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## Domestic and foreign demand for euro banknotes issued in Germany

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# **Domestic and foreign demand for euro banknotes issued in Germany**

**Nikolaus Bartzsch**, Deutsche Bundesbank and **Matthias Uhl**, Deutsche Bundesbank

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## **Abstract**

To facilitate a more detailed study of the volume of euro banknotes in circulation issued by the Deutsche Bundesbank, it is broken down into the components of foreign demand, domestic hoarding and domestic transaction balances. These banknote demand components are estimated using the direct approach “net shipments and foreign travel” as well as an indirect approach known as the “seasonal method”. According to the new estimates, which are based on a combination of the two approaches, around 65% to 70% of the arithmetical volume of euro banknotes issued by the Bundesbank were in circulation outside Germany at the end of 2015; of this figure, 40 to 50 percentage points were in circulation outside the euro area, and 20 to 30 percentage points in other euro-area countries. Between 30% and 35% of the Bundesbank’s cumulated net issuance was in circulation in Germany, of which 25 percentage points were hoarded and 5 to 10 percentage points held for transaction purposes. The newly estimated time series for domestic hoardings does not feature a noticeable break due to the euro area’s low-interest-rate environment; instead, Bundesbank-issued euro banknotes may be circulating in other euro-area countries in greater numbers.

## **JEL classification**

E41, E58

## **Key words**

Euro banknote demand, foreign demand, transaction balances, hoardings

## 1 Introduction

As a rule, the banknotes of a given currency can be used as a means of payment and store of value not only in the relevant currency area, but outside it as well. Euro and US dollar banknotes, in particular, are likely to be used on a considerable scale worldwide. Using a combination of different estimation methods, Judson (2012) asserts that just over half of US currency in circulation is probably held outside the United States.<sup>1</sup> Based on an evaluation of euro currency flows through international banknote wholesale banks, the European Central Bank estimates that, in terms of value, much more than 18% of the stock of euro banknotes in circulation is likely to be found outside the euro area (European Central Bank, 2015).

It is particularly true of the euro area that banknotes issued by a central bank do not necessarily circulate in that bank's country. There are currently 19 national central banks (NCBs) in the Eurosystem, and the euro banknotes issued by each of them can migrate freely across national borders. An NCB's arithmetical stock of banknotes in circulation therefore cannot provide direct insight into the volume of banknotes in circulation in that country. Against this background, the Bundesbank determines the components of its cumulated net issuance of euro banknotes on an ongoing basis; these are foreign demand, domestic transaction balances and domestic hoarding. These analyses help in gaining an understanding of developments in the circulation of the banknotes issued by the Bundesbank and are the key prerequisite for quantifying the scale of cash usage in Germany.

The new estimates of the components of demand for Bundesbank-issued banknotes that are presented in this paper build on the extensive studies contained in Bartsch et al (2011a, 2011b), in particular, which analyse the period up to and including 2009. Those papers found that at the end of 2009 around 65% to 70% of the Bundesbank's cumulated net issuance of euro banknotes was in circulation outside Germany. Bartsch and Seitz (2016) and Bartsch (2017) use the biometric method, as it is called, to determine the holding of transaction balances of €5, €10 and €20 banknotes in Germany and outside the euro area. According to the estimates, between one-fifth and one-sixth of the arithmetical stock of banknotes in circulation issued by the Bundesbank in these denominations is held in domestic transaction balances. Holdings of transaction balances in these denominations outside the euro area are small; only in the case of the €20 banknote are the non-euro-area transaction balances significant, with a share of just over 7% in the total arithmetical stock of Bundesbank-issued banknotes of this denomination in circulation. In what is regarded as a landmark study, Seitz

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<sup>1</sup> Further analyses of foreign demand for US dollar cash can be found in Porter and Judson (1995, 1996) and Feige (2012), for example. Feige (2012) evaluates data on net shipments of US dollar banknotes by wholesale currency shippers as well as surveys on cash taken abroad by travellers and cash remittances by migrants. In the end, Feige (2012) estimates that the amount of US dollars in circulation outside the United States is just US\$230 billion, or 23% of US currency in circulation.

(1995) estimates that at the end of 1994 between 30% and 40% of the Deutsche Mark banknotes in circulation, or Deutsche Mark banknotes with a value ranging between DEM 65 billion and DEM 90 billion, were to be found outside Germany.

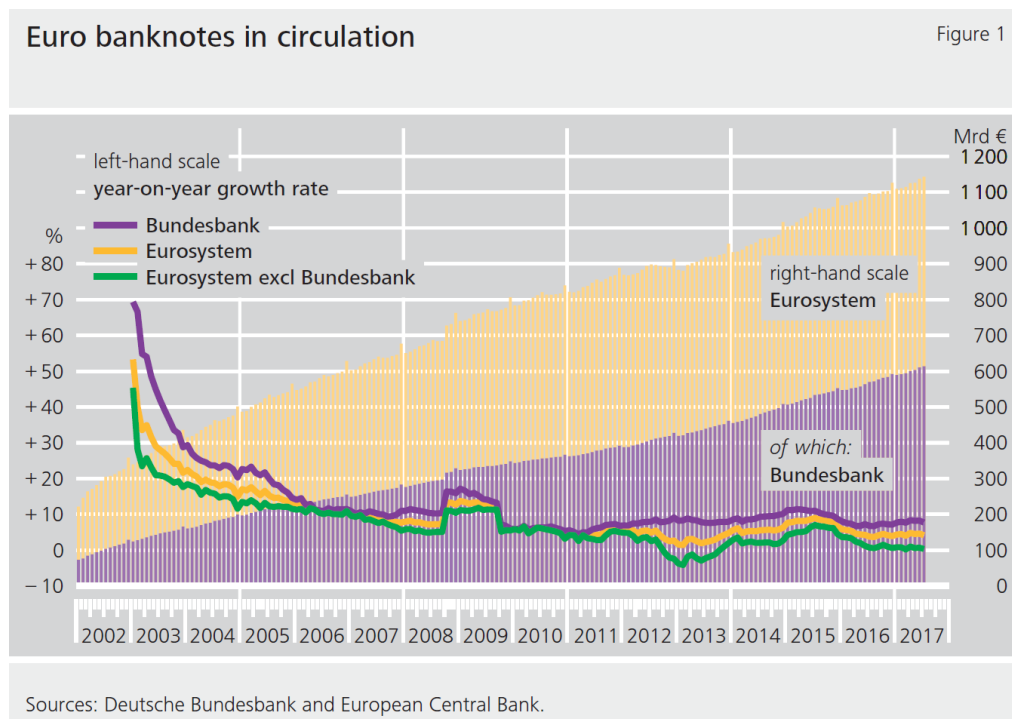
The present paper first uses a direct approach, namely the “net shipments and foreign travel” approach, to estimate the banknote demand components. In this approach, the volume of Bundesbank-issued banknotes in circulation outside Germany is determined using the Bundesbank’s cumulated net issuance derived from wholesale banks active in the global market for currency trading and using estimates of euro banknotes taken abroad by travellers. While total domestic transaction balances consisting of credit institutions’, households’ and retailers’ transaction balances can be estimated, domestic hoardings are the resultant residual in this approach. In order to directly estimate domestic hoardings and also check the validity of the estimates of the other banknote demand components, an alternative, indirect estimation approach called the “seasonal method” is additionally used. According to the new estimate, which is based on both approaches, between 65% and 70% of the euro banknotes issued by the Bundesbank were in circulation outside Germany at the end of 2015, with 40 to 50 percentage points outside the euro area and 20 to 30 percentage points in other euro-area countries. Between 30% and 35% of the Bundesbank’s cumulated net issuance was in circulation in Germany. The major part of this – 25% of the Bundesbank-issued euro banknotes in circulation – is hoarded. Only 5% to 10% of the cumulated net issuance is held in domestic transaction balances.

The development of banknote hoarding is particularly interesting in the context of the current low-interest-rate environment. The time series for domestic hoarding, estimated up to the end of 2015 using the seasonal method, indicates a smooth development despite the current low-interest-rate environment. Instead, there are indications that stocks of Bundesbank-issued euro banknotes in other euro-area countries have risen considerably in recent years.

The remainder of this paper is structured as follows. Section 2 describes developments in the circulation of euro banknotes issued by the Eurosystem and by the Bundesbank. Sections 3 and 4 go on to discuss the breakdown of the Bundesbank’s cumulated net issuance into the components of foreign demand, domestic hoarding and domestic transaction balances using a direct approach or the seasonal method. Section 5 develops a combination of these new estimates, while section 6 concludes.

## 2 Demand for euro banknotes

The volume of euro banknotes in circulation issued by the Eurosystem and by the Bundesbank is shown in Figure 1.<sup>2</sup> The volume of euro banknotes in circulation signifies the volume of banknotes held by economic players within and outside the euro area and therefore represents the total usage of euro banknotes as a means of payment and store of value. At the end of January 2002, shortly after euro cash was introduced, the cumulated net issuance of euro banknotes by the Eurosystem totalled roughly €220 billion. At the end of 2004, this cumulated net issuance came to more than €500 billion for the first time, and at the end of 2014 it exceeded the €1,000 billion mark. The volume of euro banknotes in circulation stood at €1,126 billion at the end of 2016, in addition to which the 19 Eurosystem NCBs have issued euro coins in the net arithmetical amount of €26.9 billion. These figures show that the combined use of euro cash as a means of payment and store of value within and outside the euro area is on the rise.



The Bundesbank is part of the Eurosystem and contributes to the development of the total stock of euro banknotes in circulation by issuing and accepting euro banknotes. The arithmetical volume of Bundesbank-issued euro banknotes in circulation has grown

<sup>2</sup> Descriptions of developments in the volume of euro banknotes in circulation issued by the Eurosystem and by the Bundesbank can also be found, for instance, in Bartsch et al (2015) and Deutsche Bundesbank (2016).

particularly dynamically. At the end of January 2002, the outstanding volume amounted to €73.3 billion, or 33.1% of the total stock of euro banknotes in circulation, while at the end of December 2016, it stood at €592.2 billion, or 52.6% of the total stock of euro banknotes in circulation. The Bundesbank was therefore responsible for a considerable portion of the net issuance of euro banknotes in circulation. One particular reason for this is likely to be that the Bundesbank meets the foreign demand for euro banknotes to a large degree by way of banknote shipments to banknote wholesale banks and through banknotes taken abroad by residents travelling. The Bundesbank's role in wholesale euro banknote trade has also evolved historically, because it already had business relationships with wholesale banks active in currency dealing owing to the considerable volume of Deutsche Mark cash that was in circulation abroad. Other factors contributing to the particular growth in the outstanding volume of euro banknotes issued by the Bundesbank are probably Germany's geographical location at the heart of Europe, the convenience of Frankfurt airport and the significant amount of travel undertaken by the resident population.

Figure 1 also shows the growth rates of euro banknotes in circulation compared with the same month of the previous year for the Eurosystem and the Bundesbank. These growth rates of euro banknotes in circulation were very high in the first years after the introduction of the single currency, in particular; between the end of January 2002 and the end of January 2003, for example, the total stock of euro banknotes in circulation grew by 53.3%, with the outstanding volume of euro banknotes issued by the Bundesbank even rising by 69.4%. These especially striking growth rates in the first few years after the introduction of euro cash can probably be attributed to the changeover of national currencies. Cash users are likely to have particularly dissolved banknote hoardings earmarked for long-term storage in the months preceding the replacement of the national currencies and subsequently replenished them after the introduction of euro cash. Nonetheless, the growth rates of euro banknotes in circulation are also consistently high. From December 2006 to December 2016, the stock of euro banknotes in circulation issued by the Eurosystem grew by an average of 6.0% each year, while the outstanding volume of euro banknotes issued by the Bundesbank even rose by an annual average of 8.8%. This growth can be explained, in part, by an increase in the price level as well as in economic output in the euro area and Germany. Even so, the volume of euro banknotes in circulation grew more dynamically overall than could have been expected based on these factors alone. One reason for this is the strong demand from abroad for euro banknotes, which will be analysed in more detail later in this paper. The increase in the growth rates of euro banknotes in circulation from October 2008 is also striking. During the Lehman crisis, as it came to be known, a number of investors evidently viewed euro cash as a safe investment.

Figure 2 and Table 1 show the value of euro banknotes in circulation, broken down by denomination, for both the Eurosystem and the Bundesbank. In terms of value, the €500, €100 and €50 banknotes, in particular, are significant. The increase in €500 and €100 banknotes in circulation in 2008 is notable, when investors sought these particular banknote denominations as a store of value while the financial crisis intensified. When news began emerging in February 2016 that halting production and issuance of the €500 banknote was under consideration, the outstanding volume of this banknote denomination declined. At the end of 2016, the joint share of the large €100, €200 and €500 denominations in the total volume of banknotes in circulation stood at 55.4% for the Bundesbank and 43.4% for the rest of the Eurosystem excluding the Bundesbank. In other words, the share of large banknote denominations in the total volume of euro banknotes in circulation is much higher for the Bundesbank than for the rest of the Eurosystem. One possible reason for this could be the greater use of large banknote denominations as a transaction medium or store of value in Germany. However, a study by the European Central Bank, which analysed cash usage in Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands and Spain, found that, if anything, Germany has a below-average number of users of €200 and €500 banknotes (European Central Bank, 2011). This suggests that the reason for the large percentage of high-value banknotes in the Bundesbank's outstanding volume of banknotes is likely to be the use of German-issued euro banknotes in other countries. Bartsch et al (2011b) do indeed find that €500 euro banknotes issued by the Bundesbank are especially prevalent outside Germany. After a detailed evaluation of the denomination structure of the cumulated net issuance, Bartsch et al (2011a) put the level of hoardings in Germany at the end of 2009 at €70 billion, or 20% of the Bundesbank's cumulated net issuance.



Euro banknotes in circulation by denomination

Figure 2

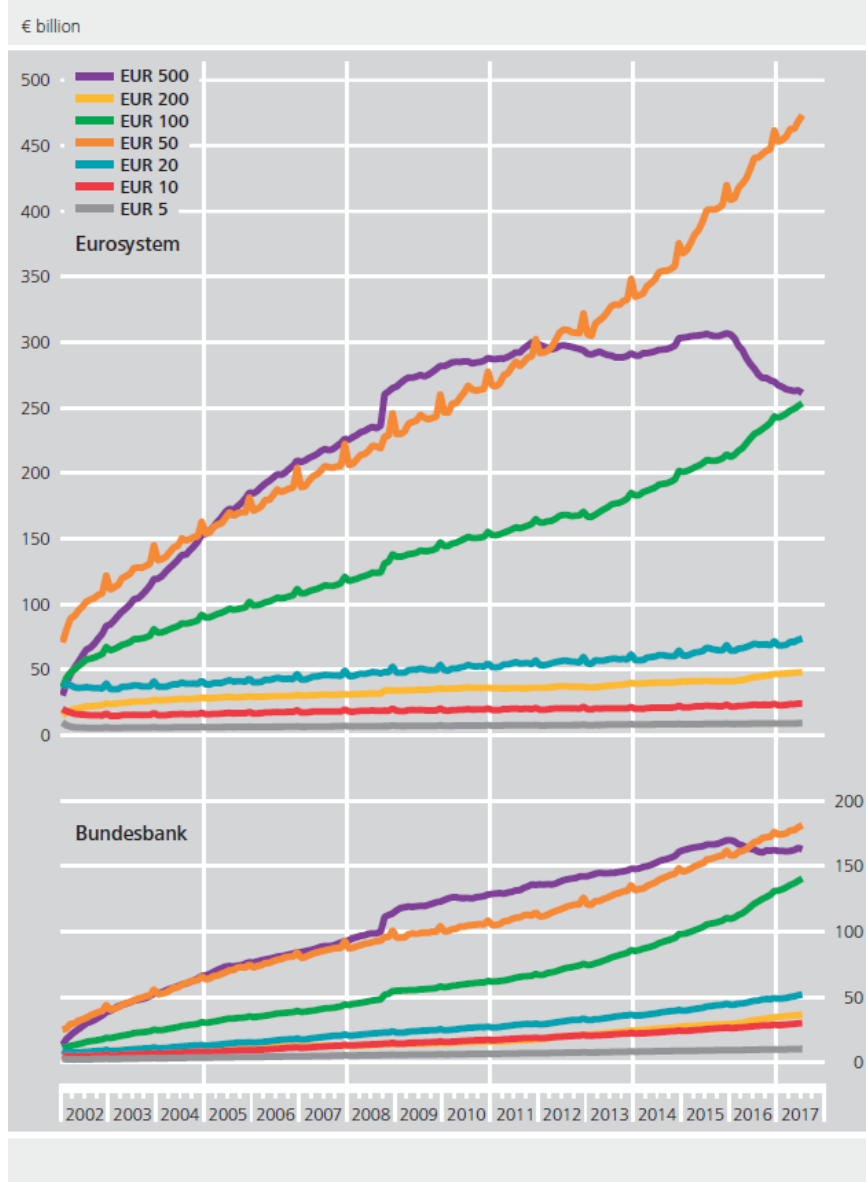
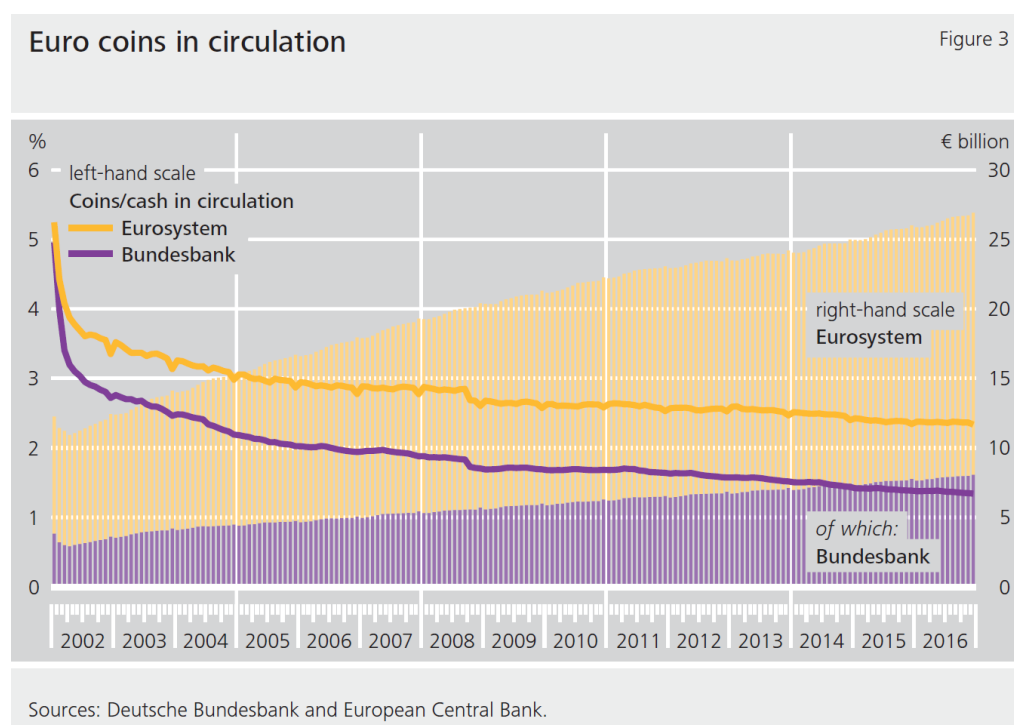


Table 1: Euro banknotes in circulation by denomination at the end of 2016

	Eurosystem		Deutsche Bundesbank	
	€ billion	%	€ billion	%
EUR 500	269.9	24.0	162.2	27.4
EUR 200	46.7	4.1	34.6	5.8
EUR 100	243.3	21.6	131.0	22.1
EUR 50	461.6	41.0	176.1	29.7
EUR 20	71.8	6.4	49.2	8.3
EUR 10	23.9	2.1	28.9	4.9
EUR 5	9.0	0.8	10.2	1.7
<b>Total</b>	<b>1,126.2</b>	<b>100.0</b>	<b>592.2</b>	<b>100.0</b>

Sources: Deutsche Bundesbank and European Central Bank.

The volume of euro cash in circulation consists of the euro banknotes and coins in circulation. Figure 3 shows the cumulated net issuance of euro coins by the Eurosystem and by the Bundesbank. The analyses presented in this paper look at the components of the outstanding volume of euro banknotes issued by the Bundesbank. Concentrating on the banknotes in circulation is warranted given the low-value share of outstanding coins in the total volume of cash in circulation.<sup>3</sup> At the end of 2016, coins in circulation accounted for a 2.3% share of the cash in circulation in the Eurosystem; the arithmetical volume of coins in circulation issued by the Bundesbank made up just 1.3% of the arithmetical cumulated net issuance of euro cash by the Bundesbank. The balance of euro coins held for transaction purposes in Germany is analysed in Deutsche Bundesbank (2015a) and Altmann and Bartzsch (2014). According to these studies, euro coins with a value of €2.3 billion were held in domestic transaction balances in 2011, corresponding to 36% of the total stock in circulation at that time.



<sup>3</sup> The Bundesbank, as Germany's central bank, issues euro banknotes. In Germany, responsibility for coin minting lies with the Federal Government, represented by the Federal Ministry of Finance. The Bundesbank purchases euro coins from the Federal Government at their nominal value and introduces them into circulation.

### **3 Components of banknote demand using direct approaches**

#### **3.1 Regional distribution of Bundesbank-issued euro banknotes using direct approaches**

International migration of euro banknotes can take place via various channels, for instance shipments of euro banknotes abroad by banks that are active in the global market for currency dealing, euro banknotes taken abroad by travellers, remittances by foreign workers and the settlement of transactions in international payments. The “net shipments and foreign travel” approach looks at two of these channels. In this approach, the volume of banknotes in circulation outside Germany is derived from the Bundesbank’s household survey on foreign travel and data on cumulated net shipments to international wholesale currency shippers who supply the German-issued euro banknotes to non-euro-area countries.

As part of the balance of payments statistics, the Bundesbank conducts household surveys on how much euro cash Germans take with them when they travel abroad. For more on the methodology used, see also Deutsche Bundesbank (2003, 2005, 2015c) and Bartzsch et al (2011a). Some of the results are shown in Table 2.<sup>4</sup> Where useful, this information includes breakdowns by cash flows to euro-area countries and non-euro-area countries (ie intra and extra-euro-area cash flows); however, Table 2 only shows the results for total inflows and outflows of euro cash as a result of foreign travel. In 2015, euro cash with a total value of €23.1 billion was taken abroad through foreign travel, of which €13.5 billion went to other euro-area countries and €9.6 billion ended up in non-euro-area countries. Travellers took euro cash totalling €4.8 billion abroad in 2015 and exchanged it for foreign currency there, while they took a total of €18.4 billion abroad and used it for cash payments there. Conversely, travellers brought an estimated €6.7 billion into Germany in 2015. Of that, some €5.3 billion originated in other euro-area countries and €1.4 billion in non-euro-area countries. Overall, a net total of approximately €222 billion flowed abroad through foreign travel up until the end of 2015. By the end of the second quarter of 2016, this figure had increased to just over €228 billion. For reasons of data availability, banknote demand components will be analysed as at end-2015 in the remainder of this study.

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<sup>4</sup> As there are no comparable surveys on what euro cash inflows foreign travellers to Germany generate, the latter are estimated based on the assumption that the behaviour of foreign travellers to Germany is similar to that of German travellers abroad. The household survey looks at cash carried, though this is primarily likely to constitute banknotes.

**Table 2: Inflows and outflows of euro cash as a result of travel in € million**

	Cash outflows			Cash inflows		Cash in circulation abroad as a result of travel	
	Total	Euro cash taken abroad and exchanged into foreign currency	Cash payments made abroad using euro imported from Germany	Estimated cash imports via travel	euro imports via	Net outflows	Cumulated
<b>2015 Q1</b>	3,975	806	3,169	1,418		2,557	208,228
<b>2015 Q2</b>	5,352	821	4,531	1,798		3,554	211,782
<b>2015 Q3</b>	8,059	1,786	6,273	1,934		6,125	217,907
<b>2015 Q4</b>	5,754	1,373	4,381	1,576		4,178	222,085
<b>2016 Q1</b>	3,972	753	3,219	1,397		2,575	224,659
<b>2016 Q2</b>	5,393	960	4,433	1,756		3,637	228,296

Source: Deutsche Bundesbank.

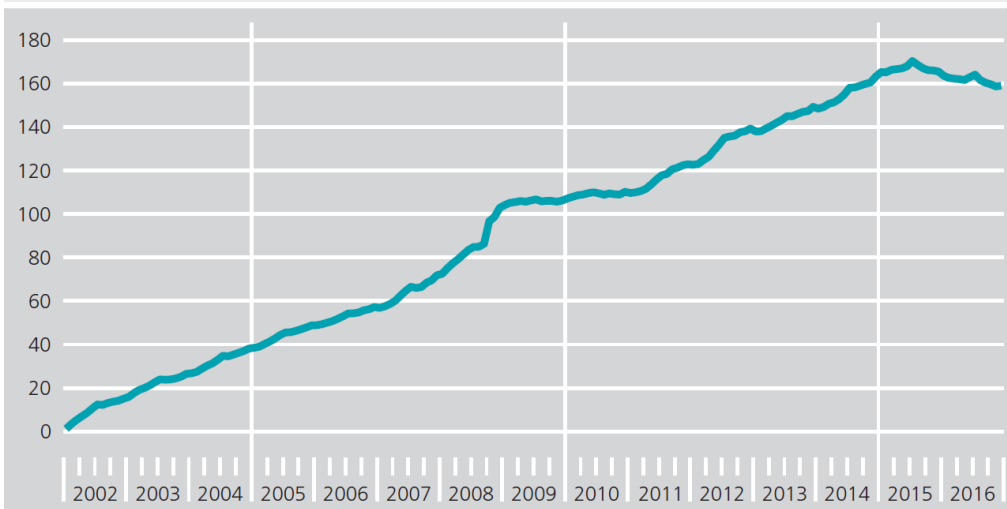
Another channel via which German-issued euro banknotes migrate abroad are outpayments to banks active in the global market for currency dealing. These banks order euro banknotes from the Bundesbank and ship them to non-euro-area countries, where they are used, for instance, to stock bureaux de change. Flows of banknotes between the Bundesbank and wholesale currency shippers are included in the Bank's accounting system.<sup>5</sup> Figure 4 shows cumulated net shipments defined as the cumulated difference between the Bundesbank's outpayments to wholesale currency shippers and the latters' inpayments to the Bundesbank.

<sup>5</sup> The data for 2002 and 2003 are, however, based on a Bundesbank survey among wholesale currency shippers and on information provided by the Bundesbank's branches.

Cumulated net shipments as a result of international banknote wholesale trade

Figure 4

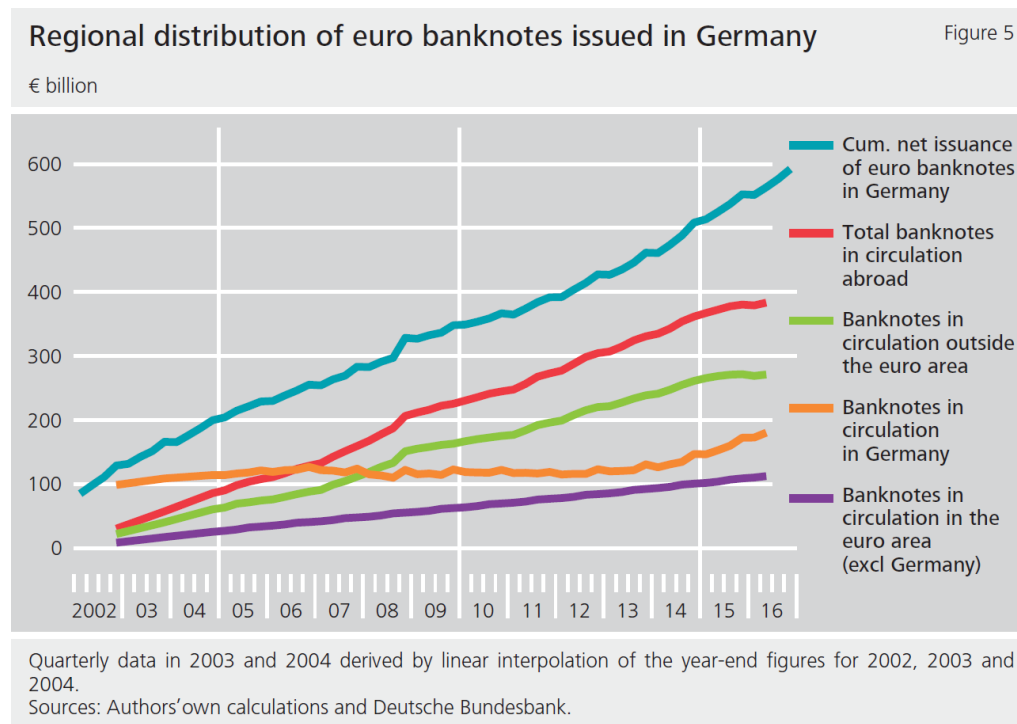
€ billion



Sources: Deutsche Bundesbank.

The regional distribution of euro banknotes issued in Germany estimated using this approach is shown in Figures 5 and 6. At the end of 2015, the lion's share of the Bundesbank's cumulated net issuance in the amount of just over €550 billion was thus accounted for by banknotes in circulation abroad, namely €380 billion, or 70% of cumulated net issuance. At roughly €270 billion, or 50% of cumulated net issuance, the majority of banknotes in circulation abroad were outside the euro area. However, Germany was also a major net exporter of euro banknotes to the rest of the euro area via foreign travel, with banknotes with a net value of approximately €110 billion, or 20% of cumulated net issuance, finding their way there. The banknotes in circulation outside the euro area can be attributed to foreign travel and net shipments, with the latter, in cumulative terms, making the largest contribution at just over €158 billion, or 29% of the Bundesbank's cumulated net issuance. The volume of banknotes in circulation in Germany rose somewhat in the first few years after the introduction of euro cash, before standing at roughly €120 billion between 2005 and 2012, with slight fluctuations. Its percentage of cumulated net issuance consequently fell steadily, from 77% at the end of 2002 to 28% at the end of 2013. The volume of banknotes in circulation in Germany did not start picking up again perceptibly until 2013. It is therefore clear that, according to the estimates using the "net shipments and foreign travel" approach, cumulated net issuance of banknotes by the Bundesbank was driven almost exclusively by banknotes in circulation abroad up until the end of 2012, while domestic demand for banknotes for transaction balance and hoarding purposes was roughly constant. This did not

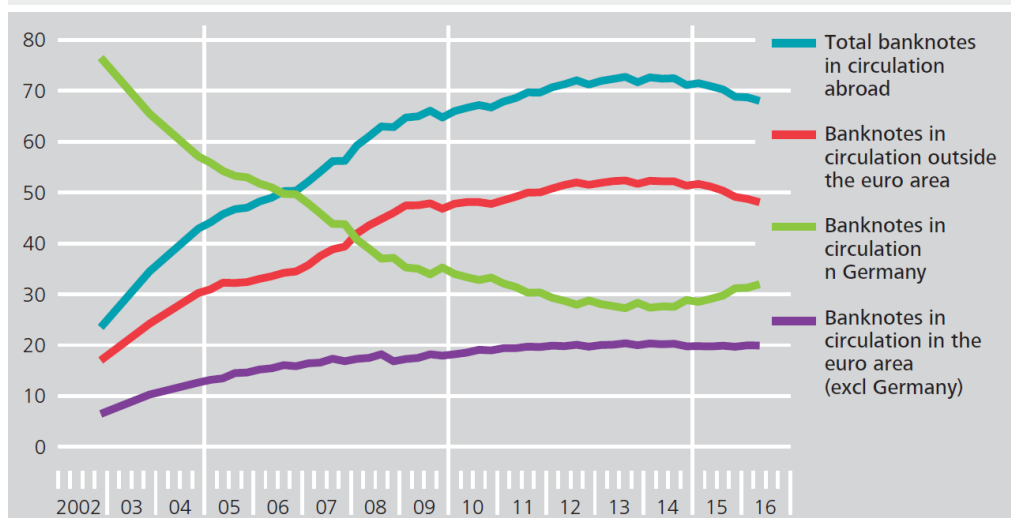
change until 2013. Of the entire increase in cumulated net issuance of euro banknotes by the Bundesbank in 2015, to the tune of €45 billion, an estimated €25 billion, or more than half, was attributable to higher domestic demand. In 2014 and 2015, the circulation of banknotes within Germany rose as a percentage of cumulated net issuance. The reasons for the growth in banknotes in circulation in Germany are examined in the following subsection.



Regional distribution of euro banknotes issued in Germany

Figure 6

As a percentage of cumulated net issuance by the Bundesbank



Quarterly data in 2003 and 2004 derived by linear interpolation of the year-end figures for 2002, 2003 and 2004.

Source: Authors' own calculations.

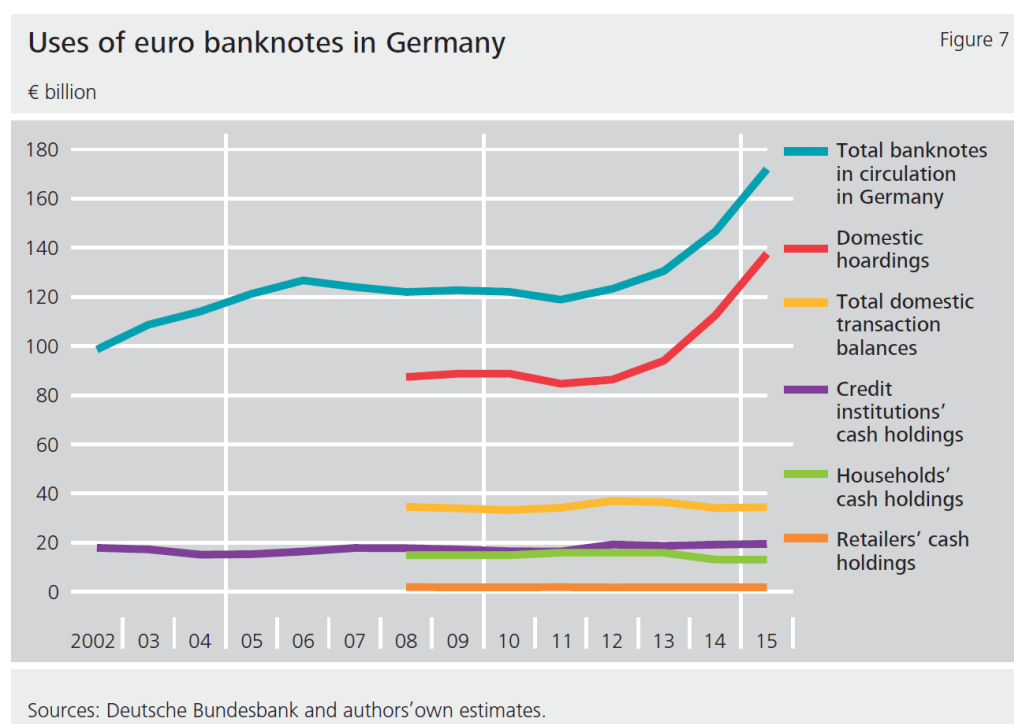
### 3.2 Uses of euro banknotes in Germany according to direct approaches

The stock of euro banknotes in Germany held in the form of transaction balances is made up of the cash holdings of credit institutions<sup>6</sup> and of retailers as well as households' transaction balances.<sup>7</sup> While credit institutions' cash holdings are statistically recorded at month-end, the cash held by retailers and households has to be estimated; the following estimates are based on Deutsche Bundesbank (2009). For households, this is done using the Bundesbank's payment behaviour studies, for which data were collected for 2008, 2011 and 2014 (Deutsche Bundesbank, 2015b, 2012, 2008). Individuals aged 18 and over were asked how much money they normally withdraw from an ATM, bank cash desk or point of sale, and how much of this cash they have left when they make their next cash withdrawal. Assuming a linear reduction in the withdrawn funds until the next time money is taken out, this yields the average amount of cash that households hold for transaction purposes, albeit only from 2008 onwards. For those years in which no survey was conducted, ie for 2009, 2010, 2012, 2013 and 2015, the transaction balances determined in the last survey are applied. Earlier years

<sup>6</sup> Credit institutions' cash holdings normally stem almost exclusively from regular domestic transactions; see also Bartzsch et al (2011b). At the end of 2016, these cash holdings were approximately €6.5 billion higher than a year earlier. This increase is probably the result of funds being shifted out of the deposit facility, which had a negative interest rate. That would mean that these holdings constituted hoardings, not cash holdings. This development will be relevant going forward, but does not yet affect the estimates presented up until end-2015.

<sup>7</sup> As Germany is a net exporter of euro banknotes, the value of euro banknotes in circulation in Germany is equal to the volume of euro banknotes issued in Germany in circulation within the country. In other words, demand for euro banknotes in Germany is completely covered by the Bundesbank's cumulated net issuance.

are not covered by the payment behaviour study. Consequently, the entire domestic stock of euro banknotes in the form of transaction balances can be determined only from 2008 onwards. Retailers' average cash holdings are derived from consumers' estimated cash spending with retailers and assumptions as to the shipments of daily takings to commercial banks. Cash spending with retailers are estimated by adjusting private consumption for items that are thought to be paid for by cashless means. Domestic hoardings are calculated as the residual of the difference between the volume of banknotes in circulation outside Germany and the domestic transaction balances. The components of banknotes in circulation in Germany estimated in this way are shown in Figures 7 and 8.

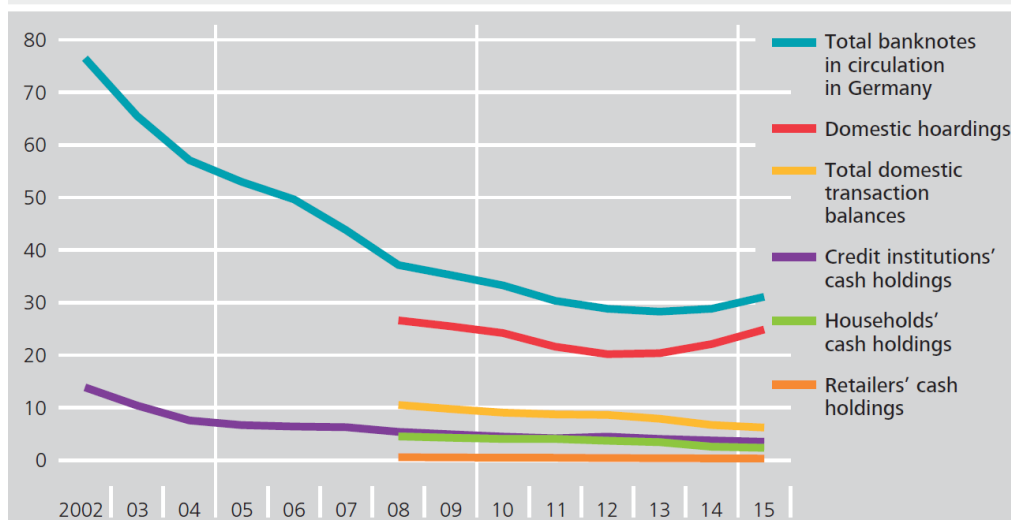




## Uses of euro banknotes in Germany

Figure 8

As a percentage of cumulated net issuance by the Bundesbank



Quarterly data in 2003 and 2004 derived by linear interpolation of the year-end figures for 2002, 2003 and 2004. Source: Authors' own calculations.

Domestic transaction balances amount fairly consistently to approximately €35 billion and are made up, in roughly equal parts, of credit institutions' and households' cash holdings. Retailers' cash holdings are consistently just under €2 billion and consequently have barely any impact. The bulk of banknotes in circulation in Germany represent hoardings. These were roughly €90 billion in 2008 to 2013. After that, they rose considerably, namely by just under €20 billion in 2014 and some €25 billion in 2015. The increase in banknotes in circulation in Germany is therefore attributable solely to the growth in hoardings. In turn, the vast majority of domestic hoardings probably constitute cash hoarded by households.

The sharp increase in domestic hoardings in 2014 and 2015 estimated here is problematic for the following reasons. First, households' bank deposits have not – with just a few exceptions – been subject to negative interest rates hitherto. This would suggest that the interest rate environment has not yet prompted a shift out of bank deposits into cash, particularly as this would also entail costs such as fees for renting a safe deposit box or the cost of buying a safe. Second, the sharp rise in domestic hoardings could be the result of an estimation error. Under the “net shipments and foreign travel” approach, domestic hoarding is calculated as the difference between the estimated total volume of banknotes in circulation outside Germany and the estimated domestic transaction balances. The volume of the domestic transaction balances can be estimated relatively reliably. It has a low absolute value which hardly changes over time. By contrast, the volume of banknotes in circulation outside Germany is very large. Estimating its size is fraught with a degree of uncertainty as

this estimation approach does not capture every channel through which cash is imported and exported. For instance, a lack of statistical data means that cash remittances by foreigners are not considered. The direct estimates presented here, therefore, might underestimate the volume of German-issued euro banknotes in circulation abroad.

Ultimately, estimates of the domestic hoardings derived as a residual are associated with relatively large uncertainties. This is particularly true of the annual changes in domestic hoardings at the current end, which are important for assessing the question of whether the current low-interest-rate environment has caused banknote hoarding to increase. The aim is therefore to establish an alternative, more reliable estimate for the time series of domestic hoardings. This is done in the next section using what is referred to as the “seasonal method”.

## **4 Components of banknote demand using the seasonal method**

### **4.1 Methodological considerations**

Unlike the “net shipments and foreign travel” approach, the seasonal method to determine banknote demand components is an indirect rather than direct estimation approach, ie it is not based on available statistics or surveys. Instead, the aim of the seasonal method is to filter out information about banknotes in circulation outside Germany from the seasonality of banknote circulation. For this purpose, it is assumed that the volume of banknotes in circulation outside Germany has little or no seasonality. Hence, the stocks of banknotes in circulation in Germany and abroad exhibit different seasonal patterns, with the seasonal term for the total volume of banknotes in circulation being dampened by the stock circulating abroad. The individual components of Bundesbank-issued banknotes can be derived using various estimates of the unknown seasonal term for the volume of banknotes circulating in Germany. The main features of the seasonal method can be traced back to Sumner (1990), who applied it to investigate the transaction and hoarding balances for the US dollar. The calculations on banknote demand components that are performed in this paper using the seasonal method are an extrapolation of the results presented in Bartzsch et al (2011b), who analyse the period 2002-09, to the end of 2015. Other papers which apply the seasonal method include Seitz (1995), Porter and Judson (1996) and Judson (2012).

**The starting point for the seasonal method** is the following multiplicative seasonal model of a time series; see Bartzsch et al (2011b).

$$(1) \quad T_t S_t = T_t^d S_t^d + T_t^a S_t^a$$

where  $T_t$  stands for the trend component and  $S_t$  the seasonal term at time  $t$ . Furthermore, the superscript indices  $d$  and  $a$  indicate an additive decomposition of the overall time series  $T_t S_t$  into the components  $T_t^d S_t^d$  and  $T_t^a S_t^a$ , with  $d$  standing for “domestic” and  $a$  for “abroad”. In addition,  $\beta_t$  denotes the share of the overall trend held domestically  $d$ , ie  $T_t^d = \beta_t T_t$  and  $T_t^a = (1 - \beta_t) T_t$ . Thus, equation (1) can be reformulated as follows:

$$(2) \quad S_t = \beta_t S_t^d + (1 - \beta_t) S_t^a$$

To solve equation (2), the seasonal term  $S_t$  is first determined using standardised seasonal adjustment approaches and  $S_t^a = 1$  is assumed throughout. The seasonal term for a suitable reference variable is used in each case for the unknown seasonal term  $S_t^d$ . The choice of reference variables is explained in greater detail in Bartzsch et al (2011b). This paper subscribes to the choice of reference variables in Bartzsch et al (2011b), as these reference variables are established and their use ensures continuity in the estimates of banknote demand components. In practice, determining the volume of banknotes in circulation outside the euro area, of banknotes in circulation abroad within the euro area, of domestic hoardings and of domestic transaction balances as a percentage of the total arithmetical stock of Bundesbank-issued euro banknotes in circulation is a three-step process, with components  $d$  and  $a$  each being defined differently.

In a **first step**, the component  $T_t^d S_t^d$  covers the volume of banknotes circulating in Germany and abroad within the euro area, while the component  $T_t^a S_t^a$  denotes the volume circulating outside the euro area, resulting in equation (3).

$$(3) \quad S_t = \beta_t^{T+H+EWU} S_t^{T+H+EWU} + (1 - \beta_t^{T+H+EWU}) S_t^{RW}$$

The superscript  $T$  is a symbolic representation of transaction balances, while  $H$  stands for hoarding,  $EWU$  for the volume of banknotes circulating in the rest of the euro area and  $RW$  for the volume of banknotes circulating in the rest of the world. The superscript symbol “+” indicates that the aggregate of each of the components forms part of the equation. The seasonal term  $S_t^{T+H+EWU}$  is unknown and is approximated by the seasonal term of French banknote circulation. France and Germany are indeed likely to be very similar in terms of their economic structure and probably play similar roles with respect to banknote migration

within the euro area, be it in connection with foreign travel or via other channels. That said, the Bundesbank plays a special role when it comes to demand from non-euro-area countries owing to the fact that, in net terms, the bulk of the Eurosystem's cumulated net issuance derived from international banknote wholesale trade comes from Germany (Bartzsch et al, 2011b).

In a **second step**, the volume of Bundesbank-issued banknotes in circulation is broken down into the total volumes of banknotes in circulation in Germany and abroad; see equation (4).

$$(4) \quad S_t = \beta_t^{T+H} S_t^{T+H} + (1 - \beta_t^{T+H}) S_t^{EWU+RW}$$

Private consumption is the chosen reference variable for the unknown seasonal term in Germany,  $S_t^{T+H}$ . The reason for this is that private consumption is a typical explanatory variable in a banknote demand model for banknotes in domestic circulation.

In a **final step**, transaction balances as a percentage of the total volume of Bundesbank-issued euro banknotes in circulation are determined; see equation (5).

$$(5) \quad S_t = \beta_t^T S_t^T + (1 - \beta_t^T) S_t^{H+EWU+RW}$$

Here, credit institutions' cash holdings are used as the reference variable. In the period under review (2002-15), credit institutions' cash holdings served as households' extended transaction balances, as banks stocked as much euro cash as they needed to supply to households. Furthermore, retailers also deposit more cash at credit institutions in periods during which transaction balances for cash spending are particularly high.

A key assumption of the seasonal method is that the volume of banknotes in circulation outside Germany and domestic hoardings have no seasonality. This assumption can be tested for a special case, as monthly data for the Bundesbank's cumulated net issuance derived from international banknote wholesale trade are available; see Table 3. A regression of cumulated net shipments on seasonal dummies shows that these are not significantly different from each other. Furthermore, there is no notable partial correlation of a time series value with the prior-year value. Both these points suggest that the volume of banknotes in circulation outside Germany does indeed have very little seasonality to speak of.

**Table 3: Seasonality tests**

	Test for deterministic season	Partial year-on-year autocorrelation
<b>Circulation of Bundesbank-issued euro banknotes</b>	5.047 (0.000)	0.39
<b>Cumulated net shipments</b>	0.39 (0.959)	-0.03

Notes: Each of the time series shows a trend that has been removed by applying the Hodrick-Prescott filter (Hodrick and Prescott, 1997), where  $\lambda=14.400$ . The test for deterministic seasonality tests the equality of seasonal dummies after regressing the time series on seasonal dummy variables. Shown here are the F-test value and the associated p-value, the latter in brackets. Monthly data for 2002 to 2015 were used. Source: Authors' own calculations.

Applied in practice, attempting to determine the share  $\beta_t$  for each calendar month  $t$  using equation (2) proves to be overly ambitious. If there is no seasonal influence in a given period, ie  $S_t = S_t^d = 1$ , the share  $\beta_t$  cannot be determined using equation (2). In addition, individual months in which the seasonal term  $S_t^d$  is less pronounced than that of the total volume of banknotes in circulation yield potentially implausible values for  $\beta_t$ . In summary, equation (2) delivers plausible results for certain months but not all; see also Bartzsch et al (2011b) and Porter and Judson (1995). For this reason, it is advisable to move to an approach based on seasonal amplitude. To do this, the time index  $t$  first needs to be replaced by the index  $m, l$ , with  $m$  standing for the month and  $l$  for the year. The circulation of Bundesbank-issued euro banknotes typically experiences a seasonal high in December and a seasonal low in February. Deducting equation (2) for February from that for December of the previous year, the share  $\beta_l$  is determined as

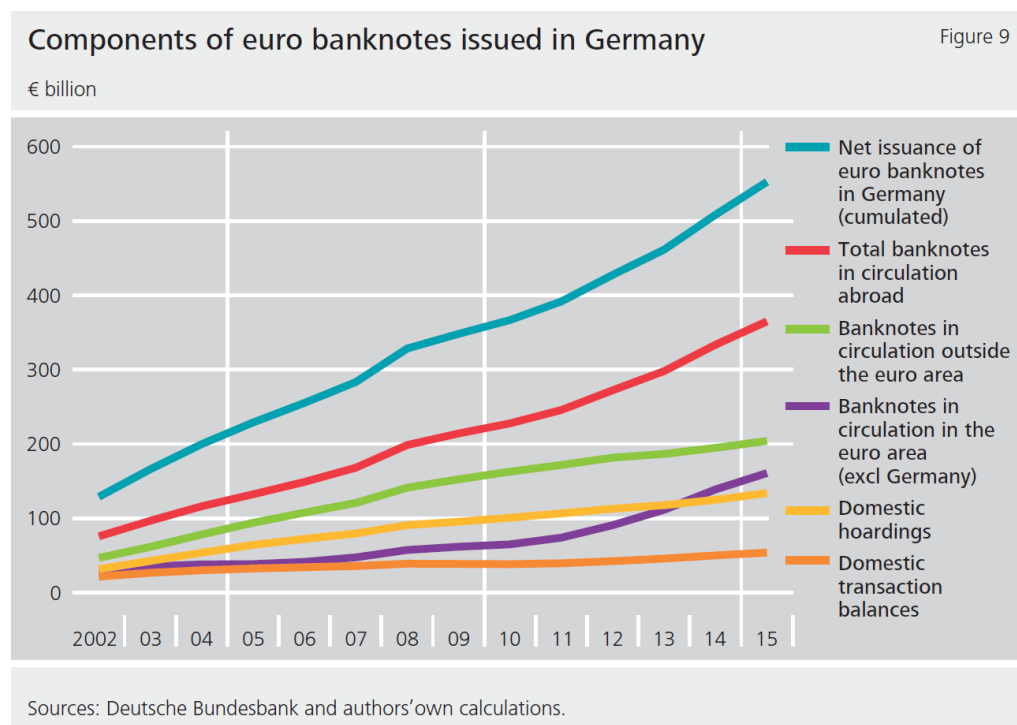
$$(6) \quad \beta_l = \frac{S_{dec,l} - S_{feb,l+1}}{S_{dec,l}^d - S_{feb,l+1}^d}$$

One particularity that should be noted here is that statistical data on private consumption are only published quarterly. Equation (6) is applied in the same manner here – with a seasonal high in the fourth quarter and a seasonal low in the first quarter.

#### 4.2 Banknote demand components using the seasonal method

The results of the estimates determined using the seasonal method are depicted in Figures 9 and 10. They show that the total volume outside Germany of euro banknotes brought into circulation by the Bundesbank amounted to €365 billion at the end of 2015 – an estimate which corresponds very closely to the €380 billion estimate calculated using the “net shipments and foreign travel” approach. The two approaches therefore come to similar

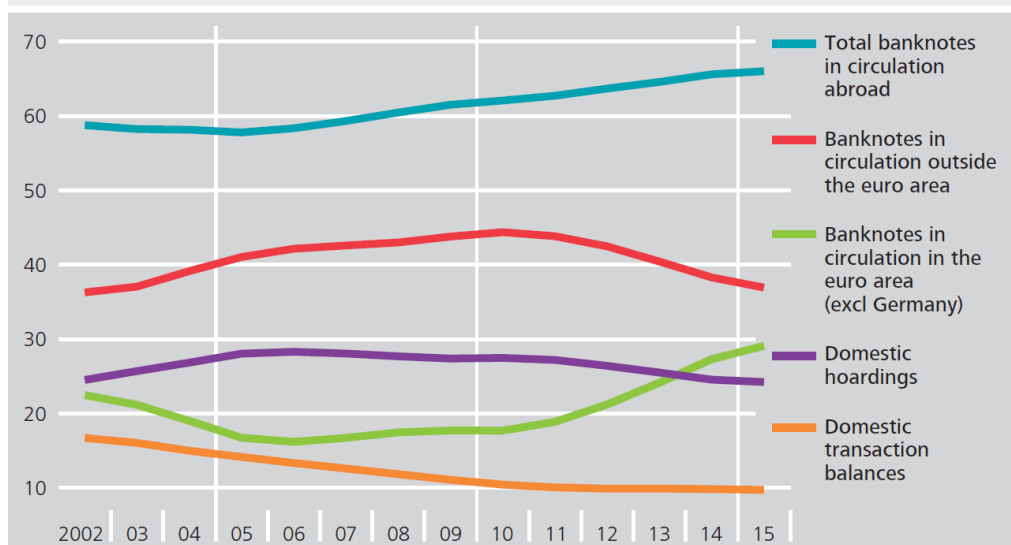
conclusions regarding the volume of banknotes in circulation both in and outside Germany, and the same can be said of the trends for these time series over time. Major differences exist with respect to the regional distribution of banknotes in circulation outside Germany. According to the seasonal method, the volume of banknotes in circulation in the rest of the euro area stood at €160 billion at the end of 2015, which is significantly higher than the €110 billion estimated using the “net shipments and foreign travel” approach. The opposite is true in the case of the stocks of banknotes in circulation outside the euro area.



## Components of euro banknotes issued in Germany

Figure 10

As a percentage of cumulated net issuance by the Bundesbank



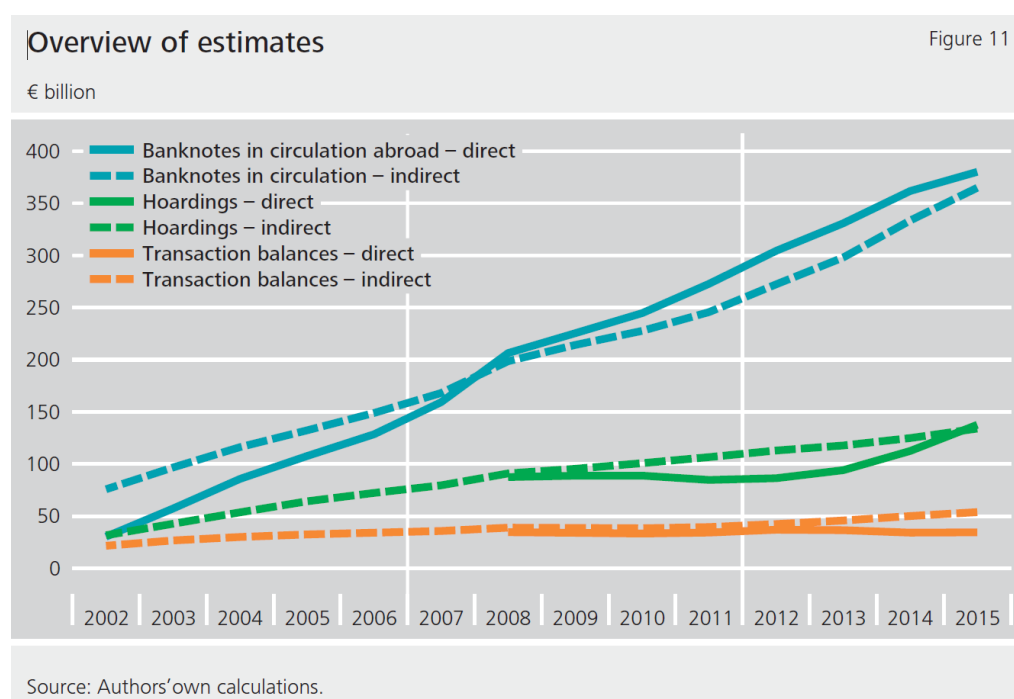
Sources: Deutsche Bundesbank and authors' own calculations.

As was the case for the direct “net shipments and foreign travel” approach presented in Section 3, domestic transaction balances have a flat trend line. They amounted to around €55 billion at the end of 2015 – approximately €20 billion higher than the estimate calculated using that approach. However, this difference has barely any impact when measured against the share of cumulated net issuance by the Bundesbank. At the current end, both approaches arrive at the same estimates for domestic hoardings, ie just under €140 billion. That said, while domestic hoardings rose sharply in 2014 and 2015 based on the “net shipments and foreign travel” approach, they have shown a steady, slight upward trend since 2010 when calculated using the seasonal method. Applying the seasonal method, there is therefore no structural break in domestic hoardings brought about by the low-interest-rate environment. Instead, this approach suggests that stocks of German-issued euro banknotes in other euro-area countries have risen considerably in recent years. Over the past few years, this component has made the greatest contribution by far to growth in the Bundesbank’s cumulated net issuance of euro banknotes.

## 5 Combination of estimates using direct approaches and the seasonal method

This paper uses the “net shipments and foreign travel” and “seasonal method” approaches to determine banknote demand components. These are the most appropriate methods for estimating the components of the arithmetical stock of Bundesbank-issued euro banknotes in

circulation. Other approaches only allow the interpretation of upper and lower bounds or the estimation of a few components at most; see also Bartzsch et al (2011a, 2011b). There is no consensus in the literature about the relative merits of direct and indirect approaches; Judson (2012) and Feige (2012), using indirect and direct approaches, arrive at different estimates for the scale of foreign demand for US currency. Direct approaches for determining the stock of banknotes in circulation abroad are based on capturing statistically as many as possible of the channels through which banknotes can flow abroad. The seasonal method presented here, meanwhile, is based on an appropriate selection of reference variables for the unknown seasonal term of banknotes in circulation in Germany; the assumptions made under this method ultimately cannot be verified empirically. Direct and indirect approaches yield comparable results for the stock of Bundesbank-issued euro banknotes in circulation; see the overview in Figure 11. The main differences between direct and indirect approaches can be found in the breakdown of banknotes in circulation abroad into non-euro-area countries and euro-area countries, which is not shown in Figure 11.



Finally, the paper presents a new estimate for the components of the stock of Bundesbank-issued euro banknotes in circulation, which is based on both approaches; see Table 4. Estimation intervals are used in Table 4 to show the shares of the banknote demand components, with the poles of these intervals being based on the estimates of one of the two approaches. Table 4 also contains an estimate of the stock at the end of 2016, which is



calculated by weighting the arithmetical volume of banknotes in circulation for the end of 2016 with the estimated shares for 2015. All estimated figures are rounded to a multiple of 5 to articulate the uncertainty surrounding the estimates. Both approaches comes to comparable results at the current end for the scale of banknote hoarding in Germany, but suggest that their patterns differ over time. Due to the presumption that the direct approach might fail to capture a notable volume of banknotes taken abroad, the seasonal method is used to estimate how banknote hoarding develops over time.

**Table 4: Components of Bundesbank-issued banknotes in circulation**

	Share end of 2015 (%)	Stock end of 2015 (€ billion)	Stock end of 2016 <sup>a</sup> (€ billion)
<b>Total circulation abroad</b>	65 – 70	365 – 380	385 – 415
of which outside euro area	40 – 50	210 – 270	235 – 295
of which rest of euro area	20 – 30	110 – 160	120 – 180
<b>Circulation in Germany</b>	30 – 35	170 – 190	180 – 205
of which hoarded	25	135	150
of which transaction balances	5 – 10	35 – 55	30 – 60
<b>Total circulation</b>		553	592

<sup>a</sup>Extrapolating the components of banknote demand with shares as at the end of 2015. Source: Authors' own calculations and Deutsche Bundesbank.

## 6 Conclusion and discussion

This paper presents a breakdown of the arithmetical stock of Bundesbank-issued euro banknotes in circulation into the components of foreign demand, domestic hoarding and domestic transaction balances. These components are estimated using the direct approach “net shipments and foreign travel” as well as the “seasonal method”. Overall, at the end of 2015, 65% to 70% of the stock of banknotes issued by the Bundesbank were in circulation abroad, with 40 to 50 percentage points in countries outside the euro area and 20 to 30 percentage points in other euro-area countries. 25% of the Bundesbank-issued banknotes in circulation were hoarded in Germany, and 5% to 10% were domestic transaction balances.

The estimates presented here show the development of cash usage in Germany throughout the period since euro cash was introduced. Of particular interest is the question whether the current low-interest-rate environment has led to a distinct increase in banknote hoarding in Germany. Where the direct approach is used to estimate hoardings as a residual at the current end, there is indeed evidence of an increase in banknote hoarding. However, the use of direct approaches to estimate foreign demand requires every last channel via which banknotes migrate abroad to be captured. Estimates based on the seasonal method do

instead suggest that banknote hoarding in Germany has developed smoothly despite the low-interest-rate environment. Rather, the seasonal method points to a rise in the stock of Germany-issued euro banknotes circulating in the rest of the euro area.

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