. In that month alone, the annual growth rate of the cumulated net issuance of German euro banknotes increased by six percentage points.
As can be seen in figure 2, the hoards of "German" euro banknotes resulting from the crisis were partially reduced in the course of 2009 in the sense that the growth rates in Germany developed more in line with those in the rest of the euro area.

Since the beginning of 2012, the volume of "German" euro banknotes in circulation, which has seen annual growth rates of between 7% and 10%, has again been showing much stronger growth than the circulation of banknotes issued by other Eurosystem member states (see figure 2). Some euro-area countries have even recorded negative rates of increase. These differences in the development of euro banknotes in circulation can be explained by the large share of the Bundesbank's cumulated net issuance of euro banknotes in circulation outside Germany. A number of different approaches can be used to measure the foreign demand for German euro banknotes (see Bartzsch et al, 2011a, b). In this connection, the regional distribution of the cumulated net issuance is determined using the "net shipments and foreign travel" approach (Bartzsch et al, 2011b, section 3.1). The volume of "German" euro banknotes in circulation abroad is estimated using data collected as part of a household survey by the Bundesbank on foreign travel as well as available data on net shipments of euro banknotes by banks (international foreign currency traders) to countries outside the euro area. These net shipments correspond to the difference between the outpayments by the Bundesbank to international foreign currency traders and the inpayments by the international foreign currency traders at the Bundesbank. The estimated regional distribution of euro banknotes issued in Germany estimated using this approach can be seen in figures 3 and 4.

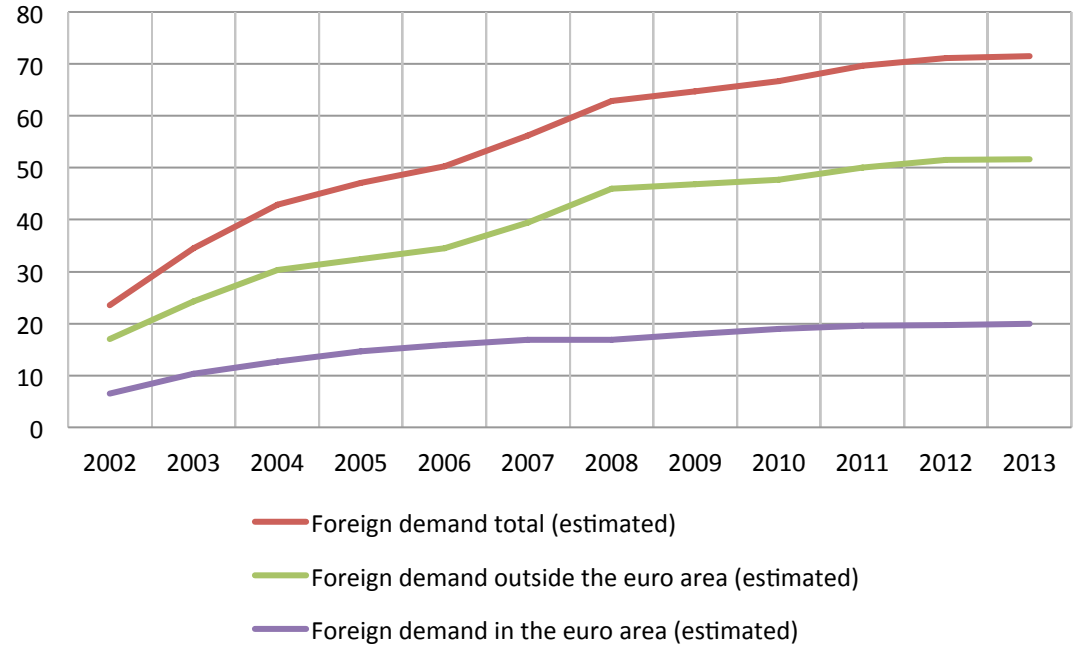
Figure 3: Regional distribution of euro banknotes issued in Germany (in € billion)



Sources: Deutsche Bundesbank and authors' own calculations.

At the end of 2013, the largest share of the Bundesbank's cumulated net issuance in the amount of just over €460 billion was accounted for by banknotes in circulation abroad (€330 billion or just over 70% of the cumulated net issuance), with the lion's share in circulation outside the euro area (just under €240 billion, or over 50% of the cumulated net issuance). Germany was, however, also a major net exporter of euro banknotes - especially via foreign travel - to the rest of the euro area (just over €90 billion, or 20% of the cumulated net issuance). The banknotes in circulation outside the euro area can be attributed to foreign travel and to the net shipments, with the latter (cumulated) accounting for the greatest share (just over €140 billion, or just over 30%) at the end of 2013. In summary, the growth in the cumulated net issuance of banknotes in Germany can be primarily explained by the volume of German-issued euro banknotes held abroad (foreign demand), whereas the domestic demand for banknotes (for transaction and hoarding purposes) remains largely constant and therefore does not make a notable contribution to the growth in the cumulated net issuance. The percentage share of the Bundesbank's cumulated net issuance of euro banknotes in circulation abroad has therefore increased significantly since the introduction of euro cash (see figure 4).

Figure 4: Regional distribution of euro banknotes issued in Germany

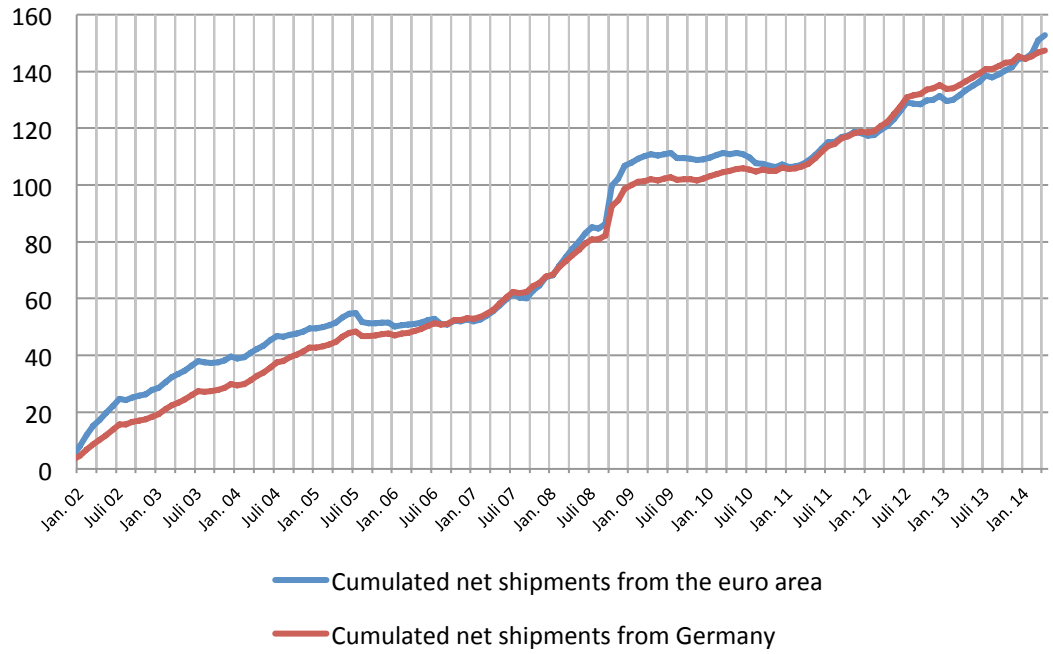


Note: Percentage shares in the cumulated net issuance.

Sources: Deutsche Bundesbank and authors' own calculations.

To complete the picture, figure 5 shows the cumulated net shipments from Germany and from the Eurosystem as a whole. Both time series lie close together over the entire time horizon and have been virtually congruent since the end of 2010. In other words, virtually all of the Eurosystem's total cumulated net issuance originates from Germany on balance. This can be explained, in part, by Germany's long-standing strong involvement since the D-Mark era in the international wholesale banknote market, its central geographical location and also by the role of Frankfurt airport. In addition to the cumulated net shipments, the (total) volume of euro banknotes in circulation outside the euro area is fed by other channels, such as foreign travel or cash sent home by foreign workers. The cumulated net shipments therefore only represent a lower limit. According to estimates by the ECB, around 25% of all euro banknotes issued by the Eurosystem are outside the euro area (ECB, 2014, p 23). At the end of 2013, this was equivalent to just under €240 billion. This corresponds exactly to the estimated value of the cumulated net issuance of "German" euro banknotes in circulation outside the euro area (see figure 3).

Figure 5: Cumulated net shipments of euro banknotes from Germany and the euro area (in € billion)

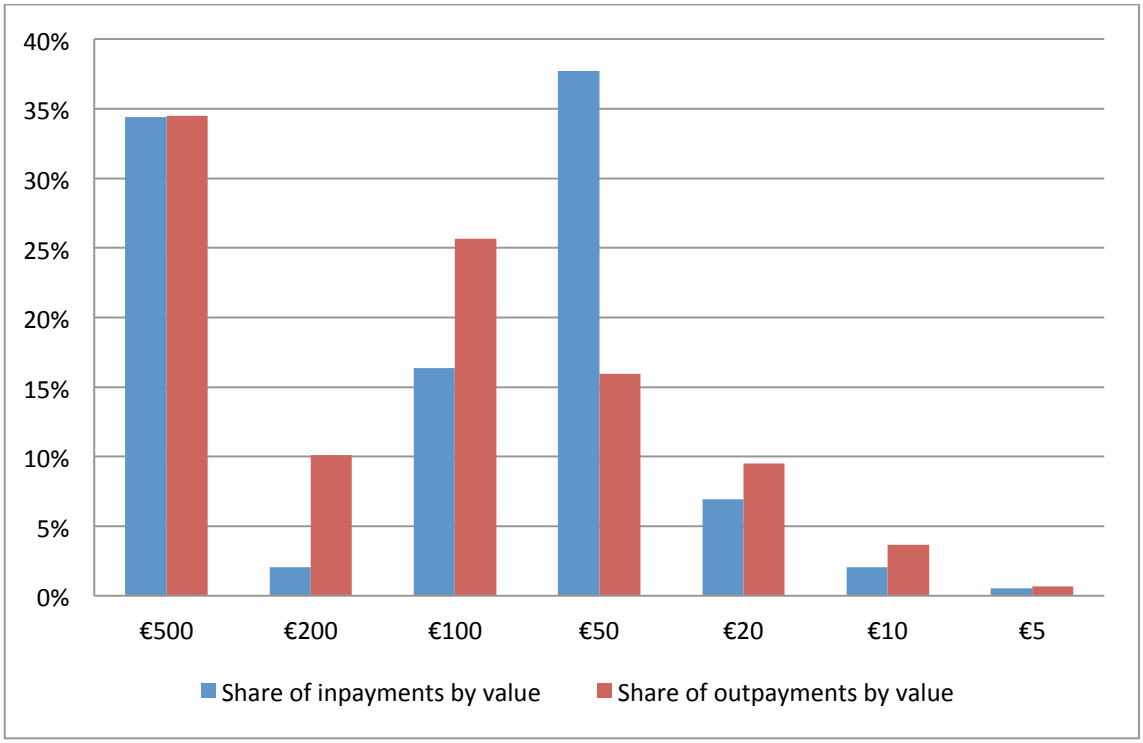


Sources: Deutsche Bundesbank and ECB.

In summary, the dynamic development of the cumulated net issuance of euro banknotes by the Bundesbank - unlike those issued by other Eurosystem member states - can be explained as follows. Practically the entire volume of euro banknotes in circulation abroad issued by the Eurosystem seems to originate from Germany. Furthermore, Germany is a major (net) exporter of euro banknotes to other euro-area countries. Moreover, the growth in the cumulated net issuance in Germany is almost exclusively driven by foreign demand. In the meantime, foreign demand is presumably also the greatest driving force behind the development of the foreign demand for euro banknotes for the Eurosystem as a whole.[2] In Germany's euro-area partner countries, the volumes of banknotes held for transaction purposes are likely to have grown less strongly owing to the subdued economic growth and the generally lesser significance of cash as a means of payment.

[2] For further information on the stronger growth in the foreign demand for euro banknotes in recent years, see ECB (2014).

Figure 6: German shipments in 2013 by denomination



Source: Deutsche Bundesbank.

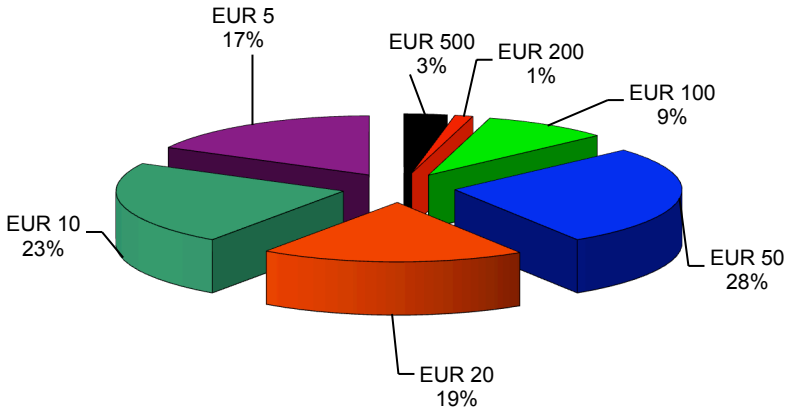
The lion's share of euro banknotes in circulation outside the euro area is presumably not used for transaction purposes, but is hoarded. Bartzsch et al (2011b, section 3.4) estimate that stocks of hoarded banknotes account for 70% of the total volume of "German" euro banknotes in circulation outside the euro area. This hypothesis is also supported by the breakdown (by denomination) of the shipments from Germany (by value). Figure 6 illustrates this by way of example for 2013, which is when inpayments at central banks, ie the purchases by wholesale currency banks, started being recorded by denomination. With regard to outpayments and inpayments, the bulk of these banknotes is accounted for by the €500, €100 and €50 denominations. The €500 and €100 banknotes are denominations that are typically used for hoarding, whereas the €50 note is probably used for both hoarding and transaction purposes.

The breakdown by denomination of the number of banknotes put into circulation is shown in figure 7 for the Bundesbank and in figure 8 for the Eurosystem without Germany. It is striking that the share of €5 notes and €10 notes for Germany (together 40%) is quite large, whereas it is negative for the rest of the euro area.[3] This means that the demand for these

[3] The percentage share is negative if the cumulated *net* issuance of the respective denomination is negative.

denominations is completely met by the Deutsche Bundesbank. Moreover, the share of €50 notes is much higher in the Eurosystem without Germany (61% compared with 28%).[4]

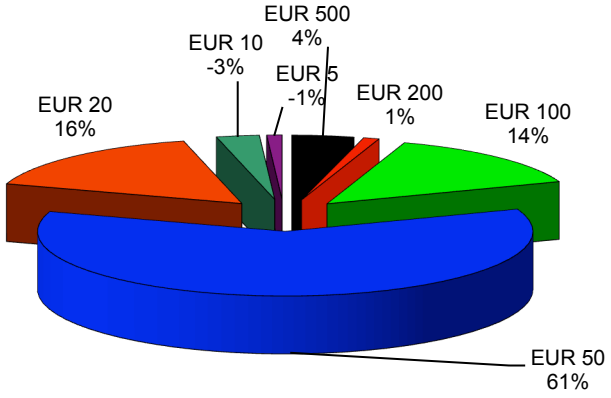
Figure 7: Denominational structure of the number of euro banknotes put into circulation by the Deutsche Bundesbank



Note: Percentage shares in the cumulated net issuance as at 15 June 2014.

Source: Deutsche Bundesbank.

Figure 8: Denominational structure of the number of euro banknotes put into circulation by the Eurosystem without Germany



Note: Percentage shares in the cumulated net issuance as at 15 June 2014.

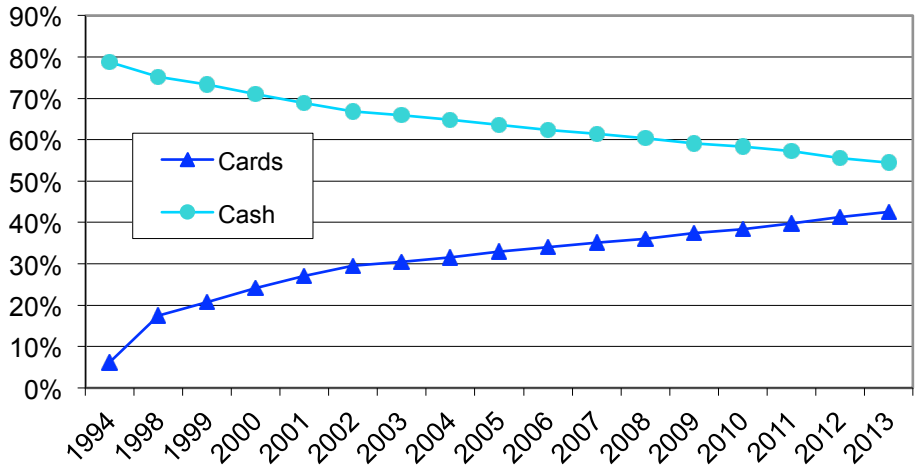
Source: ECB.

As regards cashless payments, figure 9 reveals that according to the annual surveys conducted by the Institute for Payment Systems in Retail Trade the share of payments accounted for by cash fell from 79% in 1994 to 54% in 2013, while card payments rose from 6% to just under 43% in the same period. As illustrated, the two shares are increasingly

[4] These differences also hold for the composition of the value of banknotes put into circulation by denomination, albeit to a lesser degree, see Bartzsch et al (2015).

converging. The rate of convergence is slowing down however, which could mean that, in the long run, the two will have an equal share of sales.

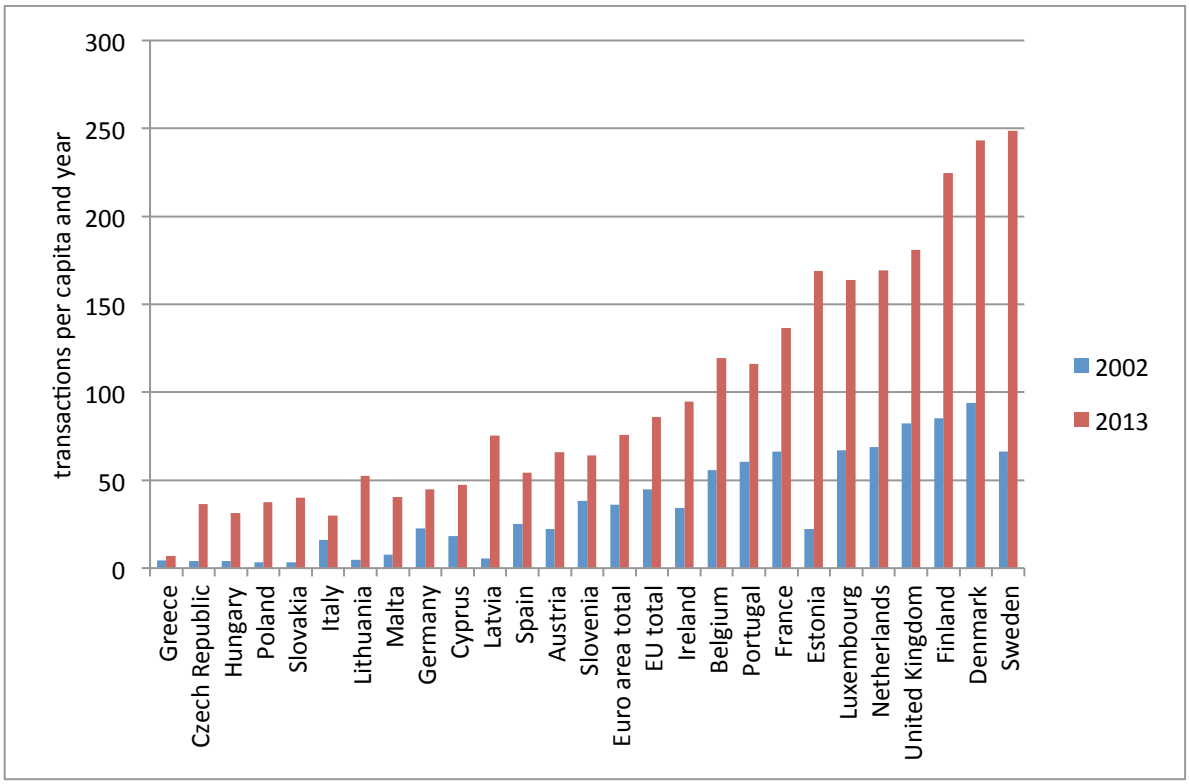
Figure 9: Share of cash and cards in retail trade



Source: EHI.

Figure 10 compares the number of card payments in selected EU countries between 2002 and 2013. The values have increased in every country. The highest levels of growth, starting from a low base level, are evidently in the Baltic states and in Poland. In 2013, the Scandinavian EU countries were clearly at the top with more than 200 transactions per inhabitant. Greece was at the bottom end of the scale with only seven transactions. With a score of 45 transactions, Germany is on a par with Malta and Lithuania, just ahead of Italy, but significantly behind France, Austria and the Netherlands. In comparison with the rest of the EU, growth in Germany has been slower. Outside the EU, the number of transactions per capita was 248 in the US (2012), 70 in Japan (2012), 89 in Switzerland (2013) and 10 in China (2013). Therefore, according to these figures and bearing in mind the level of development, the value for Germany is relatively low.

Figure 10: Card payments in the EU



Source: ECB.

4 Data and determinants of banknote holdings

The main objective of this section is to present the data used in the econometric analysis and to explain the determinants of the demand for German euro notes in circulation. The procedure is eclectic to the extent that we use a large set of variables which reflect the various motives for holding banknotes and which we test for statistical significance. This approach is followed by a look at limited data availability - a factor which is mainly related to the characteristic feature of banknotes, their anonymity.

In total, **we identify five different purposes of holding cash (or banknote) balances**. These are 1) transaction motives, 2) store of wealth (and, in this connection, opportunity cost) considerations, 3) the availability of alternative means of payment, 4) the size of the shadow economy and 5) demand by non-residents. In the following paragraphs, we describe the coding of these variables in the empirical analysis.[5]

In terms of the **transaction variable**, it would be optimal to include a variable capturing all cash transactions (Snellman and Vesala, 1999; Snellman et al, 2000). Since no data are

[5] Additional purposes and proxy variables can be found in Seitz and Setzer (2009).

available on the number of cash transactions in Germany, one solution is to resort to total private consumption, retail sales or GDP as is the case in conventional money demand studies. This is, however, only a rough proxy given the large number of cashless transactions in an economy. Therefore, we additionally construct a variable based on those components of domestic private consumption which are primarily carried out in cash (real "cash consumption", *ccr*). These include 1) accommodation and hospitality services, 2) clothing and footwear, 3) leisure, entertainment and culture, 4) food and beverages, as well as 5) other purposes, such as body care and personal articles.

In addition to its function as a payment medium, cash also serves as a **store of value**. This is the case in particular for high-value, and to a certain extent, also for medium-value banknotes. Since cash bears no interest, interest rate levels can be used as an opportunity cost measure for holding cash.[6] Appropriate choices include the three-month money market rate or the ten-year government bond yield. Following Friedman (1977), we also include a measure of the whole term structure of interest rates as estimated, for instance, by the Nelson-Siegel-Svensson method, see Deutsche Bundesbank (1997) for details. The term structure of interest rates provides a precise measure of expectations in the money and bond markets. Its pattern can thus provide information about expected changes in interest rates or inflation - both variables which are directly related to the opportunity costs of cash holdings. Moreover, this procedure circumvents multicollinearity problems when taking more than one interest rate into account in empirical applications. Friedman argues that a demand-for-currency equation should include the key characteristics of the whole structure of yields: the "general" level, the "tilt" of the term structure to maturity and the difference between real and nominal yields. A steepening of the tilt of the term spread with an unchanged mean, for example, which implies higher long-term rates and lower short-term rates, will tend to reduce cash balances, and vice versa (Friedman, 1977, p 408).[7] The formula used for estimating the term structure specifies the interest rate as the sum of a constant and various exponential terms and reads as (Deutsche Bundesbank, 1997, p 63f)

[6] In the Baumol-Tobin model (Baumol, 1952; Tobin, 1956), an inclusion of interest rates may also be rationalised by transaction demand, see Alvarez and Lippi (2007) for a modern version of this model.

[7] An empirical implementation of Friedman's proposal within a money demand framework can be found in Friedman and Schwartz (1982) for the US and in Seitz (1998) for Germany.

$$i(T,\beta) = \beta_0 + \beta_1\left(\frac{1-\exp(-T/\tau_1)}{(T/\tau_1)}\right) + \beta_2\left(\frac{1-\exp(-T/\tau_1)}{(T/\tau_1)} - \exp(-T/\tau_1)\right)$$
$$+\beta_3\left(\frac{1-\exp(-T/\tau_2)}{(T/\tau_2)} - \exp(-T/\tau_2)\right).$$

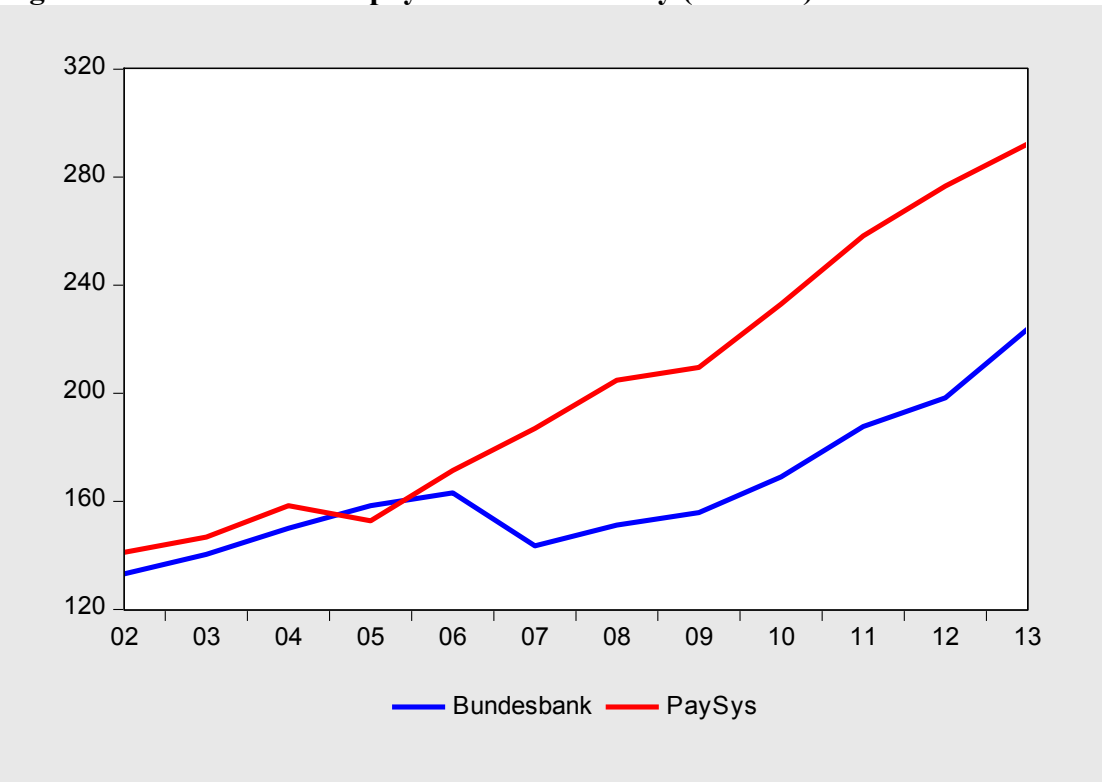
Here, $i(T, \beta)$ denotes the interest rate for maturity T as a function of the parameter vector β. $\beta_0, \beta_1, \beta_2, \beta_3, \tau_1, \tau_2$ are the parameters to be estimated. We include β_0 as a measure of the complete interest range into the analysis (*int*). It may be interpreted as a shift parameter to represent the generally prevailing interest rate level. An increase in this parameter means that the entire interest range shifts upwards.

Closely related to opportunity costs of holding banknotes are **alternative payment media**. In addition to the pressure from existing means of payment (eg, debit and credit cards), cash faces increasing competition from new payment instruments, such as contactless payment facilities in retail trade, new payment procedures for internet purchases and the use of mobile phones.[8] While new payment opportunities may reduce the use of cash, their overall distribution is still negligible. Moreover, they will also compete with existing non-cash payment procedures. We therefore refrain from including a variable for these innovative means of payment.[9] Deutsche Bundesbank (2015) investigates how payment behaviour in Germany has changed in recent years. This study is based on survey data. According to the study, individuals use cash for 53% of total expenditure (excluding regularly recurring payments such as rent). From 2008 to 2011 this share has fallen from 58% to 53%, but stayed constant since that time. Debit cards are still the most commonly used cashless payment instrument. Their share in terms of turnover is more than 29%. While cash is still the preferred method of payment for small purchases, cashless payments are mainly used to pay for high-value items. In principle, one would expect a negative impact on currency demand from card payments given that bank and credit cards provide a substitute for cash payments. For example, Amromin and Chakravorti (2009) find evidence that the demand for low denomination notes OECD countries decreases with increasing debit card usage. However, payment cards are also used to withdraw money from ATMs and could thus increase currency in circulation. As a result, the effect of cashless payment media on currency demand is ambiguous.

[8] An overview of innovative payment instruments can be found in Deutsche Bundesbank (2012).
[9] Generally, a time trend could be used as a crude proxy for the process of financial innovation.

In order to capture cashless payments, we use the volume of card payments (*cards*). However, this measure is only available on an annual basis. For our analysis we convert it to a quarterly frequency using the quadratic (match sum) method. There is one further difficulty with payment card data published by the Eurosystem. The Bundesbank which publishes the data for Germany in its payment statistics has changed its collecting methodology in 2007. After this date the Bundesbank collects its data from the issuing banks instead of using the overall data of the payment card schemes (PaySys, 2015). Consequently, there is a sharp decline of reported payment cards volumes for Germany (see figure 11). This decline is not related to actual developments in the market. The poor quality of this data set might be responsible for Bartzsch et al's (2015) result that card payments do not influence the demand for "German" notes. Therefore, we use an alternative time series published by PaySys which is based on national and international (Visa, Master) card schemes. Figure 11 shows the difference between the two which amounts to 57bn € in 2013, which is 20% of the market (PaySys, 2015, p 5).

Figure 11: Volume of card payments in Germany (€ billion)



Source: Deutsche Bundesbank, PaySys.

Shadow economy transactions are often undertaken in the form of cash due to their anonymity (Schneider, 2002). A rise in the size of the shadow economy should therefore

increase the demand for currency. We proxy this influence by taking into account the share of the shadow economy in GDP.[10] However, this variable is not directly observable and can only be estimated with considerable uncertainty. Therefore, we also use a variable that may cause hidden economy transactions. The unemployment rate is expected to have a positive impact on the shadow economy (and thus on currency demand) since a high unemployment rate encourages people to work "underground".

The cumulated net issuance of euro banknotes put into circulation by the Bundesbank differs considerably from the domestic holdings of banknotes. Due to large inflows and outflows between countries, net issuance may systematically differ from the demand for cash within the economy. The foreign demand for banknotes issued in Germany can be divided in two groups: first, there is **the demand for German banknotes resulting from residents of other euro-area countries**. This is because German banknotes are perfect substitutes for other euro-area national issuances. In other words, the demand for cash in one euro-area country may be satisfied in part by inflows of cash coming from another member state. The transaction related part of this foreign demand is taken into account via house prices (*house*) and real private consumption (*diff_pc*) in the euro area without Germany in each case. The former are likely to be a good proxy for the preference for cash payments, as real property purchases are often made in cash. The ECB house price indicator for the euro area excluding Germany is chosen as the variable for capturing this effect. **The second category of foreign demand is demand from outside the euro area**. As shown in section 3, a significant portion of the demand for German euro banknotes stems from outside the currency union. In the absence of a variable which directly indicates this demand from many different foreign countries, we proxy it with the euro exchange rate (see also Fischer et al, 2004; Seitz, 1995). An appreciating euro should be associated with a higher attractiveness and thus a higher euro demand from non-euro-area countries. As mentioned in section 3, those euro banknotes in circulation outside the euro area are presumably held, first and foremost, for hoarding purposes, ie utilised as a store of value. We use the real effective external value of the euro vis-à-vis the 12 as well as vis-à-vis the 20 most important trading partners (*er12* and *er20*).

It is implausible to assume that the coefficients of the variables determining the demand for banknotes are the same for all denominations. For example, the transaction motive should be more important for small and medium-value banknotes. By contrast, store of wealth

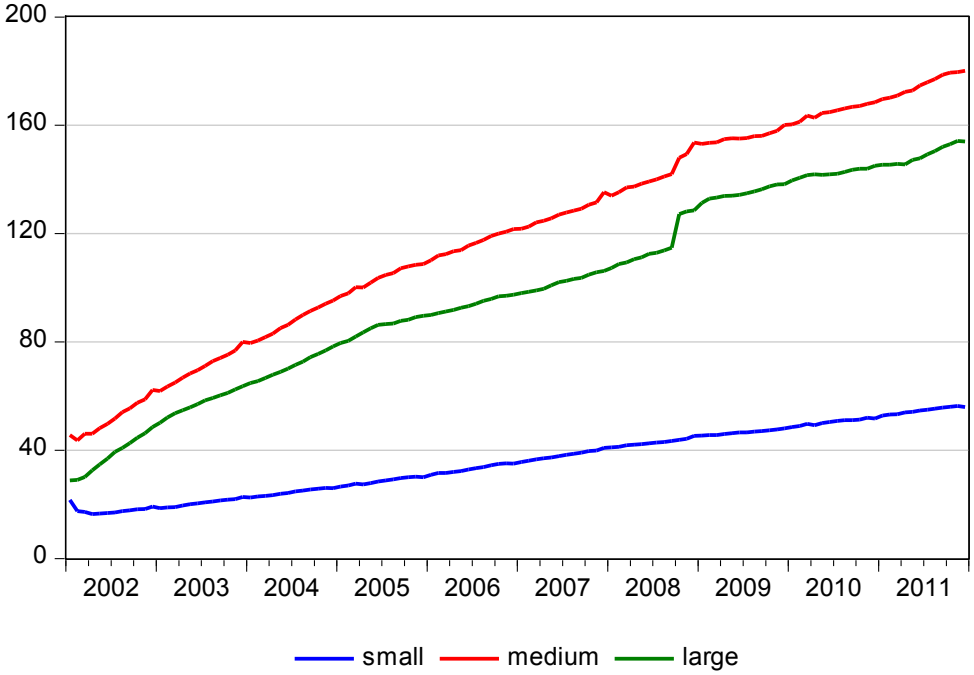
[10] We thank Friedrich Schneider for the provision of this time series on shadow economic activities in Germany. Since this time series has a yearly frequency, we converted it to a quarterly frequency using the quadratic (match average) method.

considerations may dominate with respect to high-value banknotes. At the same time, substitution effects may exist between banknotes of similar value. Therefore, we estimate three separate relations, one for small (*small*), one for medium (*medium*) and one for large (*large*) denominations. Our preferred classification is €5 - €20 for "small" notes, €50 - €100 for "medium" notes and €200 - €500 for "large" notes. This classification is chosen because large notes are not distributed by ATMs, which primarily serve to "top up" transaction balances.[11] Moreover, the €50 banknote should be the smallest denomination that is used (amongst other things) for hoarding purposes. We estimate specifications in real terms (*r*). This means that we assume long-run price homogeneity to hold. For the *small* and *medium* categories we choose the price index of domestic cash consumption of households as price deflator and for the *large* category we use the price index of domestic consumption expenditures of households.[12] The data are quarterly and (if necessary) seasonally adjusted (*sa*). Our sample covers the period from the first quarter of 2002 to the fourth quarter of 2011. In our view, the inclusion of data from 2012 and 2013 would not have a substantial impact on the results. Therefore, we have not updated our dataset. When using interest rates, we work with a semi-log specification. All other variables are in logarithms. The difference operator "d(…)" refers to the first (quarterly) difference. The three cash variables are shown in figure 12.

[11] For a similar classification scheme to isolate transactional and store of wealth roles of currency in a multi-country study, see Amromin and Chakravorti (2009). They select the medium-note category by determining which denomination is prevalently distributed by ATMs. Denominations above this threshold are categorised as "large" while those below this threshold are categorised as "small".

[12] Taking the price index of domestic cash consumption of households as a deflator for the large category does not change the results.

Figure 9: Small, medium and large value denominations, in real terms (€ billion)



Source: Deutsche Bundesbank.

5 Estimating the demand for banknotes

Our empirical approach relies on vector error correction models. We use two kinds of unit root tests: the augmented Dickey-Fuller test (ADF) and the Zivot-Andrews test. In both of these tests the null hypothesis is that the series has a unit root, ie is I(1) in levels and I(0) in first differences. We employ the Zivot-Andrews test when we presume structural breaks. For example, owing to the financial crisis there is a break in the intercept at the end of 2008 in *mediumr* and *larger* (see figure 12). Table 1 shows the results of the unit root tests for the variables that we employ in our final specifications.

As expected, the value of small denomination banknotes in circulation (*smallr_sa*), the real effective exchange rates (*er20*, *er12*), card payments and cash consumption (*ccr_sa*) are unambiguously I(1). The Zivot-Andrews test indicates that the medium and large denominations (*mediumr_sa, larger_sa*) are trend-stationary. However, we assume that they are difference-stationary. Firstly, this is in line with the usual empirical specification. Secondly, the reliability of our unit root tests is impaired owing to the short sample. Finally, and as is well known, the power of the tests is in general low if the process is (trend) stationary but with a root close to the non-stationary boundary. Moreover, we consider the house price indicator (*house*) and private consumption in the rest of the euro area

(*diff_pcr_sa*) to be I(1) instead of I(2) as the tests, which indicate that these series are I(2), are biased owing to the financial crisis.[13]

Table 1: Unit root tests

	ADF test statistic	Test specification[a)]	Zivot-Andrews test statistic	Test specification[b)]	Conclusion
smallr_sa	-2.26	C, T, 5			I(1)
d(*smallr_sa*)	-7.11***	C, 2			
mediumr_sa			-6.50***	C, 2	I(1) instead of trend-stationary
larger_sa			-8.53***	C, 1	I(1) instead of trend-stationary
ccr_sa	-2.66	C, T, 0			I(1)
d(*ccr_sa*)	-6.97***	C, 0			
int	-1.55	C, T, 6			I(1)
d(*int*)	-2.90*	C, 6			
er20	-2.87*	C, 0			I(1)
d(*er20*)	-4.61***	0			
er12	-2.72*	C, 0			I(1)
d(*er12*)	-4.35***	0			
cards	0.96	C, 5			I(1)
d*(cards)*	-3.71***	C, 0			
cards(trend)	-2.02**	0			I(0)
house			-4.17	C and T, 1	I(1) instead of I(2)
d(*house*)			-3.22	C, 2	
d^2(*house*)			-8.55***	C, 2	
diff_pcr_sa			-3.57	C and T, 1	I(1) instead of I(2)[c)]
d(*diff_pcr_sa*)			-3.72	C, 0	
d^2(*diff_pcr_sa*)			-7.73***	C, 0	

Notes: ***/ **/ *: significant at the 1, 5 and 10 per cent level, respectively. The ADF test refers to the critical values in MacKinnon (1996). The Zivot-Andrews test refers to the critical values in Andrews and Zivot (1992); *cards*(trend): deviation of *cards* from a Hodrick-Prescott trend. Sample: 2002 Q1 to 2011 Q4.
a) C: intercept, T: linear trend; 0, 1, 2, 3, …, 6: number of lags; lag selection based on (modified) Schwarz information criterion.
b) C: break in intercept, T: break in linear trend, C and T: break in intercept and linear trend; 0, 1, 2: number of lags

Source: Authors' own calculations.

Owing to the non-stationarity of the time series, the demand for the different denominations is estimated within a vector error correction model (VECM) based on the Johansen (1995,

[13] There is a "bump" in 2008 owing to the financial crisis, see the house price variable in figure 16.

2000) procedure. This approach seems to be particularly suitable for verifying the long-run equilibrium (cointegration) relationships on which the theoretical considerations are based.[14] The empirical analysis starts with an unrestricted VECM, which takes the following form:

$$(1) \qquad \mathrm{d}y_t = \mu + \Pi y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \mathrm{d}y_{t-i} + \mathrm{B}x_t + \varepsilon_t, \ t = 1,...,T,$$

where $\{y_t\}$ represents the vector of the endogenous I(1) variables. $\{\varepsilon_t\}$ denotes the vector of the independently and identically distributed residuals, B is the coefficient matrix of strictly exogenous (non-modelled) variables $\{x_t\}$, Γ is the coefficient matrix of the lagged endogenous variables and μ is the vector of constants. The number of cointegration relationships corresponds to the rank of the matrix Π. Granger's representation theorem asserts that if the coefficient matrix Π has reduced rank $r < n$, then there exist (nxr) matrices α (the loading coefficients or speed-of-adjustment parameters) and β (the cointegrating vectors) each with rank r (number of cointegration relations) such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is I(0). The cointegration vectors represent the long-term equilibrium relationships of the system. The loading coefficients denote the importance of these cointegration relationships in the individual equations and the speed of adjustment following deviations from long-term equilibrium.

Given the short sample with only 40 (quarterly) observations, the lag order (k) of the system is determined by the minimal lag order that is sufficient to eliminate autocorrelation of the residuals in the VECM. In any case, the chosen cointegration specification assumes an intercept both in the cointegrating equations and in the VAR. In other words, we assume that the level data $\{y_t\}$ have linear trends, but the cointegrating equations have only intercepts.

5.1 Structural model for the demand for small denomination notes

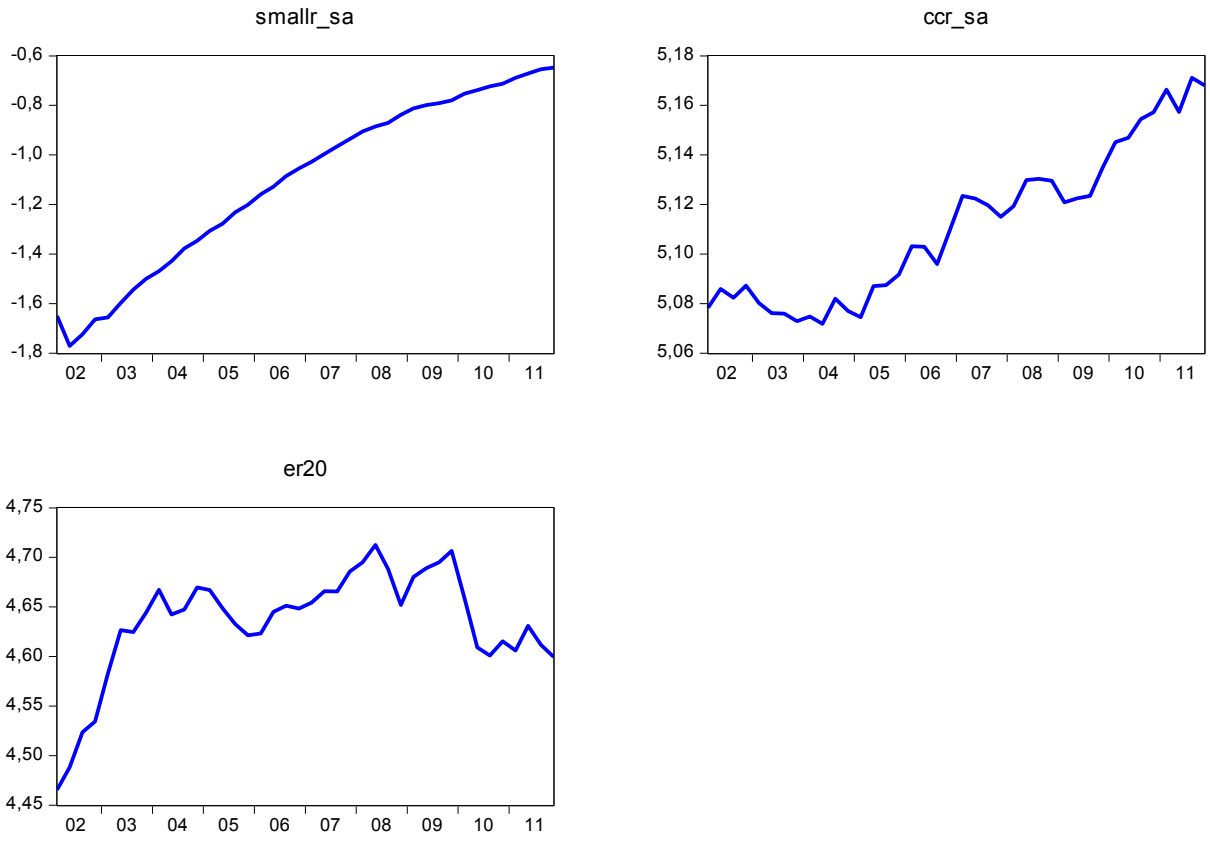
After pretesting, we select small denomination notes (*smallr_sa*), cash consumption (*ccr_sa*), and the effective exchange rate of the euro vis-à-vis the 20 most important trading partners (*er20*) to enter the cointegration space. These endogenous variables are shown in figure 13. As mentioned above, all of these variables have a stochastic trend, which is a necessary condition for the existence of cointegration relations. Furthermore, we add private consumption in the rest of the euro area (*diff_pcr_sa*) and the value of card payments (*cards*)

[14] Rao (2007) compares our chosen econometric method with others to distinguish between short-term and long-term relationships. He finds that there are often only minor differences in the estimates.

as exogenous, non-modelled variables to the system of equations. Other potential variables discussed in section 4 are insignificant. In line with Amromin and Chakravorti (2009) we find that the substitution effects with respect to card payments are confined to the demand for small denominations. The interest rate does not influence the demand for these denominations.

The chosen lag order to ensure white noise residuals is two in the VAR in levels, ie one in the corresponding VECM. This lag order is between that selected by different lag length information criteria (available upon request).

Figure 10: Endogenous variables of the VECM for small denomination banknotes



Sources: Deutsche Bundesbank and authors' own calculations.

The number of cointegration vectors is verified by determining the cointegration rank with the trace test and the maximum eigenvalue test (see table 2). These test statistics are subject to a small sample bias, which tends to reject the null of no cointegration too often. Therefore, we corrected them by the factor *(n-mk)/n*, where *n* is the number of observations, *m* the number of variables entering the cointegration space and *k* the number of lags, as suggested

by Reimers (1992).[15] However, the critical values of these tests disregard exogenous variables. Therefore, we use the critical values of MacKinnon et al (1999) who suggest a correction according to the number of exogenous I(1) variables. The tests yield unambiguous results. Both the trace test as well as the maximum eigenvalue test indicate one cointegration relationship.

Table 2: Cointegration rank tests

Number of cointegrating relationships	0		1		2	
	ts	cv	ts	cv	ts	cv
Trace test	45.6*	39.6	16.6	23.6	7.3	11.4
Max-eigenvalue test	28.9*	24.9	9.3	18.4	7.3	14.4

* Denotes rejection of the hypothesis at the 0.05 level. ts: small sample (Reimers, 1992) as well as exogenous I(1)-variables (MacKinnon et al, 1999) adjusted test statistic; cv: 0.05 level critical value.

Source: Authors' own calculations.

Table 3: Estimates and diagnostic test results of the VECM for small denominations

	Cointegrating equation
smallr_sa(-1)	1.00
ccr_sa(-1)	-8.9 (-20.2)
er20(-1)	-3.1 (-15.0)
constant	61.1
error correction term	-0.17 (-3.9)
constant	0.04 (8.2)
cards	-0.2 (-1.7)
d(*diff_pcr_sa*)	0.004 (4.5)
adj. R^2	0.73
s.e.	0.02
F-statistic	19.0
AIC	-4.9
SC	-4.6
LM (1) [p-value]	19.4 [0.02]
LM (4) [p-value]	4.4 [0.88]
JB [p-value]	1.22 [0.98]

Notes: t-statistics in ( ); JB: Jarque-Bera VEC residual joint normality test; LM (.): VEC residual serial correlation LM Tests of lag (.); s.e.: standard error of equation; AIC (SC): Akaike (Schwarz) information criterion.

Source: Authors' own calculations.

Table 3 displays the estimation results of the VECM. The long-run determinants and the short-run coefficients of the exogenous variables are displayed together with the error correction term. We do not show the equations for the other endogenous variables (real cash

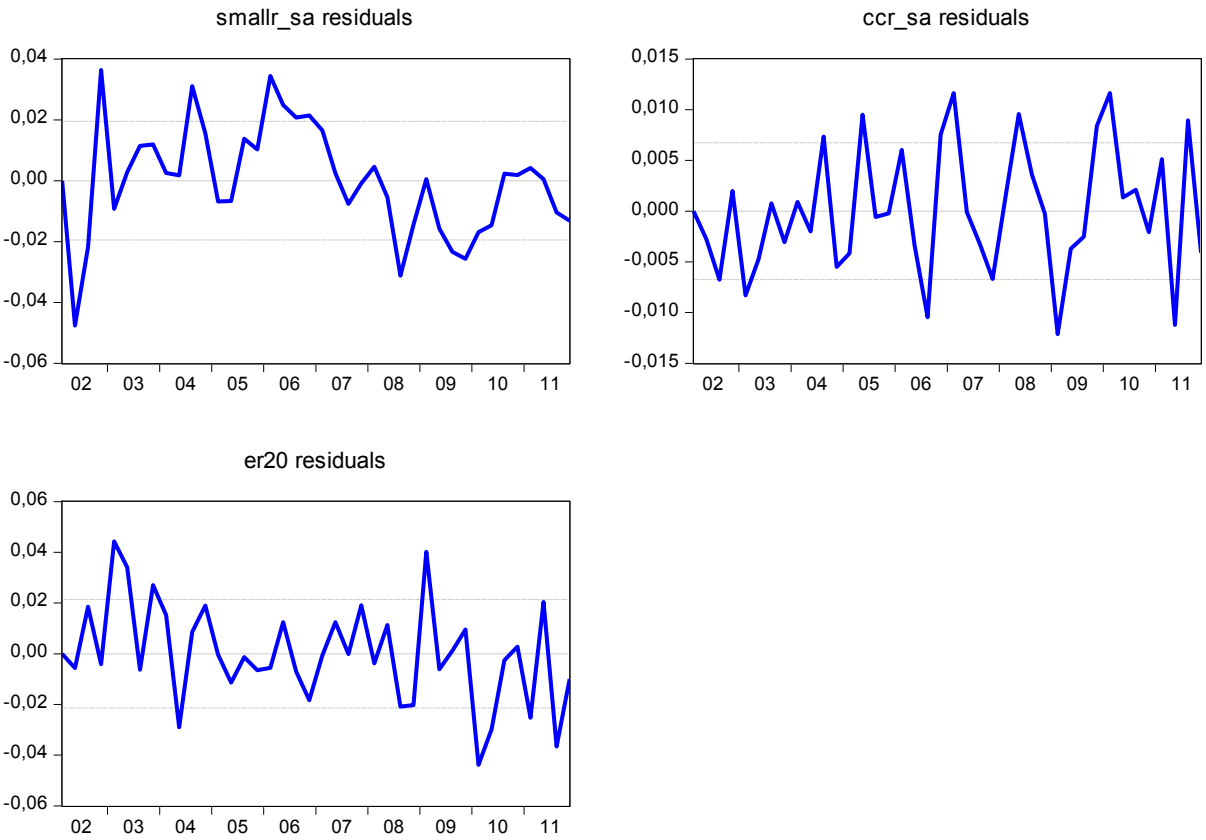
[15] An alternative would be to adjust the critical values, see Cheung and Lai (1993). As they use an analogous correction to that of Reimers (1992), the results are in any case qualitatively the same.

consumption and the real effective exchange rate) and the short-run coefficients of the lagged endogenous variables. The signs in the cointegrating equation are as expected: the demand for small banknotes rises when cash consumption and the exchange rate increase. Thus, the small denominations are mainly driven by domestic transactions and foreign demand outside the euro area in the long run. The high coefficient of cash consumption indicates that it was obviously not possible to adequately model certain determinants of cash holdings. The speed-of-adjustment parameter (*ect*) states how much of an existing disequilibrium is reduced within one quarter. Here, about 17% of the imbalance is corrected in one quarter. Cash consumption and the exchange rate are weakly exogenous which means that only cash adjusts to disequlibria. Therefore, the cointegration equation in table 3 can be interpreted as a banknote demand function. While the cointegrating relation catches the demand for small denominations in Germany and outside the euro area, the transaction motive in the rest of the euro area is part of the short-run dynamics. This motive is proxied by the (stationary transformed) seasonally adjusted real private consumption in the rest of the euro area. Its (positive) coefficient is highly significant with a t-value of 4.5. This is in line with the considerable issuance of €5 notes and €10 notes (typical transaction denominations) by the Deutsche Bundesbank. As shown in figures 7 and 8, for both of these denominations the cumulated net issuance of the Bundesbank clearly exceeds that of the Eurosystem without Germany. This is evidence that there are significant (net) exports of small denomination banknotes from Germany to the rest of the euro area. Moreover, the non-cash alternatives in the form of card payments enter the short-run dynamics with a significant negative sign, ie a substitution relationship is detected. The stationarity of this variable is generated via calculation of deviation from a trend (estimated by a Hodrick-Prescott filter). This means that only developments which differ from trend have repercussions on the demand for small banknotes.

The statistical fit of the equation is satisfactory with an adjusted R^2 of 73%. The Jarque Bera test statistic indicates normality of the residuals in the VECM. According to the LM test, the residuals are uncorrelated from lag 2 to 4 with some minor problems at lag 1. Figure 14 depicts the short-run error sequences, ie the estimated $\{\varepsilon_t\}$ series that equals the residuals in equation (1). By and large, they approximate a white noise process. Figure 15 shows the cointegration equation, ie the deviations of *smallr_sa* from the long-run relationship. Visual inspection of this long-run error series reveals its theoretical desired property in that the residuals from the long-run equilibrium appear to be stationary. This is also the case in

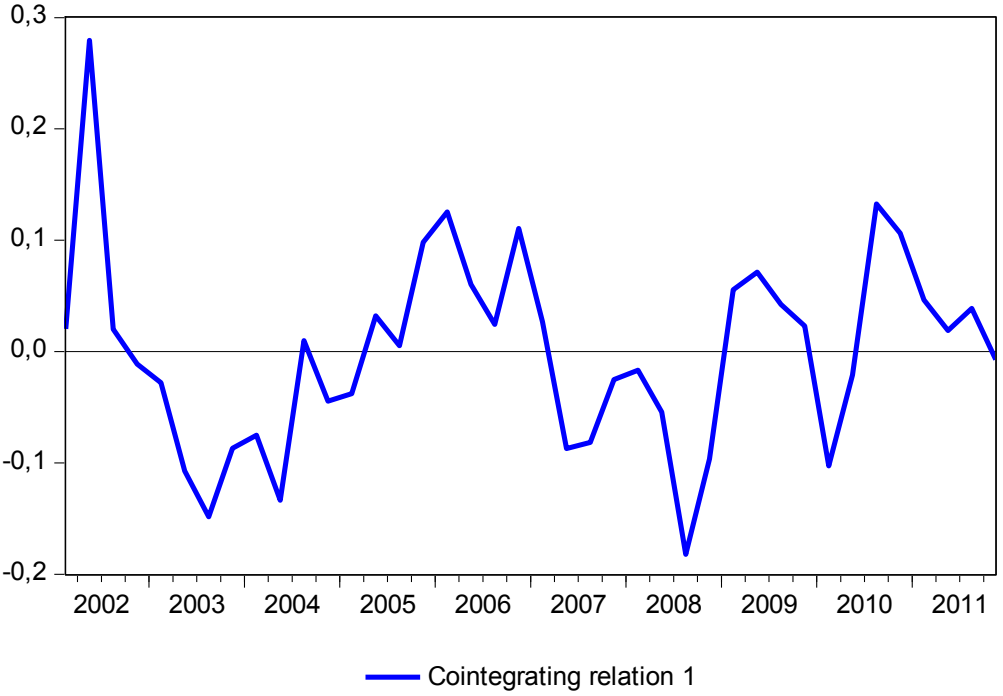
Bartzsch et al. (2015) who do not take card payments into account due to data problems. In view of the short sample of only 40 quarterly observations, we cannot employ valid tests of parameter stability. However, we have estimated the VECM for alternative samples ending in different quarters of 2011. This procedure suggests no significant changes of the cointegrating equation and the speed-of-adjustment coefficient.

Figure 11: Short-run error sequences



Source: Authors' own calculations.

Figure12: Long-run error series



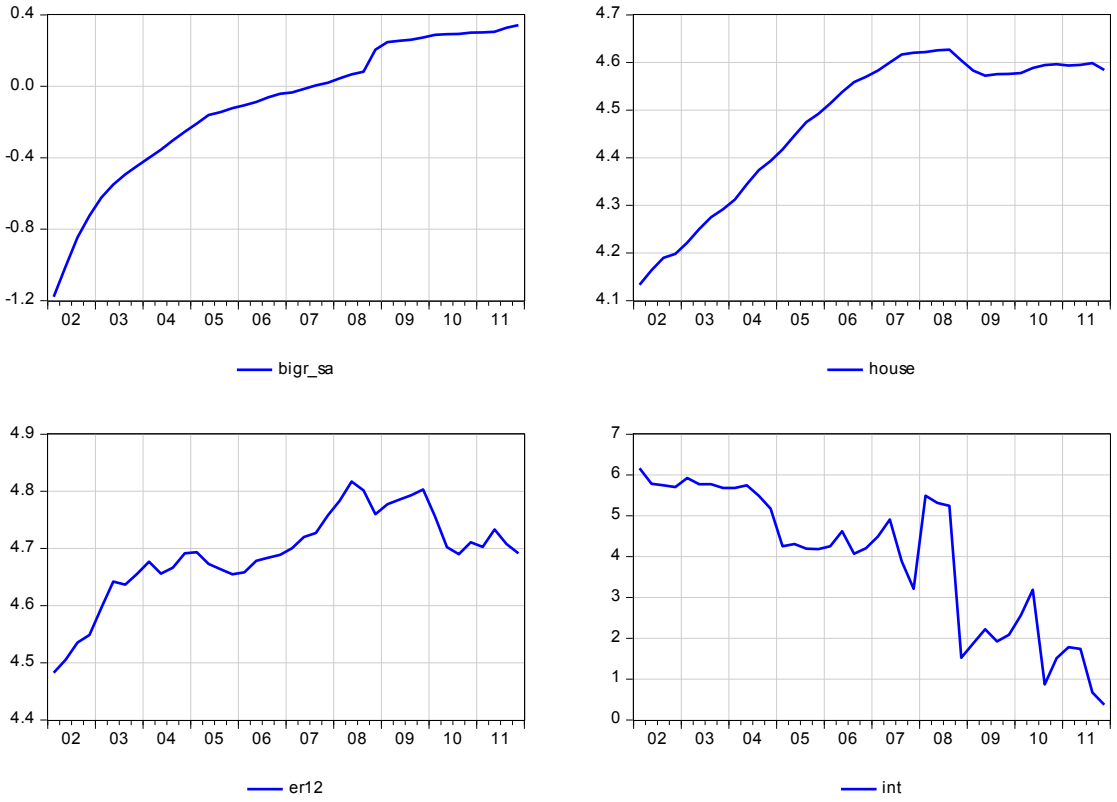
Source: Authors' own calculations.

5.2 Structural model for the demand for large denomination notes

The following variables enter the cointegrating space: large denominations (*larger_sa*), euro-area house prices outside Germany (*house*), the real effective external value of the euro vis-à-vis the 12 most important trading partners (*er12*) and the term structure parameter (*int*). These endogenous variables are shown in figure 16. Furthermore, we add the following strictly exogenous variables to the system of equations: a dummy variable for the onset of the financial crises in the fourth quarter of 2008, *d2008q4*, and a dummy variable for the public debt crisis in the euro area that began in the first quarter of 2010, *d_debt2010q1*. The latter variable should capture the public debt crisis related increase in the demand for large denominations. Other potential exogenous variables are insignificant.

The lag order (k) of the system is again determined by the minimal lag order that is sufficient to eliminate autocorrelation of the residuals in the VECM. The chosen lag order is two for the VAR in levels, ie one in the corresponding VECM. This is also the lag order suggested by the Hannan-Quinn information criterion (result available upon request).

Figure 13: Endogenous variables of the VECM for large denomination banknotes



Source: Deutsche Bundesbank and authors' own calculations.

The results of the trace and maximum eigenvalue test on the number of cointegration vectors are shown in table 4. Again we small-sample adjust the test statistics according to Reimers (1992). Both tests suggest one cointegration relationship. The critical values assume no deterministic exogenous series and this assumption is violated in our case. However, given the unambiguousness of the test results, we should be on the safe side in restricting the *VECM* to one cointegration relationship.[16]

Table 4: Cointegration rank tests

Number of cointegrating relationships	0		1		2		3	
	ts	**cv**	**ts**	**cv**	**ts**	**cv**	**ts**	**cv**
Trace test	68.72*	47.86	23.30	29.80	10.46	15.49	0.35	3.84
Max-eigenvalue test	45.42*	27.58	12.84	21.13	10.10	14.26	0.34	3.84

* Denotes rejection of the hypothesis at the 0.05 level. ts: small sample adjusted test statistic according to Reimers (1992), cv: 0.05 level critical value.

Source: Authors' own calculations.

[16] The sensitivity of the critical values in cointegration tests with respect to the deterministic specification (trend assumption) might be regarded as a benchmark here. See table 1 on p 276 in MacKinnon (1991).

Table 5: Estimates and diagnostic test results of the VECM for large denominations

	Cointegrating Equation
larger_sa(-1)	1.000
house(-1)	-0.82 (-7.9)
er12(-1)	-2.03 (-10.7)
int(-1)	0.09 (8.8)
constant	12.9
error correction term	-0.48 (-5.0)
constant	-0.02 (-1.4)
d2008q4	0.10 (2.5)
d_debt2010q1	0.03 (1.6)
adj. R^2	0.61
s.e.	0.039
F-statistic	9.79
AIC	-3.47
SC	-3.13
LM (1) [p-value]	21.38 [0.16]
LM (4) [p-value]	20.26 [0.21]
JB [p-value]	28.38 [0.00]

Notes: t-statistics in ( ); JB: Jarque-Bera VEC residual joint normality test; LM (.): VEC residual serial correlation LM Tests of lag (.); s.e.: standard error of equation; AIC (SC): Akaike (Schwarz) information criterion.

Source: Authors' own calculations.

Table 5 displays the estimation results of the VECM. Again we only show the equation for banknotes without the short-run coefficients of the lagged endogenous variables. The signs in the cointegrating equation are as expected: the demand for large denomination banknotes rises when house prices in the rest of the euro area and the exchange rate increase and it declines when interest rates increase. It seems that the large denomination notes in circulation are mainly driven by foreign demand in the long run. The interest rate semi-elasticity is fairly low. If the whole spectrum of yields rises by one percentage point, the growth rate of large denomination banknotes declines by only 0.09 percentages. In the case of large denominations, about 50% of the imbalance is corrected in one quarter. While the real effective exchange rate is weakly exogenous, the speed-of-adjustment parameter in the equation for the house price indicator is highly significant and in the equation for interest rates it is marginally significant (p-value of 0.051). However, the adjustments of house prices and interest rates to deviations from the cointegrating relation lack a convincing economic explanation and they hardly affect the equation for big banknote denominations in the system.[17] Therefore, we interpret the latter as a banknote demand equation within a system.

As mentioned, we also include two crises variables in the VECM as strictly exogenous variables. The escalation of the global financial crisis after the bankruptcy of Lehman

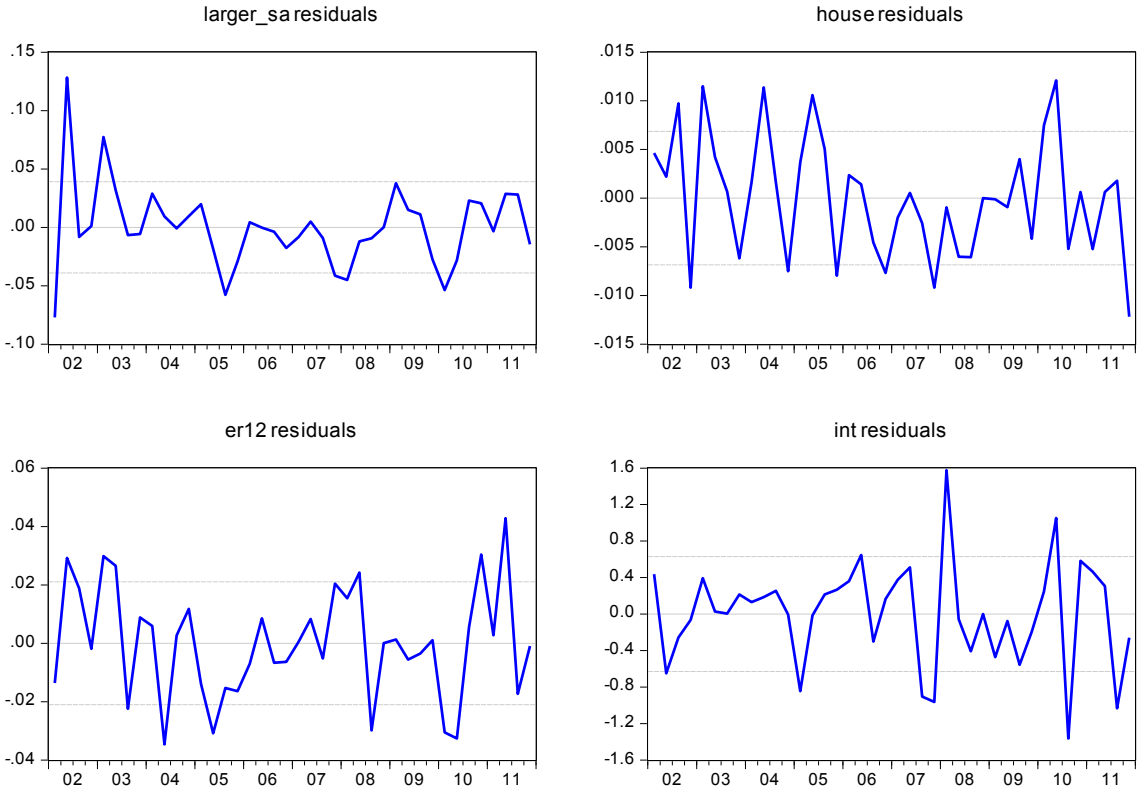
[17] In our context, it seems quite natural that only banknotes adjust to this deviation and not the other variables.

Brothers in September 2008 resulted in a sharp increase in the issuance of German large denomination notes (Deutsche Bundesbank, 2009, pp 52f). This is modelled by the dummy variable *d2008q4*. It is an impulse variable that takes the value one in the fourth quarter of 2008 and zero otherwise. In other words, the financial crisis is assumed to have resulted in a *one-time* increase in the *real* demand for large denominations. Economic crises in general go hand in hand with an increase in demand for large banknote denominations. Therefore, we also try to model the repercussions of the European public debt crisis which started at the beginning of 2010. The corresponding dummy variable *d_debt2010q1* is a shift variable. It is equal to one from the first quarter of 2010 to the end of the sample and zero in all other quarters. This corresponds to a continuously increasing *level* of (real) banknote demand. While having the right positive sign, the coefficient of *d_debt2010q1* is only marginally significant. However, the estimated coefficients of the VECM are robust with regard to the inclusion or omission of *d_debt2010q1*.

The statistical fit of the system of equations is rather good with an adjusted R^2 of 61%. There is no indication of autocorrelation of residuals up to lag 4. However, the Jarque Bera test statistic indicates non-normality of the residuals in the VECM. As cointegration theory is asymptotically valid under the assumption of independently and identically distributed residuals, this result should not be too serious a problem. Figure 17 depicts the short-run error sequences, ie the estimated $\{\varepsilon_t\}$ series (residuals) in equation (1). By and large, they approximate a white noise process. Figure 18 shows deviations of actual banknote developments from the long-run relationship. This long-run error series also appears to be stationary.

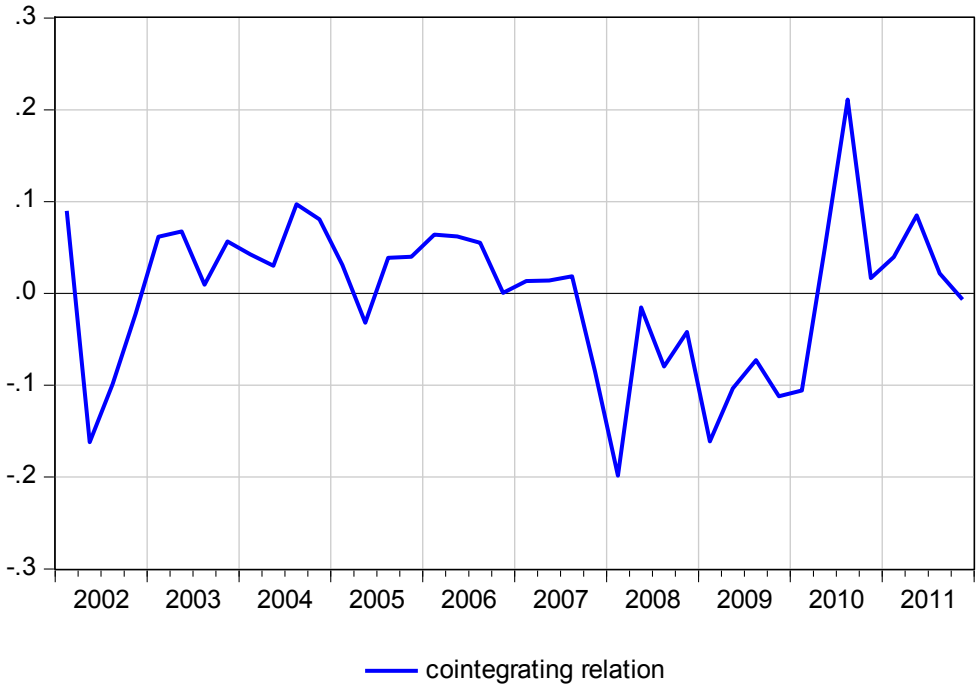
Once again we have estimated the VECM for alternative samples ending in different quarters of 2011 to get an idea of potential instabilities. Visual inspection suggests no significant changes of the cointegrating equation and the speed-of-adjustment coefficient.

Figure 14: Short-run error sequences



Source: Authors' own calculations.

Figure 15: Long-run error series



Source: Authors' own calculations.

5.3 A single-equation model for medium denominations

We do not succeed in modelling the medium denominations within a VECM. Therefore, we rely on a single equation approach for this denomination category.[18] To be more specific, we estimate a banknote demand equation with Dynamic OLS (DOLS). This method generates an asymptotically efficient estimator that eliminates the feedback in the cointegrating system (see, eg, Saikkonen, 1992; Stock & Watson, 1993). It involves augmenting the cointegrating regression with lags and leads of stationary exogenous variables so that the resulting cointegrating equation error term is orthogonal to the entire history of the stochastic regressor innovations. In our case, the lags and leads are chosen by the Akaike criterion with a maximum lag (lead) of 4. The computation of the coefficient covariance matrix is done by rescaled OLS. In this procedure, the long-run variance of the DOLS residuals is estimated with the Bartlett kernel and a fixed Newey-West bandwidth of 4.

The cointegration equation is made up of real medium denominations (*mediumr_sa*), cash consumption (*ccr_sa*) and private consumption in the rest of the euro area (*diff_pcr_sa*). Exogenous variables added are the term structure parameter (*int*), the (change in the) unemployment rate (*un*) and a financial crisis dummy variable which is 1 in the fourth quarter of 2007 and zero otherwise (*d2017Q4*). Other variables, especially card payments, do not influence the demand for medium notes. The estimation results are shown in table 6. The transaction variables in Germany and in the rest of the euro area determine the evolution of medium notes in the long run. In line with theory, the elasticity with respect to domestic transactions is lower than that of small denominations (see table 3). The short-run dynamics are governed by opportunity costs measured by interest rates and the unemployment rate: an increase in the whole spectrum of yields decreases the demand for medium notes whereas rising unemployment leads to higher banknote demand. This is in line with a shadow economic interpretation. The statistical properties of the estimation are satisfactory. Only the Engle-Granger test of cointegration points to some minor stability problems, whereas the Hansen stability test indicates stability of the cointegration relation. Figure 19 shows the residuals of the estimated equation

[18] Bartzsch et al (2015) proceed in presenting times series models for these denominations (€50, €100) which are used by the Deutsche Bundesbank within the scope of the annual banknote production planning in the Eurosystem.

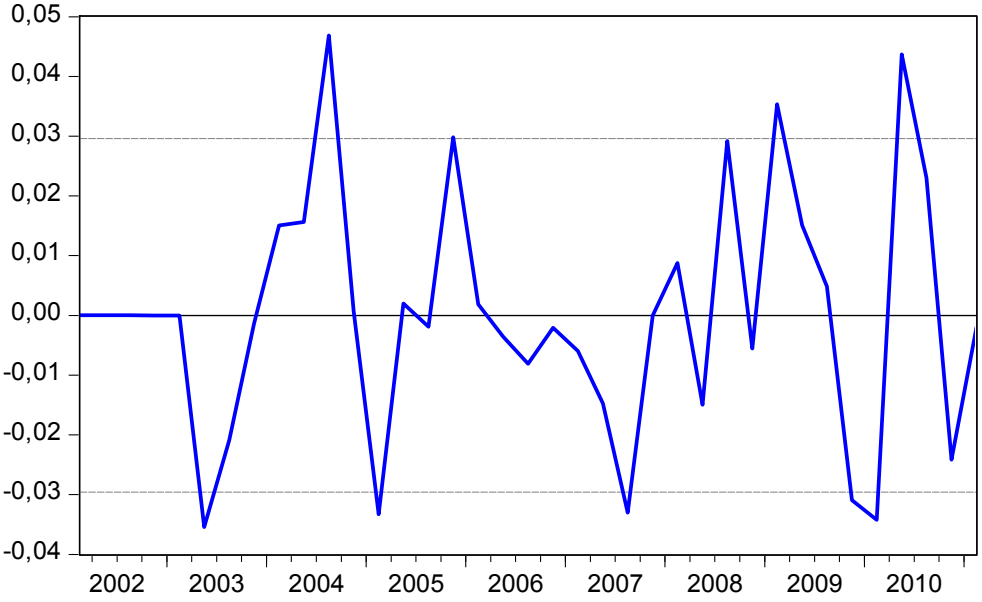
Table 6: Estimates and diagnostic test statistics of the DOLS equation for medium denominations

Variable	Coefficient
ccr_sa	2.8 (3.2)
diff_pcr_sa	5.0 (11.4)
C	-47.9 (-11.3
int	-0.03 (-2.7)
d(un)	1.0 (3.4)
D2007Q4	-0.1 (-1.7)
adj. R^2	0.99
s.e.	0.03
long-run variance	0.0009
JB [p-value]	0.49 [0.78]
Hansen [p-value]	0.07 [>0.2]
EG [p-value]	-3.47 [0.13]

Notes: t-statistics in ( ); JB: Jarque-Bera residual normality test; s.e.: standard error of equation; Hansen: Hansen parameter instability cointegration test; EG: Engle-Granger cointegration test with automatic lag selection according to Schwarz criterion.

Source: Authors' own calculations.

Figure 19: The cointegration relation for medium denominations



Source: Authors' own calculations.

6 Summary and conclusions

In this paper, we analysed the cumulated net issuance of euro banknotes by the Deutsche Bundesbank ("German" euro notes in circulation). The strong growth in German euro notes in contrast to the weak increase in other euro-area countries can be explained as follows.

Firstly, the dynamics of euro notes are, to a large extent, driven by demand from outside the euro area and this demand is predominantly met by Germany. Secondly, Germany is also an important net exporter of euro notes to other euro-area countries. However, the lion's share of foreign holdings is in non-euro-area countries.

The importance of foreign demand is reflected in the vector error correction models, which we estimate using genuine euro data up to the end of 2011. It seems that the demand for small denominations is mainly driven by domestic transactions and foreign demand from outside the euro area in the long run. Card payments as alternative means of payment influence the short-run dynamics. The transaction motive in the rest of the euro area (without Germany) is also part of the short-term dynamics. This is in line with the fact that the cumulated net issuance of €5 notes and €10 notes by the Deutsche Bundesbank exceeds that of the Eurosystem. The cointegrating equation for the large denominations reveals that the demand for these denominations rises due to foreign demand from other euro area countries and from outside the euro area and it declines with increasing interest rates. The effect of the escalation of the global financial crisis after the bankruptcy of the US investment bank Lehman Brothers in September 2008 and the euro area public debt crisis also exert a significant influence. The medium denominations which could only be modelled within a single-equation approach, are driven by domestic transactions and foreign demand from other euro area countries in the long run. Interest rates and the unemployment rate are only important in the short run.

Card payments do not exert any influence on the demand for medium and large denominations. Their influence is limited to small denominations. This is in line with the literature. This might also be due to the dominance of other the factors, especially foreign demand, poor data quality and the small sample considered.

With the reservation of the small sample period, the vector error correction models seem to be rather stable. In line with the low or even missing interest rate (semi-)elasticities, we do not expect significant portfolio shifts into cash owing to the currently very low level of interest rates. This is confirmed by financial accounts data on the acquisition of financial assets in Germany (until the end of 2014). By contrast, the declining value of the euro exchange rate since 2014 due to the unconventional monetary policy measures by the Eurosystem should exert a significant negative effect on the demand for banknotes.

Bibliography

Akinci, Ö (2003), Modeling the demand for currency issued in Turkey, *Central Bank Review*, 3, pp 1-25.

Alvarez, F E & F Lippi (2007), Financial innovation and the transactions demand for cash, *CEPR Discussion Paper* 6472.

Amromin, G & S Chakravorti (2009), Whither loose change? The diminishing demand for small denomination currency, *Journal of Money, Credit and Banking*, 41, pp 315-335.

Andrews, D W K & E Zivot (1992), Further evidence on the great crash, the oil price shock and the unit root hypothesis, *Journal of Business and Economic Statistics*, 10, pp 251-70.

Bartzsch, N, G Rösl & F Seitz (2011a), Foreign demand for euro banknotes issued in Germany: Estimation using indirect approaches, *Deutsche Bundesbank Discussion Paper*, Series 1, 21/2011.

Bartzsch, N, G Rösl & F Seitz (2011b), Foreign demand for euro banknotes issued in Germany: Estimation using direct approaches, *Deutsche Bundesbank Discussion Paper*, Series 1, 20/2011.

Bartzsch, N, R Setzer & F Seitz (2015), The demand for euro banknotes issued in Germany: Structural modelling and forecasting, *MPRA Paper* No. 64949, June

Baumol, W J (1952), The transactions demand for cash: an inventory theoretic approach, *Quarterly Journal of Economics*, 66, pp 545-556.

Boeschoten, W C (1992), Currency use and payments patterns, Kluwer Academic Publishers, Dordrecht.

Briglevics, T & S Schuh (2014), U.S. consumer demand for cash in the era of low interest rates and electronic payments, *ECB Working Paper* 1660.

Cheung, Y-W & K S Lai (1993), Finite-sample sizes of Johansen's likelihood ratio tests for cointegration, *Oxford Bulletin of Economics and Statistics*, 55, pp 313-328.

Cusbert, T & T Rohling (2013), Currency demand during the global financial crisis: Evidence from Australia, Reserve Bank of Australia, *Research Discussion Paper* 2013-01.

Deutsche Bundesbank (1997), Estimating the term structure of interest rates, Monthly Report, October, pp 61-66.

Deutsche Bundesbank (2009), The development and determinants of euro currency in circulation in Germany, Monthly Report, June, pp 45-58.

Deutsche Bundesbank (2012), Innovations in payment systems, Monthly Report, September, pp 47-60.

Deutsche Bundesbank (2015), Payment behaviour in Germany in 2014 – Third study of the utilisation of cash and cashless payment instruments.

Deutsche Bundesbank (2013), Current and projected development of coin circulation in Germany, Monthly Report, January, pp 29-41.

Doyle, B M (2000), 'Here, Dollars, Dollars …' – Estimating currency demand and worldwide currency substitution, Board of Governors of the Federal Reserve System, *International Finance Discussion Papers* 657.

European Central Bank (2014), The international role of the euro, July.

Fischer, B, P Köhler & F Seitz (2004), The demand for euro area currencies: Past, present and future, *ECB Working Paper* 330.

Friedman, M (1977), Time perspective in demand for money, *Scandinavian Journal of Economics*, 79, pp 397-416.

Friedman, M & A J Schwartz (1982), The effect of the term structure of interest rates on the demand for money in the United States, *Journal of Political Economy*, 90 (1), pp 201-212.

Johansen, S (1995), Likelihood-based inference in cointegrated vector autoregressive models, Oxford University Press, Oxford, New York.

Johansen, S (2000), Modelling of cointegration in the vector autoregressive model, *Economic Modelling*, 17, pp 359-373.

Khamis, M & A Leone (2001), Can currency demand be stable under a financial crisis? The case of Mexico, *IMF Staff Papers* 48, pp 344-366.

MacKinnon, J G (1991), Critical values for cointegration tests, in Engle, R F and C W J Granger (eds.), *Long-run economic relationships: Readings in cointegration*, Oxford University Press, New York, pp 267-277.

MacKinnon, J G (1996), Numerical distribution functions for unit root and cointegration tests, *Journal of Applied Econometrics*, 11, pp 601-618.

MacKinnon, J G, A A Haug & L Michelis (1999), Numerical distribution functions of Likelihood Ratio tests for cointegration, *Journal of Applied Econometrics*, 14, pp. 563-577.

Nachane D M, A B Chakraborty, A K Mitra & S Bordoloi (2013), Modelling currency demand in India: An empirical study, *Reserve Bank of India Discussion Paper* 39.

Pagan, A (1984), Econometric issues in the analysis of regressions with generated regressors, *International Economic Review*, 25, pp. 221-247.

PaySys (2015), ECB card payment statistics: The missing 792 billions Euro, PaySys Report 02/2015, April, pp. 5-9.

Rao, B B (2007), Estimating short and long-run relationships: A guide for the applied economist, *Applied Economics*, 39, pp. 1613-1625.

Reimers, H-E (1992), Comparisons of tests for multivariate cointegration, *Statistical Papers*, 33, pp 335-359.

Schneider, F (2002), The size and development of the shadow economies of 22 transition and 21 OECD countries, *IZA Discussion Paper* 514.

Seitz, F (1995), The circulation of Deutsche Mark abroad, *Discussion Paper* 1/95, Economic Research Group of the Deutsche Bundesbank.

Seitz, F (1998), Geldnachfrage, Zinsen und Zinsstruktur ("Money demand, interest rates and the term structure"), *Konjunkturpolitik – Applied Economics Quarterly*, 44, pp 256-286.

Seitz, F & R Setzer (2009), The demand for German banknotes: Structural modelling and forecasting, *Discussion Paper*, mimeo.

Snellman, J & J Vesala (1999), Forecasting the electronification of payments with learning curves: The case of Finland, *Bank of Finland Discussion Paper* 8/99.

Snellman, J, J Vesala & D Humphrey (2000), Substitution of noncash payment instruments for cash in Europe, *Bank of Finland Discussion Paper* 1/2000.

Tobin, J (1956), The interest-elasticity of transactions demand for cash, *Review of Economics and Statistics*, 38, pp 241-247.

Bisher erschienene Weidener Diskussionspapiere

1 **“Warum gehen die Leute in die Fußballstadien? Eine empirische Analyse der Fußball-Bundesliga“**
von Horst Rottmann und Franz Seitz

2 **“Explaining the US Bond Yield Conundrum“**
von Harm Bandholz, Jörg Clostermann und Franz Seitz

3 **“Employment Effects of Innovation at the Firm Level”**
von Horst Rottmann und Stefan Lachenmaier

4 **“Financial Benefits of Business Process Management”**
von Helmut Pirzer, Christian Forstner, Wolfgang Kotschenreuther und Wolfgang Renninger

5 **“Die Performance Deutscher Aktienfonds”**
von Horst Rottmann und Thomas Franz

6 **“Bilanzzweck der öffentlichen Verwaltung im Kontext zu HGB, ISAS und IPSAS“**
von Bärbel Stein

7 **Fallstudie: “Pathologie der Organisation” – Fehlentwicklungen in Organisationen, ihre Bedeutung und Ansätze zur Vermeidung**
von Helmut Klein

8 **“Kürzung der Vorsorgeaufwendungen nach dem Jahressteuergesetz 2008 bei betrieblicher Altersversorgung für den GGF.”**
von Thomas Dommermuth

9 **“Zur Entwicklung von E-Learning an bayerischen Fachhochschulen- Auf dem Weg zum nachhaltigen Einsatz?”**
von Heribert Popp und Wolfgang Renninger

10 **“Wie viele ausländische Euro-Münzen fließen nach Deutschland?”**
von Dietrich Stoyan und Franz Seitz

11 **Modell zur Losgrößenoptimierung am Beispiel der Blechteilindustrie für Automobilzulieferer**
von Bärbel Stein und Christian Voith

12 **Performancemessung**
Theoretische Maße und empirische Umsetzung mit VBA
von Franz Seitz und Benjamin R. Auer

13 **Sovereign Wealth Funds – Size, Economic Effects and Policy Reactions**
von Thomas Jost

14 **The Polish Investor Compensation System Versus EU – 15 Systems and Model Solutions**
von Bogna Janik

15 **Controlling in virtuellen Unternehmen -eine Studie-**
Teil 1: State of the art
von Bärbel Stein, Alexander Herzner, Matthias Riedl

16 **Modell zur Ermittlung des Erhaltungsaufwandes von Kunst- und Kulturgütern in kommunalen Bilanzen**
von Bärbel Held

17 **Arbeitsmarktinstitutionen und die langfristige Entwicklung der Arbeitslosigkeit – Empirische Ergebnisse für 19 OECD-Länder**
von Horst Rottmann und Gebhard Flaig

18 **Controlling in virtuellen Unternehmen -eine Studie-**
Teil 2: Auswertung
von Bärbel Held, Alexander Herzner, Matthias Riedl

19 **DIAKONIE und DRG's –antagonistisch oder vereinbar?**
von Bärbel Held und Claus-Peter Held

20 **Traditionelle Budgetierung versus Beyond Budgeting-**
Darstellung und Wertung anhand eines Praxisbeispiels
von Bärbel Held

21 **Ein Factor Augmented Stepwise Probit Prognosemodell für den ifo-Geschäftserwartungsindex**
von Jörg Clostermann, Alexander Koch, Andreas Rees und Franz Seitz

22 **Bewertungsmodell der musealen Kunstgegenstände von Kommunen**
von Bärbel Held

23 **An Empirical Study on Paths of Creating Harmonious Corporate Culture**
von Lianke Song und Bernt Mayer

24 **A Micro Data Approach to the Identification of Credit Crunches**
von Timo Wollmershäuser und Horst Rottmann

25 **Strategies and possible directions to improve Technology Scouting in China**
von Wolfgang Renninger und Mirjam Riesemann

26 **Wohn-Riester-Konstruktion, Effizienz und Reformbedarf**
von Thomas Dommermuth

27 **Sorting on the Labour Market: A Literature Overview and Theoretical Framework**
von Stephan O. Hornig, Horst Rottmann und Rüdiger Wapler

28 **Der Beitrag der Kirche zur Demokratisierungsgestaltung der Wirtschaft**
von Bärbel Held

29 **Lebenslanges Lernen auf Basis Neurowissenschaftlicher Erkenntnisse -Schlussfolgerungen für Didaktik und Personalentwicklung-**
von Sarah Brückner und Bernt Mayer

30 **Currency Movements Within and Outside a Currency Union: The case of Germany and the euro area**
von Franz Seitz, Gerhard Rösl und Nikolaus Bartzsch

31 **Labour Market Institutions and Unemployment. An International Comparison**
von Horst Rottmann und Gebhard Flaig

32 **The Rule of the IMF in the European Debt Crisis**
von Franz Seitz und Thomas Jost

33 **Die Rolle monetärer Variablen für die Geldpolitik vor, während und nach der Krise: Nicht nur für die EWU geltende Überlegungen**
von Franz Seitz

34 **Managementansätze sozialer, ökologischer und ökonomischer Nachhaltigkeit: State of the Art**
von Alexander Herzner

35 **Is there a Friday the 13th effect in emerging Asian stock markets?**
von Benjamin R. Auer und Horst Rottmann

36 **Fiscal Policy During Business Cycles in Developing Countries: The Case of Africa**
von Willi Leibfritz und Horst Rottmann

37 **MONEY IN MODERN MACRO MODELS: A review of the arguments**
von Markus A. Schmidt und Franz Seitz

38 **Wie erzielen Unternehmen herausragende Serviceleistungen mit höheren Gewinnen?**
von Johann Strassl und Günter Schicker

39 **Let's Blame Germany for its Current Account Surplus!?**
von Thomas Jost

40 **Geldpolitik und Behavioural Finance**
von Franz Seitz

41 **Rechtliche Überlegungen zu den Euro-Rettungsschirmprogrammen und den jüngsten geldpolitischen Maßnahmen der EZB**
von Ralph Hirdina

42 **DO UNEMPLOYMENT BENEFITS AND EMPLOYMENT PROTECTION INFLUENCE SUICIDE MORTALITY? AN INTERNATIONAL PANEL DATA ANALYSIS**
von Horst Rottmann

43 **Die neuen europäischen Regeln zur Sanierung und Abwicklung von Kreditinstituten: Ordnungspolitisch und rechtlich angreifbar?**
von Ralph Hirdina

44 **Vermögensumverteilung in der Eurozone durch die EZB ohne rechtliche Legitimation?**
von Ralph Hirdina

45 **Die Haftung des Steuerzahlers für etwaige Verluste der EZB auf dem rechtlichen Prüfstand**
von Ralph Hirdina

46 **Die Frage nach dem Verhältnis von Nachhaltigkeit und Ökonomie**
von Alexander Herzner

47 **Giving ideas a chance - systematic development of services in manufacturing industry**
von Johann Strassl, Günter Schicker und Christian Grasser

48 **Risikoorientierte Kundenbewertung: Eine Fallstudie**
von Thorsten Hock

49 **Rechtliche Überlegungen zur Position der Sparer und institutionellen Anleger mit Blick auf die Niedrigzins- bzw. Negativzinspolitik der Europäischen Zentralbank**
von Ralph Hirdina

50 **Determinanten des Studienerfolgs: Eine empirische Untersuchung für die Studiengänge Maschinenbau, Medienproduktion und -technik sowie Umwelttechnik**
von Bernd Rager und Horst Rottmann

51 **Cash Holdings in Germany and the Demand for "German" Banknotes: What role for cashless payments**
von Nikolaus Bartzsch und Franz Seitz