

# Foreign demand for euro banknotes issued in Germany: estimation using indirect approaches

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Discussion Paper  
Series 1: Economic Studies  
No 21/2011

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ISBN 978-3-86558-742-8 (Printversion)

ISBN 978-3-86558-743-5 (Internetversion)

## **Abstract**

In this paper, we endeavour to determine the volume of euro banknotes issued by Germany that is in circulation outside Germany. In so doing, we draw a distinction between banknotes outstanding in non-euro-area countries and those that are in circulation in other euro-area countries. The analysis is based on approaches that estimate the volume of banknotes in circulation outside Germany indirectly. The observation period runs from 2002 to 2009. We discover that, at the end of 2009, a total of roughly two-thirds of Germany's cumulated net issuance of euro banknotes was in circulation outside Germany. The lion's share of roughly €160 billion was in non-euro-area countries, with the remaining €80 billion in other euro-area countries. Thus, the volume of German euro banknotes in circulation in Germany accounted for only roughly one-third of all banknotes issued by the Deutsche Bundesbank (€350 billion). This confirms the results of direct approaches.

### **Key words:**

Banknotes, euro, foreign demand, hoarding, transaction balances, domestic migration

### **JEL classification:**

E41, E42, E58

## **Non-technical summary**

The outstanding volume of euro banknotes issued by the Deutsche Bundesbank has increased sharply since the introduction of euro cash. However, this growth can be explained only in part by domestic demand for transaction balances or the accumulation of cash hoardings in Germany. The extraordinary marked expansion in the net issuance of banknotes by the Bundesbank since the introduction of the euro is more likely to be predominantly due to foreign demand. As a precise statistical recording of foreign demand is not possible, it is prudent to make corresponding estimates using a number of indirect methods, which exploit the different characteristics of domestic and foreign demand for banknotes. The basic concept, which is applied in several variants, is that Bundesbank-issued euro banknotes in circulation within and outside Germany have different determinants. By using a reference country where the foreign share of banknotes is small or non-existent, the approximate foreign share of “German” banknotes can be derived. These methods can also be regarded as a robustness test for direct estimation methods.

Surprisingly, the individual indirect approaches provide a fairly coherent picture regarding foreign demand for German euro banknotes. The share of euro banknotes in circulation outside Germany in the Bundesbank’s cumulated net issuance has increased significantly since 2002. At the end of 2009, it was estimated at just under 70%, with the majority in circulation in non-euro-area countries. The growth in the volume of German euro banknotes in circulation is therefore almost exclusively driven by foreign demand. By contrast, domestic transaction balances and cash hoardings are comparatively small. This picture is also broadly consistent with the results obtained using direct estimation methods.

## **Nicht-technische Zusammenfassung**

Der Umlauf der von der Deutschen Bundesbank emittierten Euro-Banknoten hat seit der Euro-Bargeldeinführung stark zugenommen, was aber über die inländische Nachfrage nach Transaktionskasse bzw. über den Aufbau von Hortungsbeständen im Inland nur teilweise erklärt werden kann. Vielmehr dürfte die außergewöhnlich deutliche Expansion der von der Bundesbank seit der Einführung des Euro netto ausgegebenen Banknoten ganz überwiegend auf die Auslandsnachfrage zurückzuführen sein. Da eine exakte statistische Erfassung des Auslandsumlaufts nicht möglich ist, ist es sinnvoll, mit einer Vielzahl von indirekten Methoden, die die unterschiedlichen Eigenschaften von Inlands- und Auslandsumlauft von Banknoten ausnutzen, entsprechende Schätzungen durchzuführen. Eine Grundidee, die dabei in mehreren Varianten angewandt wird, besteht darin, dass die von der Bundesbank begebenen Euro-Banknoten, die im Ausland und im Inland umlaufen, anderen Bestimmungsgründen folgen. Mit Hilfe eines Vergleichslandes, in dem der Auslandsanteil der Banknoten gering ist oder gar nicht existiert, kann man dann den Auslandsanteil „deutscher“ Banknoten schätzungsweise herausfiltern. Diese Methoden können auch als Robustheitstests direkter Schätzmethoden verstanden werden.

Überraschenderweise ergeben die einzelnen indirekten Ansätze ein recht einheitliches Bild in Bezug auf den Auslandsumlauft deutscher Euro-Banknoten. Der Anteil des Auslandsumlaufts an den kumulierten Nettoemissionen der Deutschen Bundesbank ist seit dem Jahr 2002 deutlich gestiegen. Ende 2009 belief er sich schätzungsweise auf knapp 70 %. Der Großteil davon befand sich in Ländern außerhalb der Europäischen Währungsunion. Das Wachstum des Umlaufts deutscher Euro-Banknoten wird somit fast ausschließlich von der Auslandsnachfrage getrieben. Inländische Transaktions- und Hortungsbestände haben dagegen einen vergleichsweise geringen Umfang. Dieses Bild stimmt auch weitgehend mit den Ergebnissen überein, die man bei der Anwendung direkter Schätzmethoden erhält.



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# Foreign demand for euro banknotes issued in Germany: estimation using indirect approaches\*

*“Where did all the money go?,  
Where did all the cash flow?”*

(Neil Young, 2011)

## 1 Introduction

The calculation of the percentage of euro banknotes issued by the Bundesbank that are in circulation outside Germany is of interest for several reasons.<sup>1</sup> For example, the observed sharp growth in the volume of banknotes in circulation, even after stocks of hoarded banknotes were replenished following the euro cash changeover, could be driven by foreign demand. Furthermore, foreign demand is important for central banks' money market management, the Bundesbank's monetary income, interpreting monetary aggregates, as well as for measuring the Bundesbank's participation in cash processing. In this paper, foreign demand for Bundesbank-issued euro banknotes is estimated using indirect methods.<sup>2</sup> These make use of the different characteristics of domestic and foreign demand or particular events, such as the euro cash changeover.

The following overview of the literature focuses on countries exporting cash.<sup>3</sup> The majority of studies on foreign demand for cash examine the US dollar and the Hong Kong dollar.<sup>4</sup> Foreign demand is a possible explanation for the sharp rise in the volume of outstanding cash of both currencies since the 1990s. According to analyses conducted by the Federal Reserve Board, 60% to 70% of the US currency stock is held outside the USA (Porter and Judson, 1996; Anderson and Rasche, 2000; US Treasury Department, 2006).<sup>5</sup> Foreign demand as a

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<sup>1</sup> See also Bartzsch, Rösl and Seitz (2011), section 1.

<sup>2</sup> Alternatively, foreign demand can be derived from available statistics and surveys (direct methods). See also Bartzsch, Rösl and Seitz (2011).

<sup>3</sup> See also Bartzsch, Rösl and Seitz (2011), section 1. For information on countries importing cash, see, for example, Feige (2003).

<sup>4</sup> However, only the US dollar and the euro are likely to be in use worldwide.

<sup>5</sup> However, estimates in literature overall fluctuate between 20% and 70% (Feige, 2009).

percentage of the total volume of Hong Kong dollar currency in circulation in 2009 is estimated to be similarly high at between 50% and 70%. This figure has grown considerably over time (Leung, Ng and Chan, 2010).

There are only very few studies on foreign demand for cash in Europe. Seitz (1995) uses various estimation approaches and comes to the conclusion that in the mid-1990s 30% to 40% of the total volume of DM cash was in circulation outside Germany.<sup>6</sup> Fischer, Köhler and Seitz (2004) estimate that between 8% and 13% of the total volume of outstanding euro legacy currencies in 2000 was circulating abroad. As yet, however, no papers have been published that examine the (total) foreign demand for euro cash either for the euro area as a whole or for individual euro-area countries. The present paper on developments in Germany since the euro cash changeover thus fills a gap in the research. This is all the more important, as it derives estimates for foreign demand in both non-euro-area countries and other euro-area countries.<sup>7</sup> As a spin-off, we will also obtain domestic transaction balances and the amount of cash being hoarded.

The paper is structured as follows. Chapter 2 presents the indirect approaches for estimating components of the circulation of Bundesbank-issued euro banknotes. Chapter 3 contains an overview of the results of the individual approaches. These results are then summarised and interpreted in chapter 4.

## **2. Indirect approaches**

### **2.1 General considerations and overview**

Besides direct information from, for example, surveys or statistics on shipments of banknotes abroad (see Bartzsch, Rösl and Seitz, 2011), there are a number of indirect approaches, which incorporate behavioural assumptions about the characteristics of banknotes held in Germany and abroad.<sup>8</sup> As any demand for banknotes is met by the Bundesbank, the characteristics reflect demand behaviour. The problem can be formulated more precisely as follows (Feige, 1997, page 184):<sup>9</sup>

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<sup>6</sup> Doyle (2000) uses econometric methods and even arrives at a figure of almost 70%. However, this figure contradicts empirical evidence of banknotes returned following the introduction of euro cash.

<sup>7</sup> Analyses of cash movements within a currency area are relatively rare. For a country-specific perspective within the euro area, see Schneeberger and Süß (2007). For the situation in the United States, see Judson and Porter (2004).

<sup>8</sup> An overview of a large number of both forms is provided by Feige (1997), pp 168 ff.

<sup>9</sup> Initially, we do not distinguish between demand for German euro banknotes from other euro-area countries and that from non-euro-area countries.

The shares  $\beta_1$  and  $\beta_2$  of two subpopulations  $C_1$  and  $C_2$ , which together produce the total population  $C$ , are to be estimated. Let  $X_1$  and  $X_2$  denote the observed and recorded characteristics of subpopulations  $C_1$  and  $C_2$ . The average feature  $X$  is then a weighted average of both characteristics, with the weights being the unknown shares  $\beta_1$  and  $\beta_2$ .

$$(1) \quad X = \beta_1 X_1 + \beta_2 X_2$$

As  $\beta_1 = 1 - \beta_2$ , the shares can be estimated by means of the observed and measured properties.

$$(2) \quad \beta_1 = \frac{X - X_2}{X_1 - X_2}$$

$$\beta_2 = \frac{X_1 - X}{X_1 - X_2}.$$

A sensible solution to this problem exists if the characteristics of the two parts  $X_1$  and  $X_2$  differ ( $X_1 \neq X_2$ ) and the calculated shares are between 0 and 1. Therefore, to implement this approach for our purpose of the calculation of German banknotes held abroad, the characteristics of the banknotes in circulation outside Germany ( $X^a$ ) must differ sufficiently from those of the banknotes outstanding in Germany ( $X^d$ ) so that the foreign share can be identified by observing the overall behaviour.<sup>10</sup> This may involve the age, quality, velocity of circulation or seasonal pattern of the banknotes, for example. At the same time, information is required about how the demand for banknotes would have developed if there had been no demand from abroad. The domestic share is given by

$$(3) \quad \beta^d = \frac{X - X^a}{X^d - X^a}$$

and the corresponding foreign share by

$$(3') \quad 1 - \beta^d = \frac{X^d - X}{X^d - X^a}.$$

In section 2.2.2, we concentrate on the different seasonal structures of domestic and foreign demand. This method was first applied by Sumner (1990) to the calculation of domestic hoardings. Porter and Judson (1995, 1996) as well as Seitz (1995) and Fischer et al (2004) then adopted the approach for calculating foreign cash holdings. The seasonal factor of the

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<sup>10</sup> Where the term ‘‘German (euro) banknotes’’ is used below, this invariably refers to banknotes issued by the Deutsche Bundesbank. The total volume of German banknotes in circulation (including banks’ cash holdings) corresponds to the cumulated net issuance, ie the cumulated difference between monthly withdrawals and lodgements at the Deutsche Bundesbank. In the statistical section of the Deutsche Bundesbank’s Monthly Report, the volume of banknotes in circulation is calculated in a different way because the banknotes in circulation are shown in accordance with the accounting rules of the Eurosystem.

entire banknote series ( $X$ ) can be calculated using standard seasonal adjustment methods. To approximate the domestic share ( $X^{dt}$ ), use was made of comparisons with other currencies and periods of time with no foreign demand and of domestic transactions variables. A further approach makes use of the different banknote to coin ratios in Germany and abroad (section 2.2.3). As the volume of domestic coins in circulation abroad is negligible and the total banknote to coin ratio is known, only the domestic ratio still needs to be identified. A reference country can again be used to this end. For the U.S. case Canada is generally used as reference country (Porter and Judson, 1995, section 3.3). Furthermore, an attempt can be made to estimate a banknote demand function without foreign influence (section 2.2.4). This can either be based on a period of time in which there was no foreign demand (Seitz, 1995, subsection 2.4.2; Porter and Judson, 1995, section 3.4) or, once again, on a reference country whose currency is only in circulation within that country (Doyle, 2000). As a fourth variant (section 2.2.5), the pattern of banknote lodgement and withdrawal in the branches of the respective central bank can be examined (Anderson and Rasche, 2000). The basic concept is that domestic and foreign shares of banknotes differ in terms of the time it takes them to return to the issuing central bank, as banknotes in circulation outside a country either never flow back to the issuing central bank or do so only with a time lag. A final variant within this category of indirect approaches is the analysis of the age of banknotes (section 2.2.7). This approach was used by Boeschoten (1992) to calculate cash hoardings and then adopted by Seitz (1995) to estimate the foreign share. Banknotes in circulation outside a country differ from those in circulation within that country as they do not flow back to the central bank as frequently. Consequently, their measured average life is longer. The prerequisite for the application of this type of indirect method is thereby fulfilled.

Rather than making use of the different characteristics of domestic and foreign demand, other forms of indirect approaches exploit particular events, such as the euro cash changeover. These include our alternatives 2.2.1 and 2.2.6. In the first of these, we compare the circulation of German banknotes and the euro legacy currencies before the euro cash changeover at the beginning of 2002 with the period of time since the introduction of the euro. The second approach attempts to extract information about transaction balances in Germany at the beginning of 2002 from developments in D-Mark and euro banknotes in Germany during the euro cash changeover. These amounts are then extrapolated to the end of 2009 in order to derive the volume of euro banknotes in circulation outside Germany (including domestic hoarding).

## 2.2 Indirect calculation of foreign demand for euro banknotes

### 2.2.1 Banknote ratios before and after European monetary union

Below, the volume of German euro banknotes in circulation outside Germany is calculated by means of the difference between the Bundesbank's cumulated net issuance (withdrawals less lodgements) of euro banknotes and the (total) volume of euro banknotes in circulation within Germany. The latter is estimated indirectly. To do this, it is assumed that the ratio of D-Mark banknotes in circulation in Germany ( $n_{DE\_d}^{DM}$ ) to the volume of all euro legacy currency banknotes in circulation within (what is now) the euro area ( $n_{EMU\_d}^{pre-Euro}$ ) is equivalent to the corresponding ratio of euro banknotes in circulation in Germany ( $n_{DE\_d}^{Euro}$ )<sup>11</sup> to the volume of euro banknotes in circulation within the euro area as a whole ( $n_{EMU\_d}^{Euro}$ ) from the point in time at which the stocks of cash hoardings had been fully replenished owing to the euro cash changeover. The following equation is therefore assumed:<sup>12</sup>

$$(4) \quad \frac{n_{DE\_d}^{DM}}{n_{EMU\_d}^{pre-Euro}} = \frac{n_{DE\_d}^{Euro}}{n_{EMU\_d}^{Euro}}$$

The ratio of D-Mark banknotes in circulation in Germany ( $n_{DE\_d}^{DM}$ ) to the volume of all euro legacy currency banknotes in circulation within (what is now) the euro area ( $n_{EMU\_d}^{pre-Euro}$ ) on the left-hand side of equation (4) is now calculated for December 2000. At this point in time, the circulation of euro legacy currency banknotes was yet to be distorted by the euro cash changeover on 1 January 2002. According to the estimates of Seitz (1995, page 52), in the mid-1990s 30% to 40% of the total volume of D-Mark cash in circulation (outside banks) was outside Germany.<sup>13</sup> For December 2000, this gives an imputed foreign share of D-Mark banknotes in circulation (outside banks) of 35%. This corresponds to an estimated domestic

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<sup>11</sup> This should not be confused with that part of German net issues of euro banknotes in circulation in Germany. Both volumes are equal only if there is no banknote migration between Germany and the rest of the euro area. For a more detailed explanation, see Bartzsch, Rösl and Seitz (2011), section 3.3.

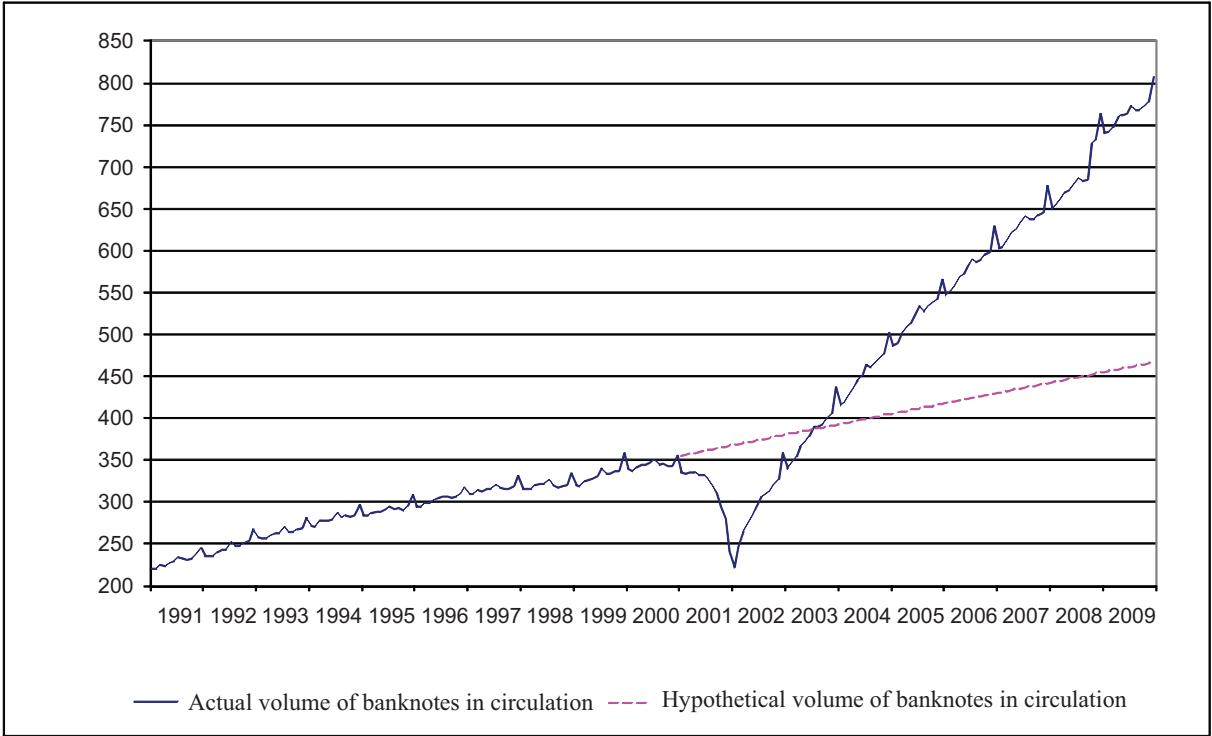
<sup>12</sup> This could, of course, be countered by the argument that the euro cash changeover led to structural changes and a corresponding reoptimisation of euro cash holdings (see also section 6.2 in Fischer, Köhler and Seitz (2004)). Examples of such structural changes are a) the introduction of a new currency in a currency union with a central bank system that is clearly committed to low inflation rates, b) the merging of various legacy currencies into a single currency in an economic area comparable in size to the United States and, therefore, suitable as a "safe haven" and c) a banknote denomination structure which makes their storage and transport as well as their use in the shadow economy significantly easier. With equation (4), it is now assumed that the reoptimisation of euro cash holdings has not substantially changed the ratio of banknotes in circulation in Germany to banknotes in circulation in the euro area. This is a simplification insofar as the individual participating euro-area countries are affected to a varying extent by the cited structural changes.

<sup>13</sup> According to information from the Deutsche Bundesbank's Cash Department, this figure is largely confirmed by the return flows from abroad to Bundesbank branches during the euro cash changeover.

volume of D-Mark banknotes in circulation ( $n_{DE\_d}^{DM}$ ) of around €90 billion as at December 2000. According to studies by Fischer, Köhler and Seitz (2004, page 72), in 2000, between 8% and 13% of the volume of cash in circulation of the euro legacy currencies was in circulation abroad (outside the euro area). Hence, a foreign share of 10% is assumed. This results in an estimated volume of euro legacy currency banknotes in circulation within the euro area ( $n_{EMU\_d}^{pre-Euro}$ ) of around €320 billion as at December 2000. Insertion into equation (4) gives the estimated volume of euro banknotes in circulation in Germany ( $n_{DE\_d}^{Euro}$ ):

$$(5) \quad n_{DE\_d}^{Euro} = 0,28 \cdot n_{EMU\_d}^{Euro}.$$

**Figure 1: Actual and forecast volume of banknotes in circulation in the euro area in € billion**



*Notes:* The actual volume of banknotes in circulation for the period from January 1991 to December 2001 corresponds to the volume of euro legacy currency banknotes in circulation (including Greece) and, for the period of time thereafter, the (total) volume of euro banknotes in circulation. In order to calculate the hypothetical volume of banknotes in circulation from January 2001 to December 2009 excluding the euro cash changeover, the actual volume of banknotes in circulation was extrapolated using its linear trend.

*Sources:* ECB and authors' own calculations

However, to make a concrete estimate of the volume of banknotes in circulation in Germany using equation (5), two things must be taken into account. First, equation (5) can logically only be applied from the point in time at which the stocks of cash hoardings had been fully replenished owing to the euro cash changeover. In order to determine this point in time, the

volume of euro legacy currency banknotes in circulation during the period from January 2001 to December 2009 is extrapolated using its linear trend. As Figure 1 shows, the stocks of hoarded euro legacy currencies which had been depleted by the end of 2001 owing to the euro cash changeover are likely to have been replenished by the end of 2003 (see also Deutsche Bundesbank, 2009, page 51).<sup>14</sup> A very similar conclusion would be reached if the volume of banknotes in circulation after 2000 were to be forecast using a banknote model optimised for the time before the euro cash changeover (see Fischer, Köhler and Seitz, 2004, page 73).

Consequently, equation (5) should apply from 2004 onwards. Furthermore, in line with equation (5), in order to derive the volume of euro banknotes in circulation in Germany ( $n_{DE\_d}^{Euro}$ ), the volume of euro banknotes in circulation within the euro area ( $n_{EMU\_d}^{Euro}$ ) must be estimated. Although the latter is unobservable, it can, in principle, be calculated by subtracting the amount of euro banknotes in circulation in non-euro-area countries ( $n_{EMU\_a}^{Euro}$ ) from the total volume of euro banknotes in circulation ( $n_{total}^{Euro}$ ):

$$(6) \quad n_{EMU\_d}^{Euro} = n_{total}^{Euro} - n_{EMU\_a}^{Euro}.$$

Foreign demand for euro banknotes ( $n_{EMU\_a}^{Euro}$ ) is approximated below using available data on (official) cumulated net shipments of euro banknotes from the euro area to non-euro-area countries. Their value amounted to just under €104 billion at the end of 2009. However, these net shipments capture only euro banknotes sent by banks and not those sent via other channels of banknote migration, such as tourism, business trips and other instances of cash being taken abroad. For example, according to anecdotal evidence, travellers from the euro area take a significant amount of euro banknotes with them on balance when travelling to non-euro-area countries.<sup>15</sup> The estimation of foreign demand for banknotes issued in the euro area used here should therefore be interpreted as the *lower bound* of actual foreign demand.<sup>16</sup> This interpretation is also suggested by surveys and other statistics. For example, the Central Bank of Russia publishes data on foreign currency cash transactions by authorised Russian banks. According to these data, cumulated net imports of euro banknotes by authorised Russian banks since the euro cash changeover alone amounted to some €45 billion as at December

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<sup>14</sup> However, the above-mentioned reoptimisation of euro cash holdings was probably not yet completed with the replenishment of cash hoardings at the end of 2003. This is indicated by the persistently high annual rates of growth in the volume of euro banknotes in circulation well into 2005.

<sup>15</sup> See also Bartzsch, Rösl and Seitz (2011), section 3.1.

<sup>16</sup> See also European Central Bank (2008), p 50 and European Central Bank (2010), p 36.



2009.<sup>17</sup> Central, eastern and south-eastern European countries are also likely to have substantial holdings of euro cash. This is substantiated by results of the Austrian central bank's semi-annual survey (OeNB Euro Survey), which has been conducted since autumn 2007. The euro cash holdings of households in these countries, derived from these surveys, amounted to approximately €12 billion in 2008 (Scheiber and Stix, 2009, Figure 5). However, this figure is likely to understate the actual amount of euro cash held there, as it is based only on a household survey.

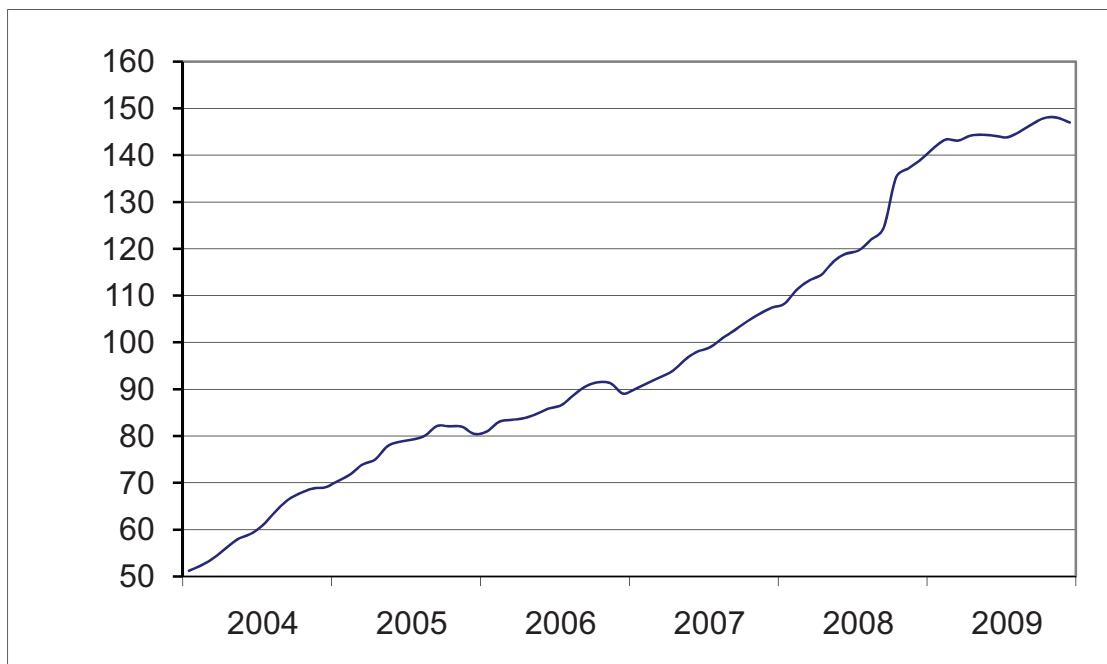
With the estimate of euro banknotes in circulation in non-euro-area countries ( $n_{EMU\_a}^{Euro}$ ), the volume of euro banknotes in circulation within the euro area ( $n_{EMU\_d}^{Euro}$ ) follows from equation (6). With equation (5), this yields an estimate of the volume of euro banknotes outstanding in Germany ( $n_{DE\_d}^{Euro}$ ). If this is subtracted from the Bundesbank's cumulated net issuance of euro banknotes, an estimate of the total foreign demand (both inside and outside the euro area) for euro banknotes issued in Germany is obtained. Since, as described above, the estimated volume of euro banknotes in circulation in non-euro-area countries forms a lower bound of the actual figure, the estimate of total foreign demand for euro banknotes issued in Germany should also be interpreted as the *lower bound* of the actual figures. As Figure 2 shows, in the period from January 2004 to December 2009, the estimated minimum level of foreign demand for euro banknotes issued in Germany increased from around €50 billion to just over €145 billion. Thus, at the end of 2009, at least roughly 40% of all euro banknotes issued in Germany were located outside Germany.

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<sup>17</sup> Cumulated net shipments of euro banknotes to non-euro-area countries by the Eurosystem comprise only transactions between euro-area central banks and wholesale banks. The cash transactions by authorised Russian banks also capture other transactions, such as those with individuals.



**Figure 2: Estimated total foreign demand for euro banknotes issued in Germany in € billion (lower bound)**



*Source:* Authors' own calculations

Deducting the volume of euro banknotes issued in Germany in circulation in non-euro-area countries from the estimated total foreign demand for euro banknotes issued in Germany produces an estimate of the (cumulated net) banknote migration from Germany to the rest of the euro area. The volume of German euro banknotes in circulation in non-euro-area countries is unknown. It is approximated here using the (official) cumulated net shipments of euro banknotes via banks from Germany to non-euro-area countries. These amounted to just under €99 billion at the end of 2009 and are to be regarded as the lower bound of the actual volume of German euro banknotes in circulation in non-euro-area countries.<sup>18</sup> From this there follows a cumulated net export of banknotes from Germany to other euro-area countries of approximately just under €50 billion as at December 2009.

### **2.2.2 Seasonal methods**

The aim of the seasonal method is to filter out information about banknotes in circulation outside Germany from the “seasonal structure of banknotes” characteristic. This idea originally came from Sumner (1990), who applied this approach to the calculation of internal cash hoardings. However, since then, this approach has also been adopted for several currencies to investigate the domestic and foreign component (Porter and Judson, 1996, p 889 ff; Seitz, 1995, section 2.2; Fischer, Köhler and Seitz, 2004, section 5.1). The fundamental

<sup>18</sup> See also Bartzsch, Rösl and Seitz (2011), section 3.1.

assumption of this approach is that foreign demand for German euro banknotes has little or no seasonality, as the growth of foreign holdings (above all those in non-euro-area countries) has little to do with domestic seasonal developments.<sup>19</sup> This depends more on the international reputation of the euro and unstable developments in the destination countries.<sup>20</sup> Hence, foreign and domestic demand differ in terms of the seasonal component and the total volume in circulation displays a dampened seasonal factor. No precise information is available on the foreign holdings of banknotes issued in Germany (these are to be determined using different procedures). However, analysing the official (net) banknote shipments from Germany to non-euro-area countries provides initial indications of whether the above assumption is justified. As Table 1 shows, these net shipments display no significant autocorrelation at the seasonal frequencies 12 and 24. By contrast, the seasonal autocorrelations of cumulated German net issuance of banknotes are highly significant, particularly for the standard seasonal frequency 12.<sup>21</sup>

**Table 1: Seasonality tests**

	Net shipments	German banknote issuance
PAC(12)	0.014 (202.46)	0.478 (68.58)
PAC(24)	-0.044 (270.92)	0.052 (88.29)

*Notes:* Monthly observations from January 2002 to December 2009. The net shipments display an upward trend. They have therefore been trend-adjusted using a Hodrick-Prescott filter ( $\lambda=14,400$ ). Banknote issuance: logarithmic difference. PAC(x): partial autocorrelation coefficient for lag x, followed by the value of the Ljung-Box Q-statistic in brackets.

*Source:* Authors' own calculations

The underlying seasonal model assumes that the time series of German banknote issuance consists of three terms: a trend component  $T_t$ , a seasonal term  $S_t$  and an irregular or noise component.<sup>22</sup> These are multiplicatively interlinked (multiplicative seasonal model). Attributing the noise term to the trend for simplicity and taking into account that German banknotes are also held abroad ( $a$ ) yields the following equation (where  $t$  represents the time index and  $d$  stands for Germany)<sup>23</sup>

<sup>19</sup> Nevertheless, seasonal influences are likely in the case of small denominations used for foreign travel, especially within the euro area. However, the share of foreign demand affected by this is likely to be fairly limited in relation to the total volume of banknotes circulating outside Germany.

<sup>20</sup> Thus, as regards its use in cash form in other countries, the euro competes almost exclusively with the US dollar.

<sup>21</sup> These results apply similarly to the United States and the US dollar, see Porter and Judson (1995).

<sup>22</sup> A cyclical component is therefore not shown separately.

<sup>23</sup> Explicitly incorporating the irregular component is not likely to have any impact on the general results; see also Porter and Judson (1995), subsection 3.1.8.

$$(7) \quad T_t S_t = T_t^d S_t^d + T_t^a S_t^a.$$

Let  $\beta_t$  denote the fraction of the overall trend held domestically and, consequently,  $(1-\beta_t)$  the share held abroad:

$$(8) \quad T_t S_t = \beta_t T_t S_t^d + (1-\beta_t) T_t S_t^a \text{ or}$$

$$(8') \quad S_t = \beta_t S_t^d + (1-\beta_t) S_t^a.$$

(8') is a concrete example of the general equation (1) in section 2.1, with the seasonal component taking on the role of the measured characteristic  $X$ . Assuming that the foreign share does not vary seasonally (see comments on Table 1 above), ie  $S^a = 1 \forall t$ , (8') can be simplified further to

$$(9) \quad S_t = \beta_t S_t^d + (1-\beta_t).$$

Given values for the seasonal terms  $S$  and  $S^d$  yields an equation for the unknown value  $\beta_t$ , the share of banknotes held domestically:

$$(10) \quad \beta_t = \frac{S_t - 1}{S_t^d - 1}.$$

The foreign share, in turn, is  $(1-\beta_t)$ .  $S_t$  corresponds to the seasonal component of total German cumulated net banknote issuance and can be calculated using standard seasonal adjustment methods (eg X12-ARIMA, Tramo-Seats). By contrast,  $S_t^d$ , the seasonal term for the share of banknotes circulating in Germany, is unknown. It must be estimated and various methods for this are presented below. However, equation (10) does not always produce meaningful results. If, for example, there is no seasonal influence in any given period, ie  $S_t = S_t^d = 1$ ,  $\beta_t$  tends to infinity, or any value of  $\beta$  is compatible with equation (10). If the seasonality of all outstanding banknotes is not less pronounced in all periods than that of the banknotes held domestically, problems can occur, too.<sup>24</sup> This method thus produces plausible results for some, but not for all frequencies.

Therefore, further modifications are needed to allow for these eventualities and to enable this method to be implemented. Fairly accurate estimation results can often be obtained only for a certain frequency within a given year (see also Porter and Judson, 1995, page 19 f). We therefore take into account the fact that seasonal fluctuations are usually greatest around Christmas owing to domestic transactions. For example, in the case of German banknote

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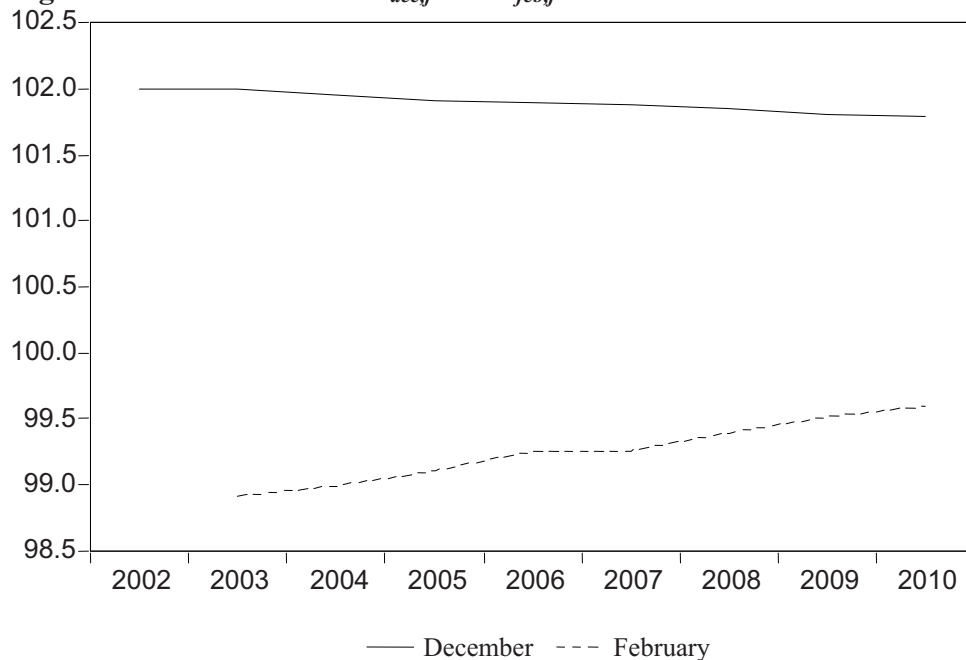
<sup>24</sup> If the seasonality in Germany is stronger than outside Germany,  $S_t < S_t^d$  applies for values greater than 1 and  $S_t > S_t^d$  applies for values smaller than 1.

issuance, the seasonal high is in December, while there is a seasonal low in February (in this case, there is accordingly a two-month frequency). In order to factor this into the equation, we replace the time index  $t$  by  $m,j$ , where  $m$  denotes the  $m^{\text{th}}$  month and  $j$  stands for the  $j^{\text{th}}$  year. If equation (9) for February is subtracted from the corresponding equation for the preceding December, the domestic share  $\beta_j$  reads as:<sup>25</sup>

$$(11) \quad \beta_j = \frac{S_{dec,j} - S_{feb,j+1}}{S_{dec,j}^d - S_{feb,j+1}^d}.$$

In Figure 3, both seasonal factors ( $S_{dec,j}$ ,  $S_{feb,j}$ ) of Germany's total issuance are presented for our observation period.

**Figure 3: Seasonal factors  $S_{dec,j}$  and  $S_{feb,j}$  of German banknote issuance**



Source: Deutsche Bundesbank

Now, what is the best way of modelling  $S^d$ , the unknown domestic part in equation (11)? We try three variants which might proxy the seasonal component of the euro banknotes held in Germany. These include

- a) Selection of a reference country
- b) Inclusion of a transactions variable
- c) Analysis of banks' vault cash.

<sup>25</sup> For an alternative, see Seitz (1995), p 29.

Options a and b have so far been used most frequently in the literature when calculating the foreign share (Seitz, 1995; Porter and Judson, 1995; Fischer, Köhler and Seitz, 2004). Since all three variants include different assumptions and hypotheses concerning what share of domestic and foreign demand is captured, the calculated  $\beta$  will also assume differing values.<sup>26</sup>

#### **a) Selection of a reference country**

The idea behind selecting a reference country is to find a country that is optimally similar to Germany in its use of banknotes, except for foreign demand. We would then insert this country's seasonal factor of banknote issuance for  $S^d$  in equation (11). After careful consideration, we decided on France as a reference country. There are several reasons in favour of this:

- France is a euro-area country.
- The standard of living in France is similar to that in Germany.
- The *overall* cashless payments behaviour of non-banks relative to cash transactions in the two countries is not too dissimilar. Furthermore, the geographical density of ATMs, the number of transactions or withdrawals by debit card, and the number of transactions at POS terminals is comparable (for more details, see Bank for International Settlements (BIS), 2009).
- The size of the shadow economy, in which most transactions are settled in cash, is similar in both countries (Feld and Schneider, 2010; Thießen, 2010).
- There should not be a major difference in hoarding behaviour in the two countries (see, for instance, the estimates in Boeschoten, 1992, chapter 4).
- Since the start of EMU, there has been a high degree of synchronisation of the business cycles and also, in particular, of private consumption expenditure between Germany and France (Aguar-Conraria and Soares, 2011; Gayer, 2007). The seasonal component of transaction demand should therefore be comparable.

Moreover, there are indications that in the case of small denominations, which usually have high seasonality, not only Germany but also France within the euro area is a net exporter of

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<sup>26</sup> Another option would be to analyse the seasonal structure of German coin issuance. However, as this is quite dampened (reasons: losses, collectors, hoarded coins) and shows two only weakly marked seasonal highs (Christmas and the holiday period), the seasonal method does not produce any plausible results in this case.

banknotes to other euro-area countries. To this extent, France and Germany could be treated similarly with regard to migration within the euro area as an initial approximation.<sup>27</sup>

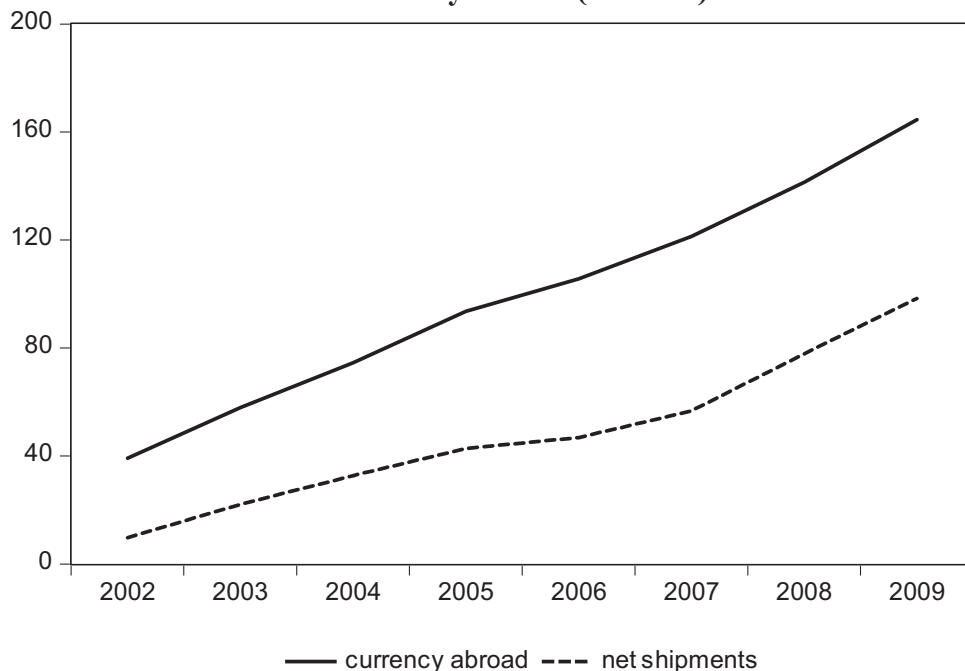
If we now assume that none of the banknotes issued by France go to non-euro-area countries (this is indicated, for example, by the fact that the official shipments are carried out almost entirely by German banks), we have found in France a reference country that is rather similar to Germany in its use of euro banknotes, with the exception of demand from non-euro-area countries. Accordingly, using this approach, we identify the share of German euro banknotes in these countries. Therefore,  $\beta$  is the share of banknotes in circulation in Germany and in other euro-area countries. The calculated holdings should at all events be higher than the cumulated official net shipments, as these can be regarded as a benchmark providing a lower bound for actual foreign demand from non-euro-area countries.

Figure 4 presents the results of this approach together with the cumulated net shipments. In the calculations, we have used a pure seasonal factor. However, a combined seasonal and calendar factor produces only marginally different figures; only the dynamics over time differ in part. It is obvious that the calculated volume of euro banknotes abroad is significantly higher than the cumulated net shipments. This consistency requirement is thus fulfilled. The movements over time are also similar. Accordingly, the volume of German euro banknotes outside the euro area amounted to around €160 billion at the end of 2009.

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<sup>27</sup> Unlike Germany and France, it can be seen that time and time again Austria, Belgium and Spain are net importers of individual banknote denominations. This can be derived from the negative cumulated net issuances of these countries. See also Bartzsch, Rösl and Seitz (2011), section 3.2.

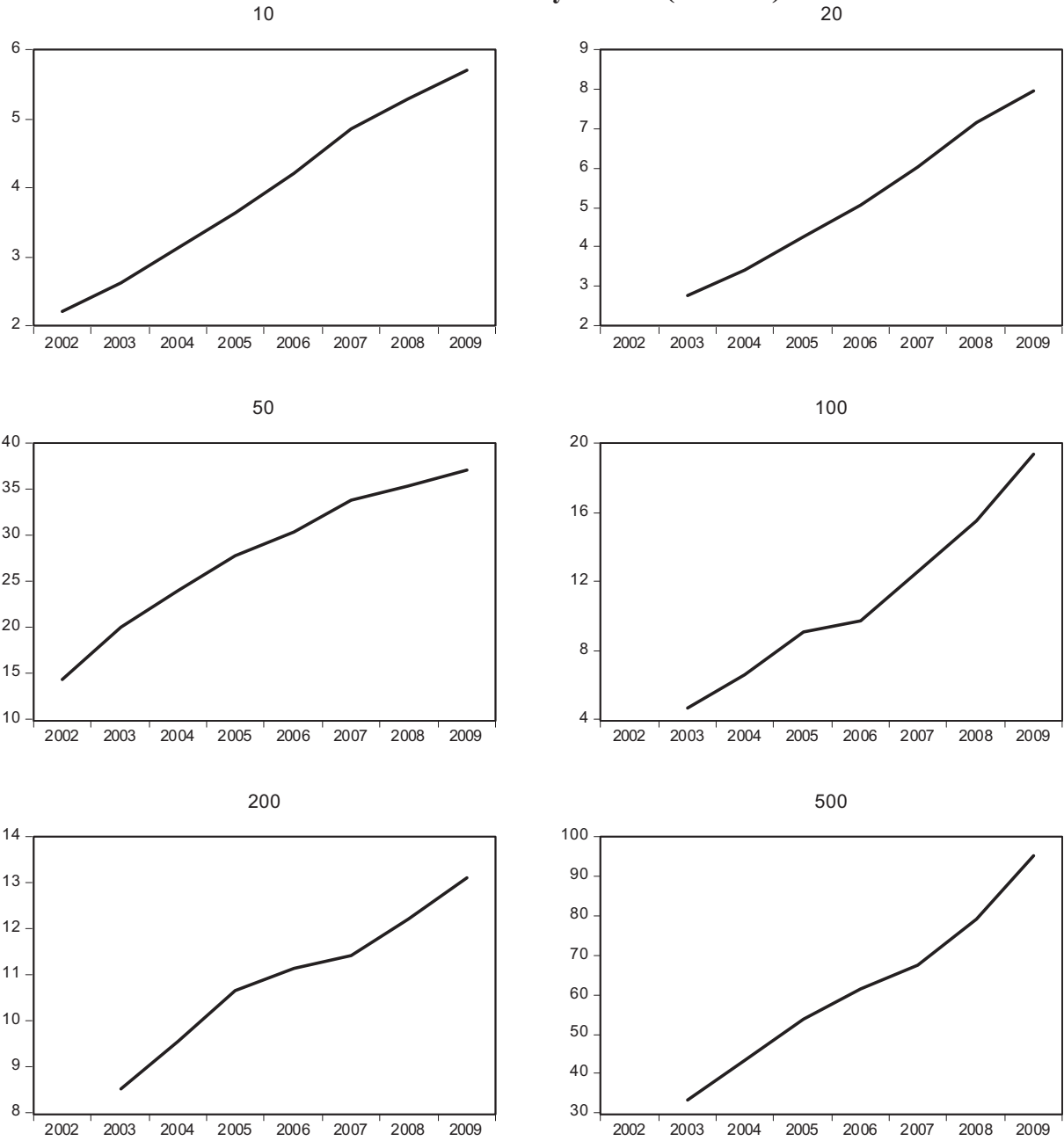
**Figure 4: Total volume of German banknotes in non-euro-area countries: calculated on the basis of the reference country France (€ billion)**



*Sources:* Deutsche Bundesbank and authors' own calculations

This approach can also be applied to individual denominations, as is done in Figure 5. The €5 banknote is not included, as only an additive seasonal component could be calculated for this denomination. Nevertheless, this is hardly likely to have distorted the results, as this denomination is not likely to be used much in non-euro-area countries. The approach had to be modified when applied to individual denominations as the seasonal lows and highs were no longer continuously in February and December. Surprisingly, the sum of the calculated holdings of individual denominations at the end of 2009 (around €175 billion) roughly corresponds to the figure when the approach is applied to the total volume of banknotes in circulation (see Figure 4: €160 billion). In terms of value, the €500 banknote is found most frequently outside Germany, followed by the €50 banknote. An increase for all denominations since 2002 can be observed. This increase appears to be declining in the case of €50 banknotes, but accelerating for €100 banknotes.

**Figure 5: German banknotes in non-euro-area countries: individual denominations calculated on the basis of the reference country France (€ billion)**



Source: Authors' own calculations

**b) Seasonal of a transactions variable**

A further option is to compare the seasonal variation of German euro banknotes in circulation with the seasonal variation of a transactions variable.<sup>28</sup> Private consumption (including

<sup>28</sup> Different variants of this method may be found in Seitz (1995), subsection 2.2.3, Fischer, Köhler and Seitz (2004), subsection 5.1.1c, and Porter and Judson (1995), subsection 3.1.7. Kajuth and Schmidt (2011) show for both the United States and the United Kingdom that real estate prices have a pronounced seasonal pattern. They connect this seasonal pattern to the consumption of consumer non-durables. As cash is also used in real estate transactions, it would be interesting to apply this idea to euro-area countries. However, in the case of Germany, it



subcategories) or retail sales in Germany could, for example, be used for this purpose. Since cash is used in Germany for hoarding *and* transactions, the seasonal of the transactions variable should be reflected in the seasonal of the volume of banknotes in circulation in Germany. This method would therefore not only record the non-euro-area countries' share, but also migration within the euro area and hoarding balances in Germany. To take hoardings into account, the approach can be modified to incorporate the domestic income elasticity (transactions elasticity) of the demand for banknotes,  $\eta$ , which, inter alia, captures the level of hoardings. Equation (11) can thus be rewritten as

$$(11') \quad \beta_j = \frac{S_{dec,j} - S_{feb,j+1}}{S_{dec,j}^d - S_{feb,j+1}^d} = \frac{S_{dec,j} - S_{feb,j+1}}{\eta \cdot \Delta S(tr)},$$

where  $\Delta S(tr)$  is the difference between the seasonal highs and lows of the transactions variable.

First, the value of the elasticity,  $\eta$ , is required for a scenario with no foreign demand. To obtain this, a banknote demand function for France during the period prior to the euro cash changeover is estimated. France is again an appropriate reference country as, during the time when both Germany and France had their national currencies, there were no major differences between the two with regard to *domestic* banknote demand behaviour. Moreover, domestic migration was not a problem before 2002, the D-Mark was not in circulation in France, and foreign demand for French francs was negligible (Seitz, 1995, footnote 1). An estimate of a (long-term) banknote demand function for France from the first quarter of 1985 to the fourth quarter of 2001 produced an income elasticity which does not deviate significantly from one.<sup>29</sup>

Real private consumption and retail sales can be used as transactions variables in Germany. As the data quality of private consumption is significantly better, we present the results only for this case.<sup>30</sup> However, this makes it necessary to switch to quarterly data ( $q$ ). Equation (11') can thus be rewritten as

$$(11'') \quad \beta_j = \frac{S_{q4,j} - S_{q1,j+1}}{\eta \cdot \Delta_{q4,j;q1,j+1} S(tr)}.$$

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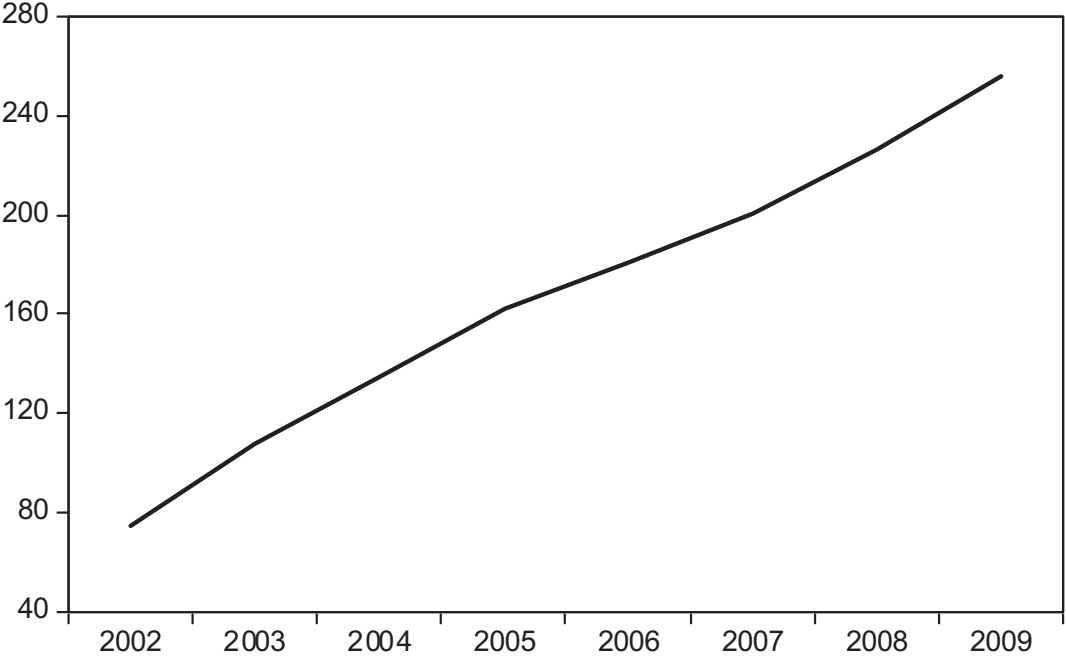
is likely that the quite sluggish development of the real estate market will mean that the approach can only be applied to a limited extent.

<sup>29</sup> Real private consumption, an interest rate variable and the consumer price index are included in the nominal estimate.

<sup>30</sup> Using retail sales figures produces similar developments over time, but at a higher (and rather implausible) level.

The resulting time series of euro banknotes circulating outside Germany is shown in Figure 6. As mentioned above, this approach captures the total volume of euro banknotes outside Germany (intra euro area and extra euro area). Once again, this results in an increasing volume since 2002, which reached approximately €250 billion at the end of 2009. Combined with the result of subsection a), €90 billion remains for the cumulated net export of German banknotes to other euro-area countries. Therefore, at the end of 2009, around €100 billion was available in Germany for hoarding and transaction purposes. From a purely statistical perspective, this is equivalent to €1,100 *per capita* of the population or €4,400 per four-person household held permanently as cash.

**Figure 6: German euro banknotes abroad: seasonal component of a transactions variable (€ billion)**



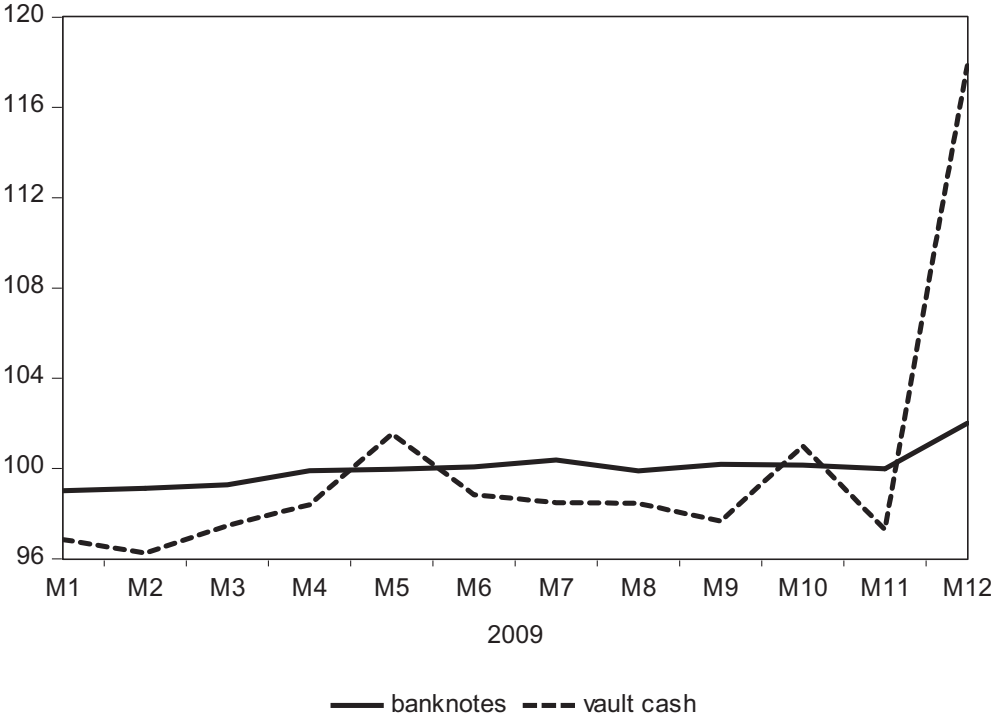
Source: Authors' own calculations

**c) Analysis of banks' vault cash**

The third possibility is to analyse the seasonal pattern of vault cash in Germany (see also Porter and Judson, 1995, subsection 4.2.3). Banks incur opportunity costs for cash balances held. They therefore keep them to a minimum and those held stem almost exclusively from regular domestic transactions (Allen, 1998). Domestic hoarding and foreign demand have virtually no impact on banks' cash balances. The seasonal component of vault cash should therefore be more pronounced than that of German banknotes in circulation. This is confirmed by Figure 7, which shows both seasonal factors for a selected year (2009). The German share in total euro-area cash balances also provides an indirect indication of the importance of

domestic transactions for the development of vault cash. In 2009 this was, at 28%, almost identical to Germany’s capital share of 27% in the (fully paid-up) capital of the ECB, which takes into consideration the respective population and GDP as a measure of the size and economic capacity of a country.

**Figure 7: Seasonal component of German banknotes in circulation and of vault cash in 2009**



Source: Deutsche Bundesbank

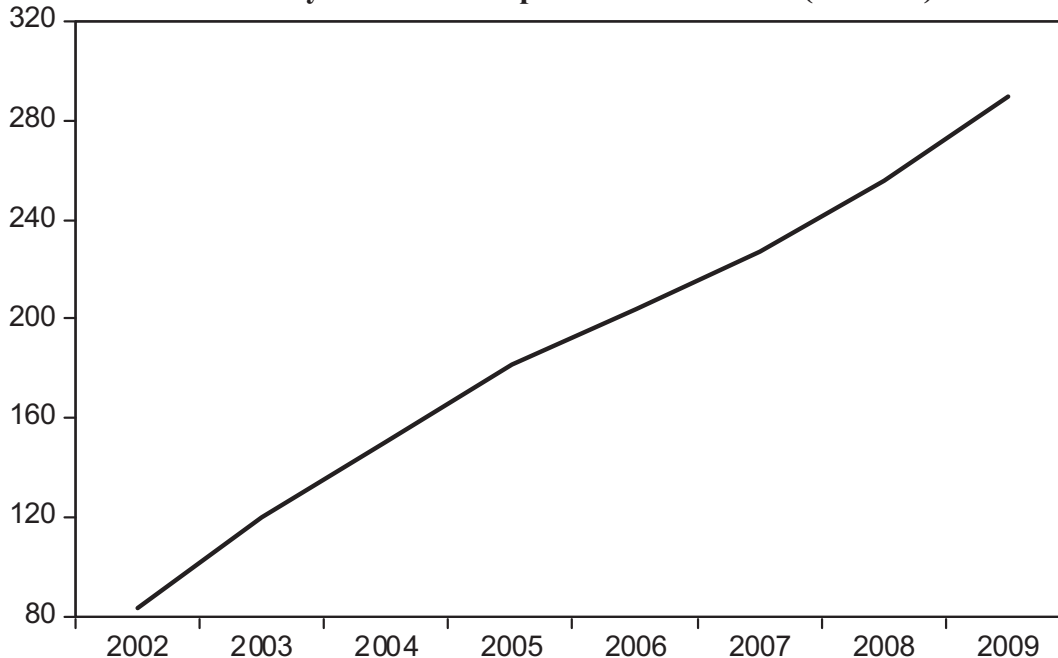
Implementing equation (11) yields the results shown in Figure 8.<sup>31</sup> Accordingly, the sum of euro banknotes outside Germany and domestic hoardings amounted to just under €290 billion at the end of 2009. If this is combined with the results from subsections a) and b), this means that around €40 billion was hoarded. The €60 billion, which has yet to be explained, can then only be accounted for by transaction demand from households and enterprises in Germany.

Overall, the various seasonal methods suggest that approximately €250 billion of German euro banknotes was outside Germany at the end of 2009. Around €160 billion of this was in non-euro-area countries and €90 billion in other euro-area countries. As a by-product of the seasonal analysis, we obtain a figure of €40 billion for cash hoardings in Germany. This still leaves around €60 billion for transactions by households and enterprises at the end of 2009.

<sup>31</sup> The results remain virtually unchanged if a combined seasonal and calendar factor is used instead of a pure seasonal factor.

Statistically, this is equivalent to *per capita* banknote holdings for transaction purposes in Germany of just over €700.

**Figure 8: German euro banknotes outside Germany and hoardings of German euro banknotes in Germany: seasonal component of vault cash (€ billion)**



Source: Authors' own calculations

### 2.2.3 Analysis of German coin issuance

Another approach for determining the volume of euro banknotes outside Germany is to filter out information from the volume of euro coins (Porter and Judson, 1995, section 3.3; Feige, 1997, p 189 f). The ratio of coins to banknotes is used for this. It is easy to calculate this ratio for the entire German issuance  $(c/n)$ . However, the corresponding domestic and foreign shares, and thus, specifically, the non-euro-area countries' share, are unknown. We approximate the domestic share  $(c/n)^d$  again by using France as a reference country. The coin to banknote ratio for non-euro-area countries,  $(c/n)^a$ , is likely to be zero as euro coins are not in circulation outside the euro area or only to a negligible extent. Equation (1) thus reads as

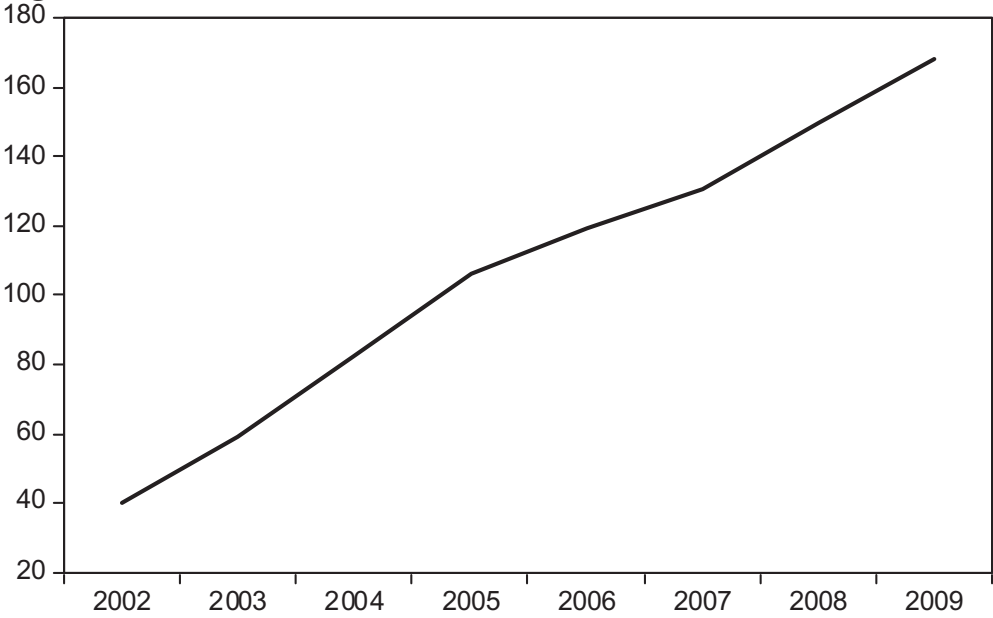
$$(12) \quad \frac{c}{n} = \beta^d \left( \frac{c}{n} \right)^d + (1 - \beta^d) \left( \frac{c}{n} \right)^a.$$

As it is assumed that  $(c/n)^d \approx (c/n)^F$  and  $(c/n)^a \approx 0$ , the following relationship holds for  $\beta^d$ :

$$(13) \quad \beta^d = \frac{c/n}{(c/n)^F}$$

and  $\beta^a = (1-\beta^d)$ . Figure 9 shows the results derived with this approach. Both the dynamic pattern and the absolute figures confirm the comments made in subsection 2.2.2 a). Applying this method, the volume of euro banknotes in non-euro-area countries amounted to just under €170 billion in 2009 (compared with just over €160 billion in subsection 2.2.2 a). As Deutsche Bundesbank (2003, page 208 f) notes, theoretically speaking, there is little to suggest a net outflow of euro coins from Germany to other euro-area countries, since it may be assumed that, as far as coins for transaction purposes are concerned, German tourists take a similar amount of coins with them when travelling both from and to their home country.<sup>32</sup> However, as Germany is a net exporter of banknotes, the total volume of banknotes in circulation outside Germany (extra euro area and intra euro area) must be higher than the calculated €170 billion.

**Figure 9: German banknotes in non-euro-area countries: benchmark coins (€ billion)**



Source: Authors' own calculations

**2.2.4 Estimation of a banknote demand function**

Another approach is to set up a demand function for German banknotes without foreign demand. To date, two alternatives have been employed in the literature. The first consists in finding a period of time in which foreign influence was negligible (Seitz, 1995, subsection 2.4.2; Porter and Judson, 1995, section 3.4). The second option consists in trying to find a country that is comparable to Germany in terms of banknote demand, except for foreign demand for banknotes (Doyle, 2000). The first approach can be ruled out in our case, as there

<sup>32</sup> On calculating domestic migration of coins within the euro area, see Seitz, Stoyan and Tödter (2009).

has been a foreign demand for German banknotes since the euro cash changeover in 2002. We therefore concentrate on the second option and, once again, adopt France as a reference country.<sup>33</sup> Foreign demand for “German” euro banknotes is thus given by the difference between the cumulated net issuance of euro banknotes and domestic circulation estimated using the banknote demand function for France. As in the previous section, we assume that French banknotes are not in circulation in non-euro-area countries. Furthermore, we do not incorporate into the banknote demand function any variables that model the domestic migration of German and French banknotes within the euro area.<sup>34</sup> We initially assume that Germany and France have a comparable domestic migration of banknotes to other euro-area countries. We would therefore use this method to calculate the total volume of German euro banknotes outside Germany. If Germany were a larger net exporter of banknotes to other euro-area countries than France, the volume of German euro banknotes circulating outside Germany would have to be increased accordingly.

At a general level, this approach divides the total volume of German euro banknotes at a specific point in time  $t$  ( $n_t$ ) into one part that is held in Germany ( $n_t^d$ ) and another that is held outside Germany ( $n_t^a$ ).

$$(14) \quad n_t \equiv n_t^d + n_t^a$$

In (14), only  $n_t$  is known initially, but not the division into the two parts. We therefore have an equation with two unknowns. In order to determine the division unambiguously, we need a conditional equation for  $n_t^d$  or  $n_t^a$ . We focus on  $n_t^d$  and, in a second step, calculate  $n_t^a$  as a residual.

To capture  $n_t^d$  we estimate a nominal banknote demand function for France (index  $F$ ) which incorporates the price level ( $p$ ), an opportunity costs variable ( $i$ ), and a transactions variable ( $y$ ) as arguments.

$$(15) \quad n_t^F = \alpha_1 + \alpha_2 p_t^F + \alpha_3 y_t^F + \alpha_4 i_t^F + etc_t + \varepsilon_t,$$

where  $\varepsilon_t$  stands for the disturbance term and “*etc*” comprises, above all, deterministic dummy variables (to depict the seasonal structure, for example). If France is comparable to Germany, except for foreign demand, the volume of banknotes held in Germany ( $D$ ) can be calculated

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<sup>33</sup> Doyle (2000) chose the Netherlands as a reference country for Germany for the period before monetary union, above all owing to its comparable denomination structure.

<sup>34</sup> On such variables in the context of a banknote demand estimate for Germany, see Seitz and Setzer (2009), section 3.

using the parameter estimates for  $\alpha_i$ 's ( $\hat{\alpha}$ ). This is done by simply combining the parameter values from equation (15) with German data for  $p$ ,  $y$  and  $i$ .

$$(16) \quad \hat{n}_t^D = \hat{\alpha}_1 + \hat{\alpha}_2 p_t^D + \hat{\alpha}_3 y_t^D + \hat{\alpha}_4 i_t^D$$

The volume of banknotes in circulation outside Germany,  $n^a$ , is approximated by calculating the difference between the total volume of banknotes in circulation,  $n$ , and the estimated domestic holdings,  $n^D$  ( $= n^d$ , see equation (14)).

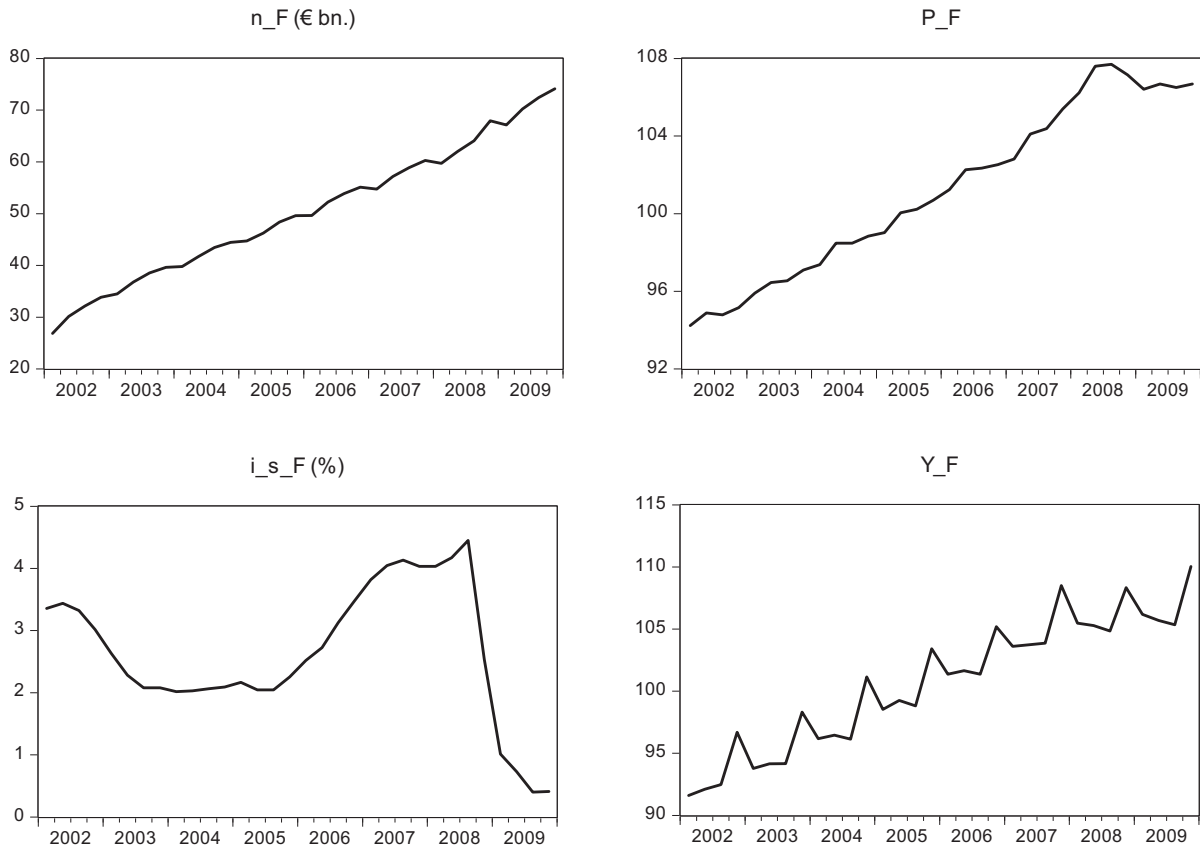
To implement this approach, we proxy the transactions variable with real private consumption. Accordingly, the private consumption deflator is the relevant price measure.<sup>35</sup> We use a short-term interest rate (three-month money market rate) as opportunity costs. All the variables are in logarithms. This means that all the coefficients, even the interest rate coefficients, are to be interpreted as pure elasticities. Consequently, an interest rate cut of 1 percentage point has a greater impact on the demand for banknotes, the lower the interest rates are. In other words, the interest rate semi-elasticity is greater in absolute terms, the lower the interest rate level is.<sup>36</sup> The original data are presented in Figure 10. The estimation period runs from the first quarter of 2002 to the fourth quarter of 2009.

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<sup>35</sup> Working with the Harmonised Index of Consumer Prices (HICP) does not produce any qualitative change in the results.

<sup>36</sup> Formulation in semi-log form would not make any change to the general results derived. However, it can be demonstrated that the double-log specification inevitably follows from individual utility maximisation (Chadha, Haldane and Janssen, 1998).

**Figure 10: Data used to estimate domestic demand for banknotes**



Notes:  $n_F$  in € billion,  $i_{s\_F}$  in %;  $p_F$  and  $y_F$  are each index values.

Sources: Deutsche Bundesbank and ECB

Various unit root, stationarity and cointegration tests indicate that the variables are  $I(1)$  and cointegrated.<sup>37</sup> Accordingly, despite the small sample size, we estimate a long-term relationship in levels, as is now common practice in the literature on money demand. For reasons of robustness, we use five different variants: a) static regression in the spirit of Engle and Granger, b) dynamic OLS (DOLS), c) fully modified OLS (FMOLS), d) canonical cointegration and e) Johansen's system estimator. Especially in small samples, the single-equation approaches, above all cases b)-d), have proved to be quite robust and more stable than the vector error correction model e). We estimate all versions with unadjusted and seasonally adjusted data. Overall, it turns out that there is hardly any difference in the results in terms of the calculated holdings, the dynamic level, and the size of the coefficients, either with regard to the estimation methodology applied or the use of adjusted or unadjusted data. Therefore, we show only the results of variant c) (FMOLS) with unadjusted data.

<sup>37</sup> The results of these tests are available from the authors on request.



The estimation of equation (15) with FMOLS produces the following result (standard errors in parentheses below the coefficients):<sup>38</sup>

$$(15a) \quad n_t^F = -23.60 + 5.00 p_t^F + 0.96 y_t^F - 0.05 i_t^F + \varepsilon_t$$

(0.31)
(0.18)
(0.15)
(0.00)

Adj R<sup>2</sup> = 0.97; SE = 0.05; DW = 0.48; JB = 0.37.

The parameters have the theoretically expected signs and are all highly significant. Furthermore, the estimation exhibits satisfactory statistical properties. The null hypothesis of an income elasticity of 1 cannot be rejected.<sup>39</sup> By contrast, the hypothesis of a price elasticity of 1 and thus freedom from money illusion must clearly be discarded. This justifies the specification in nominal terms. If the parameter values from equation (15a) are combined with German data (see equation (16)) to calculate foreign demand,  $n^a$ , we get the curve shown in Figure 11. This takes account of the standard error of the French estimation (regression), adjusted for the different sizes of the German and French banknote holdings. The thereby determined two standard error bands are also shown. This is an attempt to capture the estimation uncertainty to some extent. The calculated holdings and levels are also robust vis-à-vis the additional or alternative use of the long-term interest rate and the inclusion of a linear deterministic trend. In line with these estimates, the total volume of German euro banknotes outside Germany has been rising continuously since 2002. Thus, at the end of 2009, between €210 billion and €270 billion were located outside Germany, with a point estimate of €240 billion. This largely corresponds to the figure calculated in subsection 2.2.2. There is a clear jump in foreign demand in the fourth quarter of 2008 owing to the financial crisis in the wake of the Lehman Brothers insolvency.<sup>40</sup> Nevertheless, if fewer French banknotes than German banknotes were in circulation in other euro-area countries, the figures would have to be revised upwards. At all events, they appear to represent more of an upper bound. It is not unusual for such an approach to reach this conclusion, as is shown by the results in Doyle (2000).

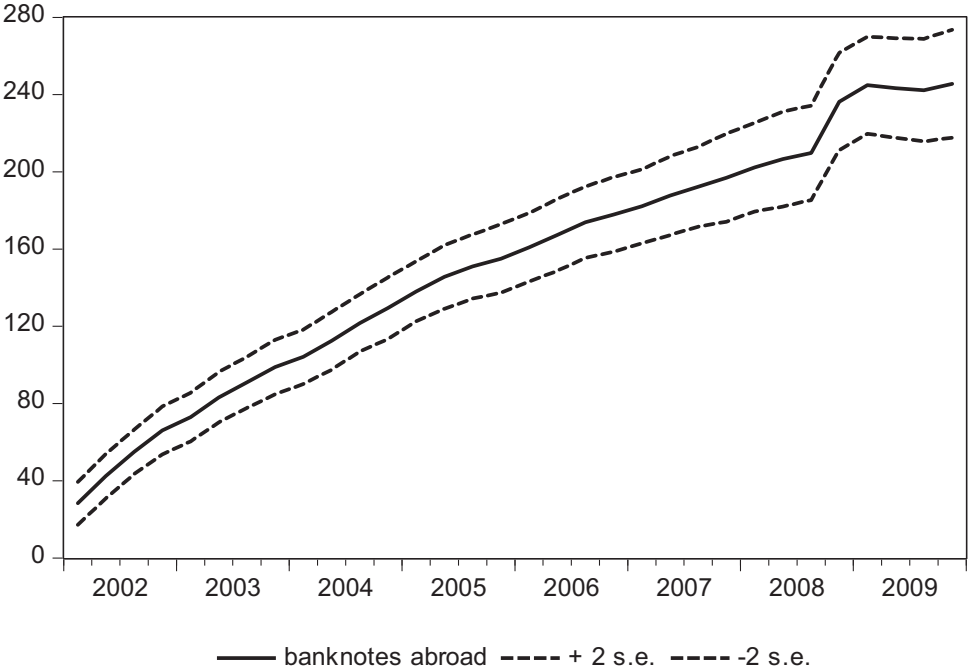
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<sup>38</sup> The equation was estimated with a constant in the cointegrating relationship. In addition, three seasonal dummies were included (not shown). The estimation itself was carried out in difference form. To calculate the long-term covariance, the lag specification was set in accordance with the Akaike criterion; furthermore, the Bartlett Kernel with the Newey-West determination of bandwidths was used. Adj R<sup>2</sup>: adjusted coefficient of determination, SE: standard error of regression, DW: Durbin-Watson test statistic, JB: Jarque-Bera test statistic for verifying the assumption of a normal distribution (p value).

<sup>39</sup> This confirms the results prior to monetary union (see subsection 2.2.2 b).

<sup>40</sup> Deutsche Bundesbank (2009, p 53) also assumes that the rise in banknote demand in the wake of the financial crisis can be attributed to a considerable extent to foreign demand. This is also indicated by the surge in net shipments of euro banknotes from Germany to non-euro-area countries (see Bartzsch, Rösl and Seitz (2011), section 3.4).

**Figure 11: Estimation of euro banknotes outside Germany by means of a banknote demand function (€ billion)**



Source: Authors' own calculations

**2.2.5 Analysis of the pattern of banknote withdrawal and lodgement**

Another approach for indirectly quantifying foreign demand for German euro banknotes is to analyse the pattern of banknote withdrawal from and lodgement at the Deutsche Bundesbank, broken down by denomination. The basic idea behind this is that foreign holdings of banknotes either never flow back to the issuing central bank or do so with a time lag. This is reflected in a larger ratio of amounts withdrawn outstanding to amounts lodged at the central bank in comparison to the corresponding ratio for banknotes which are required to meet domestic demand. By analogy with Anderson and Rasche (2000), it is first assumed that of the Bundesbank's net banknote issuance, only large denominations (ie €100, €200 and €500 banknotes) permanently remain outside Germany on balance. It is also assumed that the withdrawal and lodgement velocity of large banknote denominations circulating in Germany does not differ from that for smaller denominations. This approach therefore completely disregards domestic hoardings and the net amounts of small banknote denominations which are typically taken by residents in Germany when travelling to non-euro-area countries. However, under these restrictive assumptions, it is still possible to estimate, for a given point in time  $t$ , the ratio ( $\mu_{L,t}$ ) of withdrawals of large denominations made for domestic use ( $A_t^{L,d}$ ) to the corresponding lodgements at the central bank of large denominations stemming from domestic banknote use ( $E_t^{L,d}$ )

$$(17) \quad \mu_{L,t} = \frac{A_t^{L,d}}{E_t^{L,d}}$$

by using the corresponding withdrawal-lodgement ratio for smaller denominations:<sup>41</sup>

$$(18) \quad \hat{\mu}_{L,t} = \frac{A_t^{S,d}}{E_t^{S,d}}.$$

This ratio and the lodgements of large banknote denominations at the Bundesbank, which are assumed to stem solely from domestic circulation ( $E_t^L = E_t^{L,d}$ ) in the given period, can be used to estimate the volume of large banknote denominations issued that is in circulation in Germany during the period of time  $t$

$$(19) \quad \hat{A}_t^{L,d} = \hat{\mu}_{L,t} \cdot E_t^{L,d}.$$

If the estimated amount that remains in Germany in a given period ( $\hat{A}_t^{L,d}$ ) is subtracted from the total gross volume of large denominations ( $A_t^L$ ) issued by the Bundesbank in the same period, the corresponding amount of large denominations sent to other countries during this period ( $\hat{A}_t^{L,a}$ ) is obtained:

$$(20) \quad \hat{A}_t^{L,a} = A_t^L - \hat{A}_t^{L,d}.$$

Since it is assumed that no large denominations flow back from abroad to the Bundesbank ( $E_t^{L,a} = 0$ ), the gross volume of large denominations sent abroad ( $\hat{A}_t^{L,a}$ ) can also be interpreted as an increase in foreign demand for large denominations during the corresponding period. As it is furthermore assumed that small denominations are (at least) not permanently in circulation outside Germany, foreign demand for euro banknotes issued by the Bundesbank can be calculated for each point in time  $T$  by aggregating the net amount of large denominations issued that are circulating abroad up to that point in time ( $\sum_{t=0}^T \hat{A}_t^{L,a}$ ).

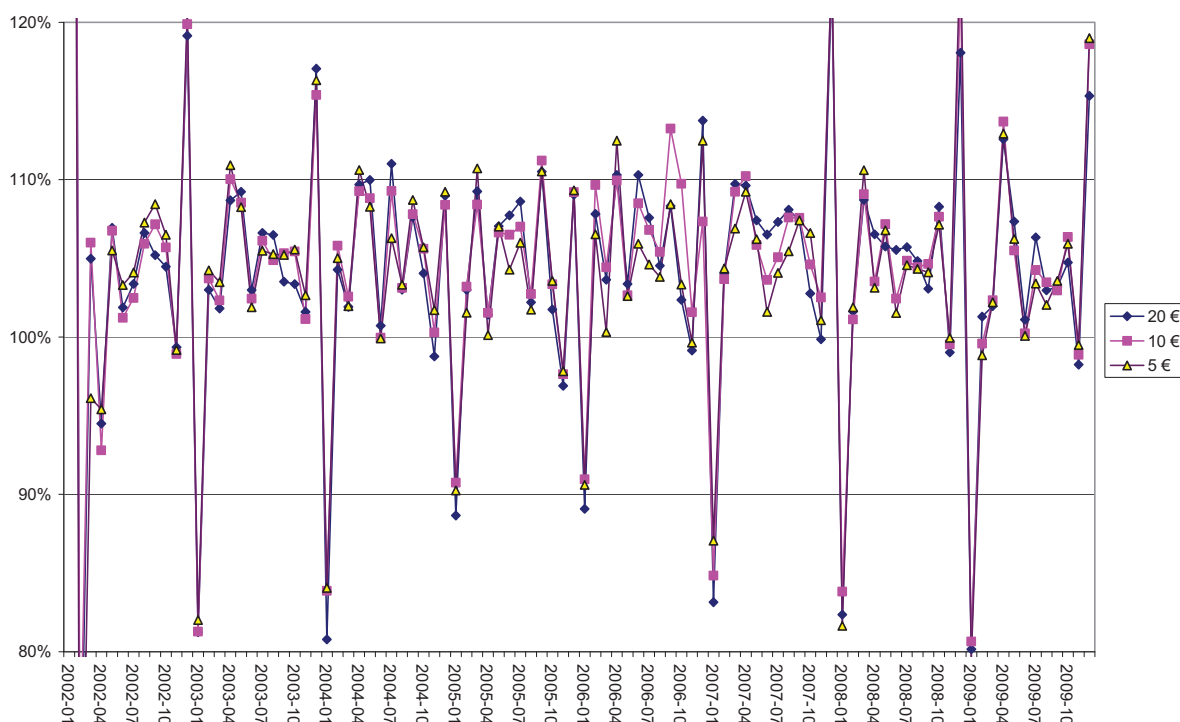
In order to produce a concrete estimation of foreign demand using this approach, it first has to be decided which “small” denominations are to be used to identify the volume of large denominations circulating in Germany. As is indicated by Figure 12 below and confirmed by the appropriate benchmark calculations, it is immaterial whether the withdrawal-lodgement

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<sup>41</sup>  $t$  stands for a given point in time,  $S$  and  $L$  stand for small and large banknote denominations, respectively, and  $d$  and  $a$  denote domestic and foreign use, respectively.

ratio for €5, €10 or €20 banknotes is used, as they display a virtually identical pattern over time.<sup>42</sup>

**Figure 12: Ratios of banknotes withdrawn at the Bundesbank to banknotes lodged at the Bundesbank for small denominations**

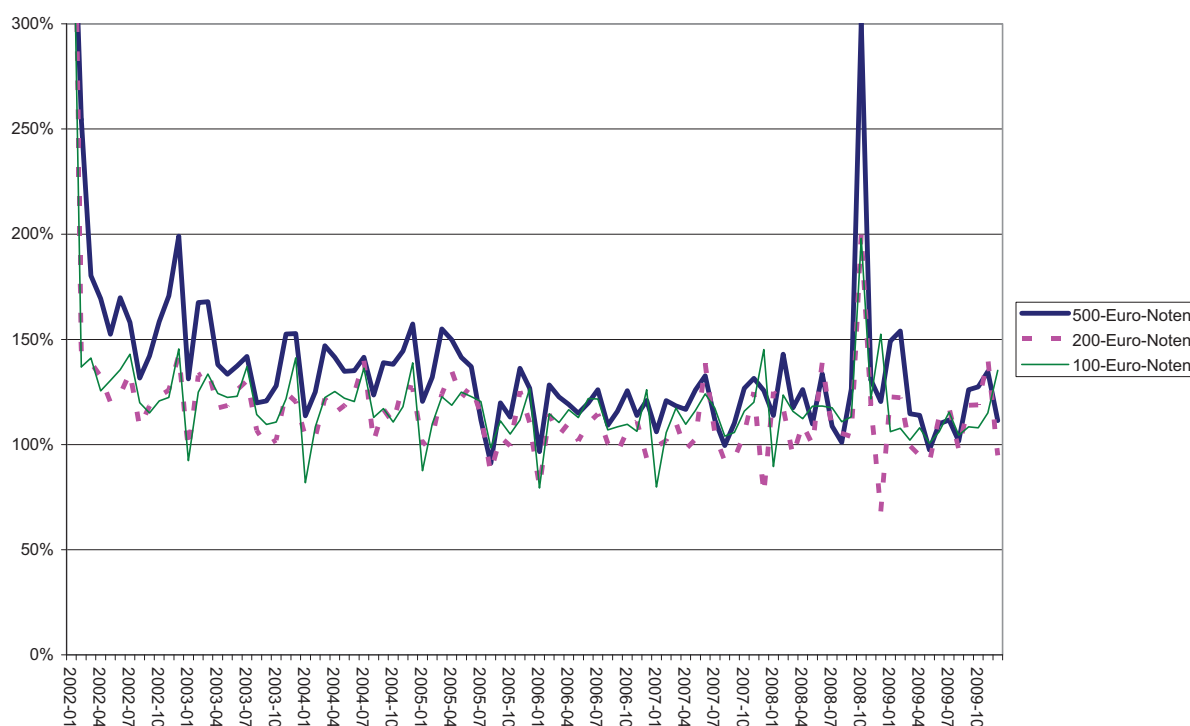


Source: Deutsche Bundesbank

By contrast, the withdrawal-lodgement ratios for large denominations behave differently (see Figure 13), revealing both the rapid replenishment of cash hoardings in Germany and abroad after the euro cash changeover, as well as the impact of the financial crisis in the wake of the Lehman Brothers insolvency (see Bartzsch, Rösl and Seitz (2011), subsection 3.4).

<sup>42</sup> This is also essentially the case for the €50 denomination.

**Figure 13: Ratios of banknotes withdrawn at the Bundesbank to banknotes lodged at the Bundesbank for large denominations**



Source: Deutsche Bundesbank

The following calculations of foreign demand for German euro banknotes are based on the €5 banknote withdrawal-lodgement ratio at the Deutsche Bundesbank, which is used as a filter to identify the volume of large denominations issued that are circulating in Germany. €100, €200 and €500 banknotes issued by the Bundesbank during the observation period are included as large denominations, as, in conceptual terms, their levels provide the closest possible approximation of hoarding outside Germany.<sup>43</sup> This produces the amounts of banknotes shown in Figure 14, which, according to the calculations, were made available by the Bundesbank to other countries on a monthly basis in net terms.

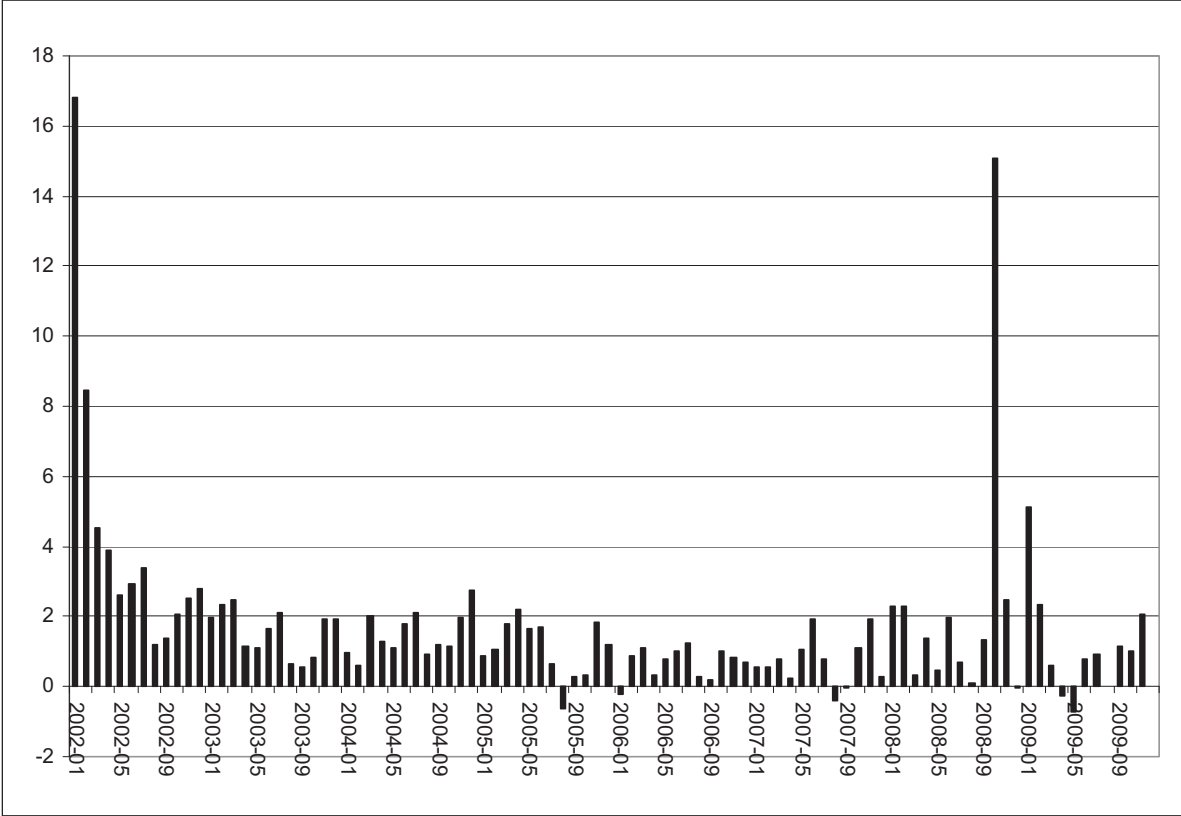
In contrast to the calculations of Anderson and Rasche (2000), who employ this method to try to calculate foreign demand for US dollar banknotes, we have decided not simply to exclude by definition those months in which there were net return flows to the Bundesbank in mathematical terms,<sup>44</sup> ie to set them to zero. This is conceptually at odds with the model assumption that large banknote denominations, once they have gone abroad, on balance never

<sup>43</sup> According to bank data, gross shipments of €100, €200 and €500 euro banknotes combined comprised over 80% of all euro banknotes sent via banks from Germany to non-euro-area countries between the start of 2002 and the end of 2009. See also Bartzsch, Rösl and Seitz (2011), section 3.1.

<sup>44</sup> For example, in December 2008, three months after the insolvency of Lehman Brothers, when the exceptionally strong net issuance of the previous months, due to hoardings in non-euro-area countries, was corrected.

return to the central bank. Nevertheless, the method adopted here is preferable on grounds of transparency, as only extremely minor adjustments are required (see Figure 14). This produces the estimated curve of foreign demand for German euro banknotes shown in Figure 15 below.

**Figure 14: Estimated monthly net issuance by the Bundesbank that went abroad on a permanent basis (€ billion)**



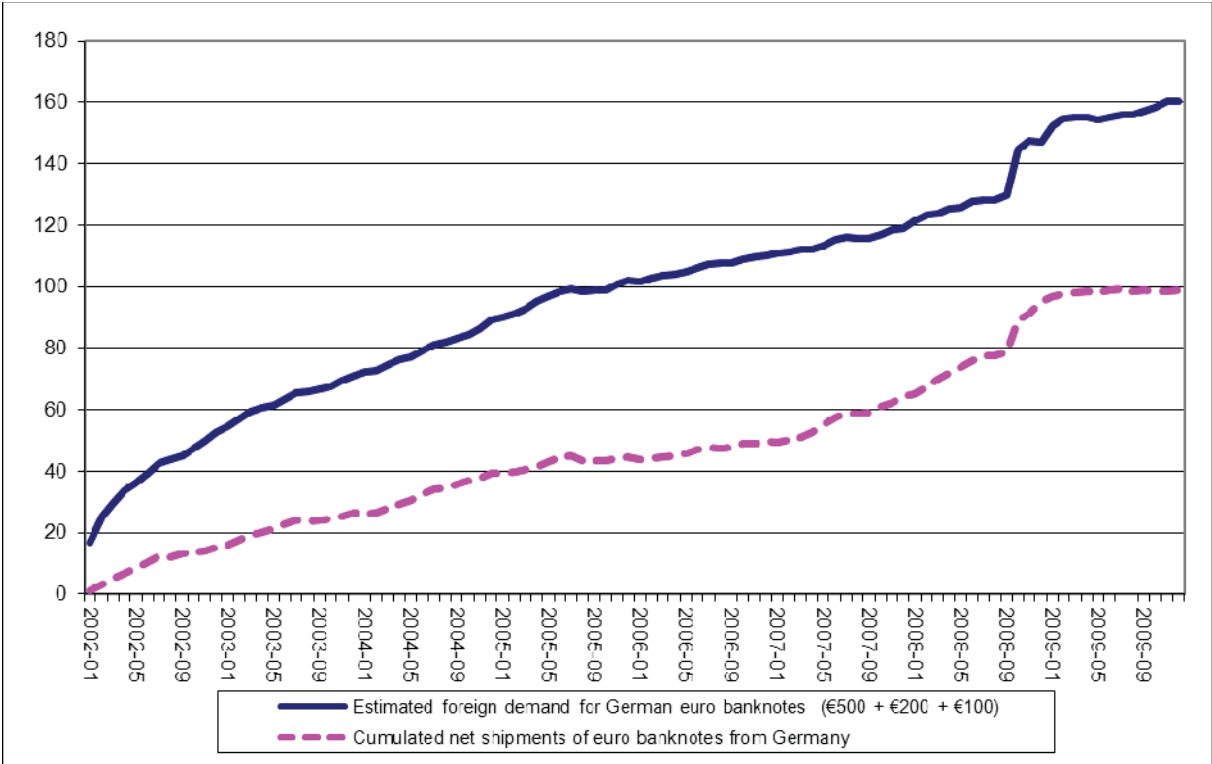
Source: Authors' own calculations

It is therefore likely that, at the end of 2009, around €160 billion of the approximately €350 billion worth of banknotes issued by the Bundesbank were circulating outside Germany (in other euro-area countries and non-euro-area countries).

If the results are scrutinised, it may first be noted that the timeline is quite similar to the official net shipments via banks to non-euro-area countries of euro banknotes issued by the Bundesbank. Furthermore, the fact that the total estimated cumulated net foreign issuance by the Bundesbank is constantly higher than the data on cumulated net shipments initially appears plausible in light of cash taken abroad by individuals. Nevertheless, the estimation method applied here implies that individuals take only large denominations abroad. Yet it would be wrong to assume this, as small denominations (up to €50) are actually likely to constitute the bulk of the cash taken abroad by Germans on their frequent holiday and

business trips.<sup>45</sup> In this respect, the approach presented here probably underestimates foreign demand for German euro banknotes. Conversely, the exclusion by definition of domestic hoardings results in the approach used overstating foreign demand. The question thus remains as to which of the two effects is dominant. This must be answered so that the results of the estimation approach based on the withdrawal and lodgement ratios can at least be interpreted as a lower or upper bound of foreign demand for German euro banknotes.

**Figure 15: Total foreign demand for German euro banknotes estimated on the basis of withdrawal and lodgement ratios (€ billion)**



Source: Authors' own calculations

Using seasonal estimation approaches, the value of €10, €20 and €50 banknotes issued by the Bundesbank that were circulating in non-euro-area countries at the end of 2009 was estimated at just over €50 billion. The analysis of cash taken abroad via foreign travel and net shipments to non-euro-area countries produces a value of just under €75 billion for the small denominations (€5 up to and including €50).<sup>46</sup> Added to this would be the (net) volume of cash taken abroad by Germans when travelling to other euro-area countries, the total amount of which can be estimated at around €60 billion (including large denominations, which are,

<sup>45</sup> See also Bartzsch, Rösl and Seitz (2011), section 3.1.  
<sup>46</sup> See also Bartzsch, Rösl and Seitz (2011), section 3.2.

however, not taken abroad in large quantities).<sup>47</sup> Foreign demand for Bundesbank-issued small denominations of up to €50 is thus likely to have amounted to around €135 billion at the end of 2009. Despite all the estimation uncertainties, this amount is probably significantly higher than the volume of €100, €200 and €500 banknotes hoarded in Germany, the total value of which is estimated at between €40 billion and €110 billion at the end of 2009, depending on the estimation method.<sup>48</sup> The analysis of the extreme event of the financial crisis in autumn 2008 produces an upper bound for domestic hoardings of €110 billion, assuming the same hoarding behaviour for residents and non-euro-area residents throughout the observation period.<sup>49</sup> This assumption may well be justified for during the crisis. It appears somewhat implausible before (and after) the crisis, however.<sup>50</sup> Accordingly, the volume of hoarding in Germany would have to be set at a lower level than in the financial crisis approach. A value of around €70 billion appears realistic here. Not only does this amount fall between the rather conservative estimate based on seasonal methods (around €40 billion) and the estimate based on the financial crisis approach, which is probably significantly overstated (€110 billion). It also corresponds roughly to the value derived for the volume of €200 and €500 banknotes remaining in Germany (just over €75 billion), which is produced by adjusting the corresponding Bundesbank cumulated net issuance by the amount of cash taken abroad when travelling and the official net shipments via banks.<sup>51</sup>

As the estimated figure for domestic hoardings of around €70 billion during the observation period is probably considerably lower than the net outflows of small denominations from Germany to other countries (around €135 billion), the above point estimate of total foreign demand for German euro banknotes of €160 billion needs to be revised upwards significantly and should therefore be interpreted as a lower bound.

### **2.2.6 Information from the euro cash changeover**

The following section attempts to extract information about residents' transaction balances at the beginning of 2002 from developments in D-Mark and euro banknotes in Germany during the euro cash changeover. These balances will then be extrapolated using the growth rate of

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<sup>47</sup> See also Bartzsch, Rösl and Seitz (2011), section 3.1.

<sup>48</sup> See the overview of results in chapter 3 as well as the overview of results in Bartzsch, Rösl and Seitz (2011), chapter 4.

<sup>49</sup> See also Bartzsch, Rösl and Seitz (2011), section 3.4.

<sup>50</sup> See also Fischer, Köhler and Seitz (2004), section 6.2.

<sup>51</sup> See also Bartzsch, Rösl and Seitz (2011), Table 9.



nominal private consumption expenditure up to the end of 2009.<sup>52</sup> The difference between actual cumulated German banknote issuance and the transaction balance calculated using this method then produces the sum of total foreign demand and domestic hoarding.

We use two alternatives to derive the starting values. Alternative 1 is based on the volume of D-Mark banknotes still in circulation at the end of 2001 (€76.5 billion). At the same time, due account is taken of the fact that, after the first nine days of 2002, roughly 90% of domestic cash payments were already being made in euro (Deutsche Bundesbank, 2002). The conversion of the transaction balances therefore appears to have been largely completed by this time. The remaining D-Mark banknotes still outstanding on 9 January 2002 to the value of €46.7 billion (Deutsche Bundesbank, 2002), less 10% that was still in use for cash payments in D-Mark (€8.5 billion), can therefore be assigned to domestic hoarding and foreign demand. The €8.5 billion corresponds to 10% of euro banknotes in Germany on 9 January 2002 in the amount of €76.1 billion, extrapolated to 100% ( $76.1/0.9 = 85$ ).<sup>53</sup> This gives a transaction balance of €38.3 billion in Germany at the start of 2002 [ $76.5 - (46.7 - 8.5)$ ]. Extrapolating this to the end of 2009 results in (domestic) transaction balances of around €42 billion.

Alternative 2 resorts to Seitz (2007), who calculated a transaction share in Germany of 25% in 2000. This corresponds to roughly €35 billion. Extrapolating this figure, in turn, by nominal private consumption results in transaction balances of €40.4 billion at the end of 2009. Both variants thus yield amounts which are higher than those calculated by Deutsche Bundesbank (2009, p 49) for 2008 of €31 billion, which were also used in Bartzsch, Rösl and Seitz (2011), section 3.3. However, the differences are likely to be in a range covered by estimation uncertainties. Thus, according to the calculations presented here, the sum of foreign demand and domestic hoarding accounted for just under €310 billion at the end of 2009.

### **2.2.7 Age of banknotes**

In the Eurosystem, the fitness of euro banknotes in circulation is checked by national central banks or by commercial banks as part of the cash cycle. In addition to identifying counterfeits, this is also designed to ensure the high quality of the banknotes. This

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<sup>52</sup> The seasonal structure of banknotes could also be used for this extrapolation. If, for example, the intra-monthly and intra-weekly seasonal figures display an increasingly dampened amplitude over the years, this is likely to be due to non-transaction-driven demand (hoarding, foreign demand). The transaction balances in Germany can then be derived from this information. Unfortunately, no daily seasonally-adjusted banknote time series, which might be used to calculate daily seasonal factors, is available for Germany.

<sup>53</sup> We assume here that, during the first nine days of 2002, foreign holdings and domestic hoardings of banknotes had not yet accumulated.

furthermore implies that damaged or soiled banknotes are removed from circulation and replaced by new ones.

A banknote issued by the Bundesbank will either be located in Germany or in a euro-area or non-euro-area country. If it is circulating in another euro-area country, it will be removed from circulation at some point by the national central bank. If it is located in a non-euro-area country, it will either never return to the Bundesbank or do so with a time lag. Foreign demand thus results in banknotes issued by the Bundesbank having a longer (measured) life (with possibly lower quality). The foreign share can be derived by comparing the actual age of notes with the “normal” lifespan.<sup>54</sup>

In the Currency Information System 2 (CIS2) of the European Central Bank, all of the Eurosystem national central banks provide their issuance data on a monthly basis, including the average volume of banknotes in circulation, the volume of new issuance, and the number of banknotes removed from circulation. The data are broken down by denomination. However, due to the changeover from CIS1 to CIS2, it has been possible to consistently examine the data only since September 2008. For our purposes, this means that we cannot derive a time series for foreign demand since 2002 and must confine ourselves to the average holdings in 2009.

Formulas for calculating the average life of banknotes have been developed by central banks and the institutions charged with printing banknotes (in line with the calculation of the average life expectancy of the population).<sup>55</sup> Here, we use the Eurosystem formula (see CIS2). The average lifetime is calculated as a weighted arithmetic mean of the inflows and outflows.

$$(21) \quad AL_t = \frac{n_t}{\frac{q_t + v_t}{2}},$$

where  $n$  denotes the (average) volume of banknotes in circulation,  $q$  the (average) volume of new issuance,  $v$  the (average) number of banknotes destroyed (each in units) and  $t$  the corresponding year (in our case, 2009).<sup>56</sup> Equation (21) produces meaningful results given a stable volume of banknotes in circulation and if the banknote has been in circulation for a

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<sup>54</sup> Originally, an attempt was made to draw conclusions about the hoarding or transaction share of various denominations from the average life of banknotes. See, for example, Boeschoten (1992), section 3.3.

<sup>55</sup> For a general (and formal) description of the calculation of the lifespan of banknotes, see Den Butter and Coenen (1982).

<sup>56</sup> Seitz (1995), section V.2.5 works in the numerator with the term  $(n_t + n_{t-1})$ . Owing to persistencies in banknote developments, the results change only marginally as a result of this.

sufficiently long period of time.<sup>57</sup> To achieve this, the currency must have already existed with the same denomination structure for some years and show no extreme banknote movements during the observation period. The first condition is undoubtedly fulfilled for the euro. However, distortions in the results might be produced by the insolvency of Lehman Brothers in September 2008 and its impact on the demand for cash (see also Bartzsch, Rösl and Seitz (2011), subsection 3.4), which could still be felt in 2009.

To calculate the “normal” lifespan of German banknotes, we again use France as a reference country. Once more, it is assumed that there is no significant non-euro-area demand for banknotes issued by France. Therefore, “French” banknotes should have a shorter lifespan than “German” banknotes. This is precisely the case. While the average age of “French” euro banknotes in 2009 was around two years, German banknotes were more than twice as old during the same period, with an average age of just under five years. In France there are slight differences in the ages of the banknotes when broken down by denomination, but with no clear trend. The oldest banknotes are the €20 and €100 denominations, at four and six years, respectively. In Germany, by contrast, higher denominations are generally older than lower denominations.

Given the methodology of section 2.1, the age characteristics can be used to derive the domestic share ( $\beta^d$ ) and the foreign share ( $\beta^a = (1 - \beta^d)$ ) (Feige, 2009, page 185 ff).

$$(22) \quad \begin{aligned} AL &= \beta^d AL^d + (1 - \beta^d) AL^a \\ \Leftrightarrow \beta^d &= \frac{AL - AL^a}{AL^d - AL^a} \end{aligned}$$

Specifically, by comparing the average ages of German and French euro banknotes, the foreign share of “German” banknotes ( $\beta^a$ ) in 2009 can be calculated using equation (23)

$$(23) \quad \beta_{2009}^a = (1 - \beta_{2009}^d) = \frac{(AL_{2009}^D - AL_{2009}^F)}{AL_{2009}^D}$$

where  $D$  and  $F$  stand for the countries Germany and France. The percentage of foreign holdings calculated using this equation amounted to just over 60% on an annual average for 2009, weighted over all denominations. In absolute terms, this corresponds to just under €215 billion. As “German” banknotes also circulate in other euro-area countries (to a significantly greater extent than “French” banknotes), this figure refers to *total* foreign demand (intra euro area and extra euro area). In light of the estimation uncertainties and the fact that the

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<sup>57</sup> The Eurosystem assumes a period of at least one year.

changeover from CIS1 to CIS2 did significantly reduce the age of German banknotes, this figure is compatible with the foreign holdings of banknotes estimated earlier.

### **3 Overview of results**

The results of the approaches discussed in chapter 2 are shown in Table 2 below. Chapter 4 concludes with an analysis of these results.

**Table 2: Overview of estimation results**

	2.2.1 Banknote ratios	2.2.2 Seasonal methods	2.2.3 Coin issuance	2.2.4 Banknote demand function	2.2.5 Pattern of withdrawal and lodgement	2.2.6 Euro cash changeover	2.2.7 Age of banknotes
	€ billion (end of 2009)						
<b>Cumulated net issuance of euro banknotes in Germany</b>	350	350	350	350	350	350	350
<b>Total volume of German euro banknotes in circulation outside Germany</b>	145 (LL)	250	170 (LL)	240 (210 LL, 270 UL)	160 (LL)	310*	215
Volume of German euro banknotes in circulation outside the euro area	100 (LL)	160	170	-	-	-	-
Cumulated net exports of euro banknotes from Germany to other euro-area countries	50	90	-	-	-	-	-
<b>Domestic circulation</b>	<b>205 (UL)</b>	<b>100</b>	<b>180 (UL)</b>	<b>110 (80 LL, 140 UL)</b>	<b>190 (UL)</b>	<b>40</b>	<b>135</b>
Transaction balances	-	60	-	-	-	40	-
Hoarding	-	40	-	-	-	-	-
	Percentage of cumulated net issuance of euro banknotes in Germany (end of 2009)						
<b>Cumulated net issuance of euro banknotes in Germany</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>
<b>Total volume of German euro banknotes in circulation outside Germany</b>	<b>40% (LL)</b>	<b>70%</b>	<b>50% (LL)</b>	<b>70% (60% LL, 75% UL)</b>	<b>45% (LL)</b>	<b>90%*</b>	<b>60%</b>
Volume of German euro banknotes in circulation outside the euro area	30% (LL)	45%	50%	-	-	-	-
Cumulated net exports of euro banknotes from Germany to other euro-area countries	15%	25%	-	-	-	-	-
<b>Domestic circulation</b>	<b>60% (UL)</b>	<b>30%</b>	<b>50% (UL)</b>	<b>30% (25% LL, 40% UL)</b>	<b>55% (UL)</b>	<b>10%</b>	<b>40%</b>
Transaction balances	-	15%	-	-	-	10%	-
Hoarding	-	10%	-	-	-	-	-

*Notes:* Lower limit: LL, upper limit: UL. \* Including domestic hoarding. All values have been rounded to the nearest €5 billion or 5%. Figures may not add up due to rounding.

*Sources:* Deutsche Bundesbank and authors' own calculations

## 4 Summary and conclusions

This paper has endeavoured to use indirect methods to determine foreign demand for euro banknotes issued in Germany. It has been found that, at the end of 2009, around 70% of the cumulated net issuance was held outside Germany (approx €240 billion). Of this, the lion's share (roughly €160 billion) was in non-euro-area countries, with the remainder in other euro-area countries. This also means that only a relatively small share – approximately €110 billion – was used for transaction purposes and hoarding in Germany. Although the results of the indirect approaches are therefore slightly higher than the figures obtained in the direct approaches (see Bartzsch, Rösl and Seitz, 2011), the latter are largely confirmed. In our opinion, a realistic figure for banknotes hoarded in Germany is €70 billion. Consequently, only around €40 billion were used in Germany for transaction purposes. This is the equivalent of around €500 *per capita*.

According to estimates by the ECB (European Central Bank, 2010, p 36 and 2011, p 31), between 20% and 25% of all euro banknotes issued by the Eurosystem are in non-euro-area countries. At the end of 2009, this was equivalent to somewhere between €160 billion and €200 billion. Therefore, at least 80% of these banknotes are likely to have come from German origin. This is also in line with statistics on the shipments of banknotes via banks to non-euro-area countries, which put (cumulated) net shipments from Germany at the end of 2009 at 95% of total net shipments.

In a study of the consequences of the introduction of the euro for individual euro-area-countries' seigniorage income, Sinn and Feist (2000) as well as Rösl (2002) determined that, due to the pooling of monetary income (national central banks' interest income from banknote issuance) following the changeover from D-Mark to euro, Germany is a clear loser, as the pooling process means that income from central bank assets, which national central banks had before they joined the euro area, is also communitised. In the pooling process, seigniorage, which is distributed to the national central banks (NCBs) for further use, is ultimately not dependent on net issuance by the NCBs but on the respective ECB capital share. Seitz, Stoyan and Tödter's (2009) analysis of coin issuance and movements of coins in the euro area concluded that Germany transfers coin seigniorage to other euro-area countries. Furthermore, Rösl (2010) discovered that the Bundesbank's seigniorage income is increasingly being reduced as a result of the introduction of virtual central bank safes at commercial banks (notes-held-to-order systems) in other euro-area countries.

Foreign demand, which is predominantly met by Germany, entails costs which can be directly allocated. Germany is reimbursed for only part of these costs via the allocation mechanism in the euro area. While the costs of banknote *production* are allocated to the NCBs in accordance with their ECB capital share, when monetary income is allocated claims cannot be made for banknote *processing* costs incurred by the NCBs. In Germany, these costs are higher than the German capital share of 27%. However, it must be borne in mind that German banknote issuance has increased at a significantly faster pace since the euro cash changeover. How banknote issuance would have developed without monetary union is a matter of speculation.

As demonstrated by Seitz and Setzer (2009), the statistical-econometric quality can be raised and the economic interpretation of cash demand functions for Germany can be made easier if arguments for foreign demand are incorporated.<sup>58</sup> Given the results and the figures derived in this paper, this comes as no surprise. Aksoy and Piskorski (2005; 2006) have determined for the US that the indicator properties of narrow monetary aggregates with regard to cyclical and price developments can be improved considerably by taking foreign demand into account. Whether this is also the case for Germany or the euro area as a whole should be the subject of future research.

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<sup>58</sup> See also Krüger (2007).

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