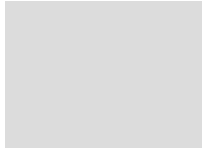# Cash use in Germany

Macroeconomic estimates of the extent of illicit
cash use in Germany

Nikolaus Bartzsch, Friedrich Schneider and Matthias Uhl

# Cash use in Germany

Macroeconomic estimates of the extent of illicit cash use in Germany*

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## Foreword

**Dr Johannes Beermann**
Member of the Executive Board
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"Do you need an invoice?" – The two terms, cash and the shadow economy, are often mentioned in the same breath. And, on the surface of things, the connection seems a reasonable one to make. It is often assumed that cash is used extensively in the shadow economy. This, in turn, has prompted vehement calls for the introduction of measures to restrict the use of cash.

Is this right? Are we talking about demonstrable links here, or are we simply succumbing to a notion that is all too tempting?

With these issues in mind, the Bundesbank has conducted a study on the extent of "illicit cash use" in Germany, in collaboration with Professor Friedrich Schneider of the Johannes Kepler University Linz. The study includes an overview of economic research on the use of cash in the shadow economy as well as fresh empirical analyses by the authors.

The study concludes that cash is, of course, also used in the shadow economy. But, the shadow economy is naturally underpinned by cashless payments, too. Nobody is safe from unlawful behaviour. This study is about scrutinising simplistic conclu-

sions and sensationalised estimates of the extent of cash use in the shadow economy. The study shows that, without more in-depth analyses, it is impossible to distinguish those stocks of banknotes that are being held as a store of value – and kept at home under the mattress totally legally and legitimately by every citizen – from illicit banknote stocks. This alone is indication enough that approaches to assessing the shadow economy which rely on direct reference to the volume of banknote circulation or the demand for large-denomination banknotes fall short.

Available estimates for the size of the shadow economy lie between 2% and 17% of gross domestic product. This range alone shows that studies of the shadow economy are subject to an above average degree of uncertainty and all results should be interpreted with care. The paper incorporates empirical research by the authors. These studies look at the influence of the shadow economy on cash lodgements at Bundesbank branches and the demand for banknotes in Germany.

There are some questions which the study does not address. The discontinuation of the €500 banknote and the cash ceilings introduced in some European countries represent measures to restrict the use of cash. The study does not examine such measures, leaving the question of their effectiveness open.

This study serves as a sound aid to an open, more objective debate on the issues relating to illicit cash use, making it an enriching read for all those with an interest in this area.

Yours,

**Dr Johannes Beermann**
Member of the Executive Board of the Deutsche Bundesbank

# Summary of the main empirical results

For some time now, the role of cash as a driver of the shadow economy and means of funding crime has been the subject of increased discussion in the public arena. Some of those contributing to the debate argue that cash is used on a significant scale for illegal purposes and call for the introduction of measures to restrict cash use. This study examines the significance of illegal motives for cash demand in Germany, making a valuable contribution to the current discussion on cash restrictions. Alongside a detailed overview of the relevant literature, this study includes two empirical investigations of the authors' own on cash use in the shadow economy.

Illegal uses of cash refer to those where the surrounding circumstances are not consistent with established law. In the economic literature, illicit uses of cash are mostly studied in connection with what is known as the shadow economy. This means the production of goods and provision of services which is concealed so as to circumvent requirements to pay tax and social security contributions or for other reasons. Studies into the shadow economy often rest on the assumption that shadow economic transactions are predominantly carried out using cash. Due to the secretive nature of illegal activities, it is not possible to observe the size of the shadow economy directly; instead, it must be estimated. Available estimates for Germany place the size of the shadow economy at between 2.4% and 16.6% of gross domestic product (GDP). Looking at GDP for 2017, that equates to around €80 billion to €550 billion. The broad span covered by the estimates reflects the fact that studies on the shadow economy are subject to an above average degree of uncertainty. All results should therefore be interpreted with caution.

Cash use for day-to-day activities has long been a subject of academic research, for instance in the Bundesbank's surveys on payment behaviour. This means that the extensive use of cash by consumers is well documented. Illicit uses of cash are, by their very nature, harder to capture, however. Macroeconomic studies on the role of illicit cash use therefore sometimes have to rely on hefty assumptions. In the literature, the size of illegal cash holdings is generally determined by comparing the actual figure for cash in circulation with an assumed reference value that would result if all cash use were entirely legal. Some macroeconomic estimates in this vein draw directly on the volume of cash in circulation or high-denomination banknotes in circulation. At the end of 2017, euro currency in circulation amounted to around €1,200 billion, equivalent to roughly €3,500 per inhabitant of the euro area. At that time, €100, €200 and €500 banknotes accounted for a 47% share of euro cash in circulation. Some analyses argue that the overall amount of cash in circulation and the circulation of high-denomination banknotes are greater than can be expected if cash were being used solely for legal purposes. It is important to remember when looking at this data on cash circulation, however, that there is a significant amount of euro currency circulating abroad and that this portion cannot simultaneously be used in the domestic shadow economy. Furthermore, splitting the holdings in Germany into those which are legal and those which are illicit is no straightforward task. Legitimate cash holdings, kept under the mattress by savers in Germany, are likely to play an important role too, for instance. These simple estimates are therefore hardly appropriate for the purposes of investigating illicit cash use.

A more promising prospect are macroeconomic estimates applying the currency demand approach, where the significance of the shadow economy for the amount of cash in circulation is examined using an empirical model. Since it is not possible to observe the scale of the shadow economy directly, indicators that should correlate with the size of the shadow economy are considered as proxies. In empirical studies, the tax rate is often selected as one such indicator for the shadow economy. The reasoning behind this is that the tax burden is seen as a core motive for shadow economic production. If the tax rate or other shadow economy indicators explain part of the demand for currency, this allows us to draw indirect inferences as to the

significance of the shadow economy for currency demand. Applying the currency demand approach correctly is challenging, however. The currency demand approach should, in particular, also take into account legal hoarding of cash as a store of value and foreign demand; to date, this has only been done to a partial extent in the literature.

We have therefore followed up the literature overview by including two of our own empirical analyses based on the currency demand approach. A panel econometric analysis looks at the impact of illicit cash use on cash lodgements at Bundesbank branches. The significance of illegal motives in driving demand for small, medium and large denominations of banknotes from the Bundesbank and for domestic banknote demand is investigated using a time series econometric regression analysis. These analyses of our own represent an enhancement of the currency demand approach in several respects. Both the panel and the time series econometric approach take greater account than other studies of the fact that cash is also being used abroad. In this way, cash lodgements are a clearer reflection of transactions than is the total amount of cash in circulation since they primarily stem from the use of cash as a means of payment in Germany. The time series econometric approach takes account of the different uses of cash by modelling small, medium and large denominations as well as domestic circulation separately, and through the selection of appropriate control variables. While many investigations confine themselves to employing the tax and social security contributions burden as a general indicator for illicit cash use, the present study also looks at a range of indicators for possible illegal cash use. This should yield a more coherent picture overall of the significance of illicit motives as a driver for cash demand than that produced by using just single variables.

The Bundesbank is an integral operative in the cash payment system and its branches are responsible for a significant portion of banknote processing in Germany. The panel econometric analysis of cash lodgements at Bundesbank branches thus enables the examination of cash use in the economy. When interpreting the results, it should be borne in mind that, for the central bank, cash deposits stemming from illegal income are indistinguishable from other deposits since the cash concerned is merely paid in indirectly via retailers or commercial banks. In the regressions, two of the nine indicators for illicit cash use that we consider exhibit a significant influence with the expected positive sign; these are the self-employment rate and an indicator for the extent of drug-related crime. According to model-based analyses, €60 billion worth of cash lodgements annually can be indirectly traced back to illegal cash transactions. If one also makes allowance for the fact that a portion of the cash is processed and brought back into circulation by private cash agents, the estimate for illicit cash lodgements on the basis of cash lodgements at the Bundesbank and credit institutions comes to €75 billion. In conceptual terms, this estimate is not an estimate for the size of the shadow economy. The figure of €75 billion for the volume of illicit cash deposits can be interpreted as a lower bound for the size of the cash-based shadow economy in Germany. As with other estimates of the shadow economy's size, this estimated lower bound is also open to an above average degree of uncertainty and should therefore be interpreted with care.

In the second analysis, we estimate regression models for demand for Bundesbank-issued euro banknotes in small, medium and large denominations as well as for domestic circulation. Table 1 provides an overview of the key findings. In each case, of the seven shadow economy variables considered, two, at most, have a bearing. The effects of the shadow economy are at their smallest when it comes to demand for the low-denomination banknotes. A 1 percentage point rise in the unemployment rate or the growth rate of the total number of criminal offences generates a 0.7 percentage point rise in the growth rate for these denominations. The significant indicators have the biggest impact on the circulation of large denominations. A 1 percentage point rise in the employment rate in the agricultural sector or the construction sector sees the growth rate for the real circulation of these denominations climb by 12 percentage points and 9 percentage points, respectively. These

effects qualify as quantitatively significant since they are similar in magnitude to the strong increase in the circulation of large banknotes in the fourth quarter of 2008, when the financial crisis prompted a surge in hoarding by economic agents.

| Long-term effects of the shadow economy on the value of banknotes in circulation | Table 1 |
|---|---|
| **Sustained increase in shadow economy** | **Long-term effect on the real circulation of German-issued euro banknotes** |
| Unemployment rate increases by 1 percentage point | Growth rate of the circulation of small denominations increases by **0.7 percentage point*** |
| Growth rate of the total number of crimes increases by 1 percentage point | Growth rate of the circulation of small denominations increases by **0.7 percentage point*** |
| Number of drug-related crimes increases by 1% | Circulation of medium denominations increases by **1.1%*** |
| Employment rate in the construction sector increases by 1 percentage point | Growth rate of the circulation of medium denominations increases by **3.3 percentage points**** |
| Employment rate in the agricultural sector increases by 1 percentage point | Growth rate of the circulation of large denominations increases by **12 percentage points*** |
| Employment rate in the construction sector increases by 1 percentage point | Growth rate of the circulation of large denominations increases by **9 percentage points*** |
| Tax and social security contributions ratio rises by 1 percentage point | Growth rate of domestic circulation increases by **2.2 percentage points**** |

Notes: *** statistically significant at 1%, ** statistically significant at 5%. Economically significant effects are displayed in bold. Small denominations: €5-€20 banknotes, medium denominations: €50 and €100 banknotes, large denominations: €200 and €500 banknotes.
Source: Authors' own calculations.

The employment rate in the construction sector is also a factor in demand for medium-denomination banknotes, although it exerts considerably smaller effects here. The circulation of medium-denomination banknotes climbs proportionately with the number of drug-related crimes. Given an increase of 1 percentage point in the tax and social security contributions ratio, the growth rate of domestic demand climbs by just over 2 percentage points.

The question of whether restrictions on cash use could help to shrink the shadow economy is explicitly left untreated in this study. However, taken as a whole, the findings suggest that it is far from easy to adduce empirical evidence for the significance of the shadow economy in driving demand for cash. Those in favour of restrictions on cash should bear in mind that empirical studies dealing with the shadow economy are subject to an above average degree of uncertainty and should only be interpreted with caution.

# Table of contents

# ▎Figures

# Tables

# ▌1 Introduction

At the end of 2017, the total value of euro banknotes and euro coins in circulation amounted to €1,200 billion, of which €640 billion was issued by the Bundesbank. This study examines the motives for holding cash in Germany from a macroeconomic perspective.

Cash can be used as a means of payment and store of value without explicit documentation. Naturally, then, there is also a lack of complete statistical data on the reasons for, and extent of, cash usage. Estimates decomposing the circulation of Bundesbank-issued euro banknotes into currency in circulation abroad, domestic hoarding and domestic transaction balances have been made in a series of prior studies (Bartzsch et al., 2011a; Bartzsch et al., 2011b; Bartzsch and Uhl, 2017; Deutsche Bundesbank, 2011, 2018). According to those estimates, at the end of 2016, 65% of the Bundesbank's net issuance of banknotes was located abroad, while 25% was being hoarded by domestic users of cash and 5% to 10% was being held as transaction balances.

This breakdown of the Bundesbank's cumulative net issuance does not tell us anything about the significance of illegal motives for cash demand. Cash is also likely to be used illicitly on an unknown scale, for example when goods or services are traded in such a way as to circumvent taxation or other regulations and cash is employed as the means of payment. The idea that cash is being used on a significant scale to make illegal transactions has recently been advanced to justify calls for regulatory measures, ranging from abolishing high-denomination banknotes to doing away with cash altogether (Bofinger, 2015; Rogoff, 2016; Sands, 2016). With an eye toward potential undesirable uses of the €500 banknote, the Governing Council of the ECB decided to cease production and issuance of that particular denomination. The Bundesbank does not have any data as to whether regulatory

measures of this kind really are suitable means of achieving the objectives that prompt them. This study analyses the extent to which it is possible to make reliable estimates of the scale of illicit cash use using macroeconomic methods and what results they yield. In so doing, it contributes information to the discussion currently taking place as to potential illegal uses of cash.

The study opens with a look at methods applied in the economic literature to estimate the extent of illicit cash use. One strand of the literature argues that there is too much cash or too many high-denomination banknotes in circulation than could be explained through legal cash use alone (Rogoff, 1998; Rogoff, 2015; Rogoff, 2016). The currency demand approach is also popular. This generally involves modelling cash circulation as a function of a transaction variable, an interest rate variable, and an indicator for illegal cash use – for example, a tax rate (Tanzi, 1983; Klovland, 1984; Schneider, 1986). The demand for cash explained by whichever indicator has been selected in the statistical model is interpreted as illegal cash use. One of the criticisms of the method employed in the economic literature, which we elaborate below, is the fact that some applications fail to take due account of legal hoarding of cash in its function as a store of value and of foreign demand. This tends to result in the over-estimation of illicit cash use. Empirical approaches to quantifying illegal cash use must tackle the demanding task of factoring in these reasons behind the demand for cash, too.

Following on from the literature review, we present our own studies of illegal cash use in Germany, which build on the currency demand approach. A panel econometric analysis is conducted to examine the influence of a range of possible indicators of illicit cash use on cash deposits at Bundesbank branches. The analysis of cash in-payments is followed by time series econometric analyses of circulation of Bundesbank-issued euro banknotes.

The remainder of the study is structured as follows. Section 2 contains a descriptive overview of the evolution of euro banknote circulation and presents a breakdown of Bundesbank-issued banknotes into three components: circulation abroad, domestic hoarding and domestic transaction balances. Section 3 discusses methodologies deployed in the economic literature to estimate the extent of illicit cash demand, while Section 4 contains our own studies. Section 5 summarises the paper and discusses the implications of its findings.

# ▌2 Demand for euro currency

### 2.1 Euro currency in circulation
Since the introduction of euro cash, the amount of euros in circulation has been constantly increasing (see Figure 1). At the beginning of 2002, immediately after the euro was brought in, around €220 billion was in circulation in the form of euro banknotes, while at the end of 2017, approximately €1,170 billion worth of euro banknotes was circulating, in addition to roughly €28 billion worth of euro coins. These figures show that the combined use of euro cash as a means of payment and store of value is on the rise.



**Euro currency in circulation***     Figure 1

€ bn, month-end data

Sources: European Central Bank and authors' own calculations. * Euro circulation coins and euro banknotes.
Deutsche Bundesbank
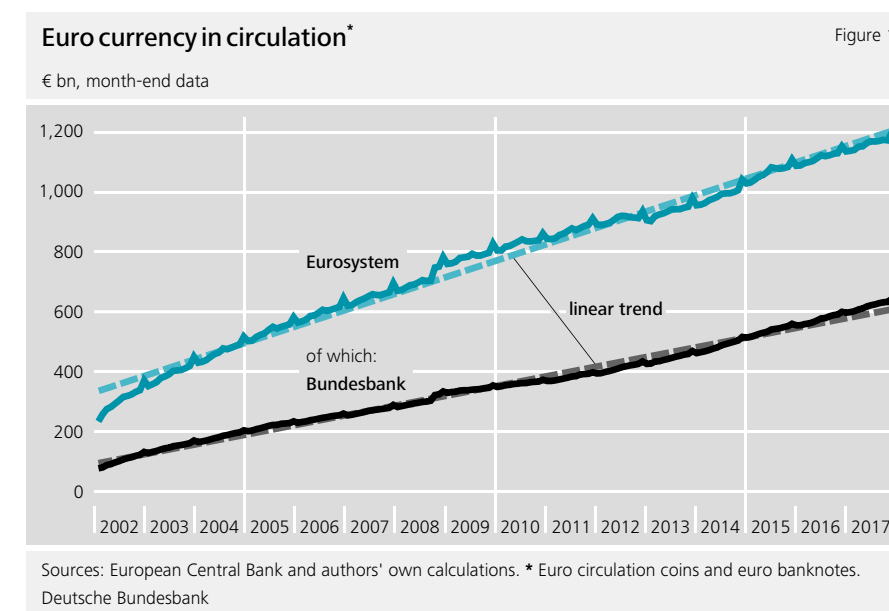
The Bundesbank is part of the Eurosystem and contributes to the development of the total stock of euro cash in circulation by issuing and accepting euro cash. In fact, the cash in circulation issued by the Bundesbank exhibits especially dynamic growth. At the end of January 2002, the outstanding volume amounted to €77 billion, or

33% of the total stock of euro cash in circulation, while at the end of 2017, it stood at around €640 billion, or 54% of the total stock of euro cash in circulation. The Bundesbank was therefore responsible for a considerable portion of the net issuance of euro cash in circulation. This very sharp rise in the volume of cash in circulation traced back to the Bundesbank is likely attributable to the migration of euro banknotes from Germany to the rest of the euro area and to non-euro area countries (Bartzsch et al., 2011a; Bartzsch et al., 2011b; Bartzsch and Uhl, 2017; Deutsche Bundesbank, 2011, 2018).

Figure 2 shows the growth rates of euro cash in circulation compared with the same month of the previous year for the Eurosystem and for cash issued by the Bundesbank. These growth rates of euro cash in circulation were very high especially in the first few years after the single currency was launched. Between the end of January 2002 and the end of January 2003, for instance, the total euro cash in circulation rose by around 50%. Taking the average of the past ten years (from December 2007 to December 2017), the total euro cash in circulation increased annually by 5.6%, and the amount issued by the Bundesbank by 8.3%. The rise in the growth rates of euro cash in circulation after October 2008 is noticeable as it is attributable to the fact that during the Lehman crisis, some investors clearly saw euro currency as a secure investment. This occurrence shows that euro currency is used as a means of storing legitimate wealth.

Growth in the value of euro cash in circulation is primarily determined by the growth in the amount of euro banknotes in circulation. The proportion of euro coins in circulation to the total circulation of euro banknotes and coins was 2.3% for the Eurosystem at the end of 2017, and just 1.3% for the Bundesbank. As a result, it is largely those analyses that refer to banknotes in circulation that are presented below. However, the results are nevertheless also meaningful with regard to the circulation of cash.



Growth rates of euro currency in circulation* — Figure 2

%, month-end data

Bundesbank
Eurosystem
Eurosystem excluding Bundesbank

Sources: European Central Bank and authors' own calculations. * Euro circulation coins and euro banknotes.
Deutsche Bundesbank
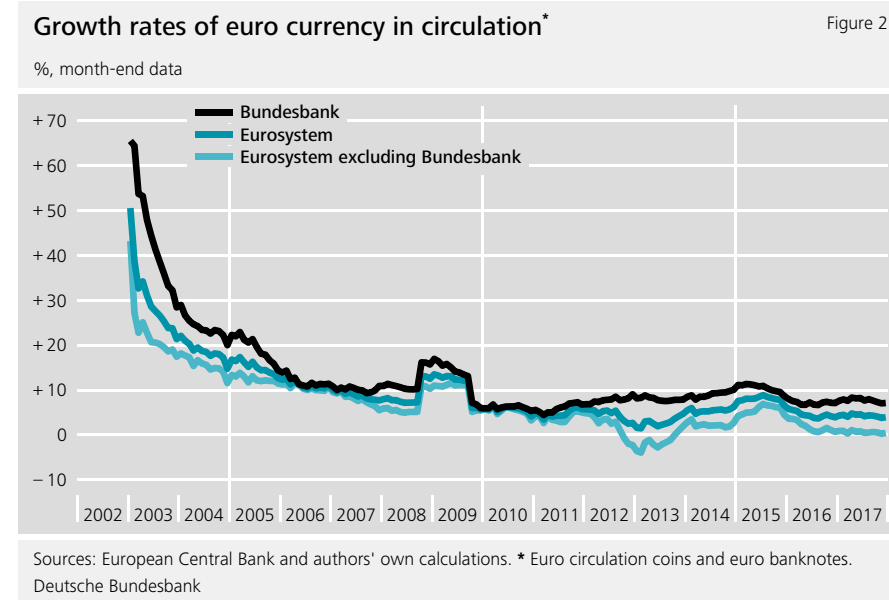
## 2.2 Components of euro banknotes in circulation

Reasons for the demand for cash put into circulation by the Bundesbank can be investigated first of all by breaking down the cumulative net issuance of euro banknotes by the Bundesbank into the components of domestic transaction balances, domestic hoarding and circulation abroad (Bartzsch et al., 2011a; Bartzsch et al., 2011b; Bartzsch and Uhl, 2017, Deutsche Bundesbank, 2018).[1]

These components of the Bundesbank's cumulative net issuance cannot be observed directly but, instead, are estimated using a combination of direct and indirect approaches, meaning that the results presented are subject to a degree of estimation uncertainty. Foreign demand for euro banknotes issued by the Bundesbank is derived directly from a household survey on travel and the available data on the

[1] Deutsche Bundesbank (2015a) examines the transaction balance amounts of euro coins in Germany.

cumulative net deliveries of euro banknotes from Germany to countries outside the euro area by international banknote wholesalers. A direct approach can also be employed to determine the stock of euro banknotes held in Germany in the form of transaction balances. This is made up of the cash holdings of credit institutions and of retailers as well as households' transaction balances. While credit institutions' cash holdings are statistically recorded, the cash held by retailers and households has to be estimated (Deutsche Bundesbank, 2009a). For households, this is done using the Bundesbank's payment behaviour studies (Deutsche Bundesbank, 2009b; Deutsche Bundesbank, 2012a; Deutsche Bundesbank, 2015b). Hoarded banknotes are estimated using what is known as the seasonal method, where the components of banknote demand can be extrapolated by comparing the seasonal structure of the Bundesbank's cumulative net issuance with the seasonal structure of reference variables (Seitz, 1995; Porter and Judson, 1996; Bartzsch et al., 2011b; Bartzsch and Uhl, 2017).[2]

Figure 3 and Figure 4 show the breakdown of the cumulative net issuance by the Bundesbank. At the end of 2016, the lion's share of the Bundesbank's cumulative net issuance in the amount of just over €590 billion was thus accounted for by banknotes in circulation abroad, namely an estimated €390 billion, or around 65% of the cumulative net issuance. At €270 billion, or roughly 45% of the cumulative net issuance, the majority of banknotes in circulation abroad were outside the euro area. An estimated amount of €120 billion, or 20% of the cumulative net issuance by the Bundesbank, is in other Member States of the euro area.



**Components of the cumulative net issuance by the Bundesbank** — Figure 3

€ bn, end-of-year data

- Net issuance of euro banknotes in Germany (cumulative)
- Total banknotes in circulation abroad
- Banknotes in circulation abroad outside the euro area
- Banknotes in circulation abroad within the euro area
- Banknotes hoarded in Germany
- Transaction balances in Germany

Deutsche Bundesbank

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.[3] Retailers' cash holdings were just under €2 billion and consequently had barely any impact. Hoarded banknotes in Germany amounted to around €150 billion according to the latest estimates at the end of 2016, and the relative share

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**2** Banknote hoarding is deduced from the seasonal method because hoarded banknotes in the direct approach merely result from the residual, meaning the estimates obtained in this manner are likely to be linked to considerable uncertainty; see Bartzsch and Uhl (2017).

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**3** During 2016, the cash holdings of credit institutions in Germany rose considerably, presumably because they held euro banknotes in storage to avoid negative interest rates on deposits at the Bundesbank.

of domestic hoardings therefore stands at approximately 25%. The estimates presented here regarding the components of banknotes in circulation issued by the Bundesbank do not differentiate between their legal and illegal use.

### Relative composition of the cumulative net issuance*      Figure 4



%, end-of-year data

- Total banknotes in circulation abroad
- Banknotes in circulation abroad outside the euro area
- Banknotes in circulation abroad within the euro area
- Banknotes hoarded in Germany
- Transaction balances in Germany

**\*** Percentages relative to the cumulative net issuance of euro banknotes by the Bundesbank.
Deutsche Bundesbank

# 3 Illicit use of cash in the economic literature

## 3.1 Subject of the studies

In the economic literature, the estimation of the illicit use of cash is generally an intermediate step when estimating the size of the shadow economy. The starting point for the cash-based method of investigating the shadow economy is the assumption that cash is a suitable payment medium for activities in the shadow economy thanks to its universal acceptance as well as the simple, secure, quick and anonymous transfer options that it provides. Irregularities in the use of cash are consequently taken as an opportunity to determine the extent of the shadow economy (Cagan, 1958; Gutmann, 1977; Feige, 1979; Tanzi, 1983; Schneider, 1986).[4]

The concept of the shadow economy generally refers to clandestine economic activities.[5] Table 2 shows a taxonomy of economic activities that could be considered part of the shadow economy. The activities are shown by the dimensions for the legal status of the created value added (legal/illegal) and the organisation of the production (market-based/non-market-based). Accordingly, the shadow economy

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**4** Public surveys (Isachsen and Strøm, 1985; Pedersen, 2003; Feld and Larsen, 2005, 2012), discrepancies in macroeconomic accounting systems (Petersen, 1982; Caridi and Passerini, 2001), structural equation modelling with the shadow economy as a latent variable (Frey and Weck-Hanneman, 1984; Schneider, 2005; Buehn et al., 2009) or irregularities in the consumption of electricity (Kaufmann and Kaliberda, 1996; Lackó, 2000; Eilat and Zinnes, 2002; Onnis and Tirelli, 2010) may also be tools in the investigation of the shadow economy. Surveys of the economic literature on the shadow economy and especially of the estimates regarding the size of the shadow economy can be found, for example, in Frey and Pommerehne (1984), Kirchgässner (1984), Karmann (1986), Barthelemy (1988), Feige (1989a), Schneider and Enste (2000), Schneider (2001), OECD (2002), Kazemier (2006), Georgiou (2007), Boockmann et al. (2010), Feld and Schneider (2010), Schneider and Enste (2013) and Schneider (2015a). This study is distinguished from this extensive range of literature by its focus on the illicit use of cash. Owing to this focus, approaches which cannot be used to derive illicit cash use are mostly disregarded.
**5** The term "shadow economy" is not uniformly defined in the economic literature. A large number of other terms are also used to refer to the shadow economy. Explanations of the term "shadow economy" and related concepts can be found, for instance, in Feige (1989a), Smith (1994), Schneider and Enste (2000), Pedersen (2003), Georgiou (2007), Boockmann et al. (2010), Schneider (2015a) and Feige (2016).

includes market-based value added where the underlying economic activity – trade or construction services, household services – is generally legal but which, for example, is rendered without the knowledge of the relevant authorities to circumvent taxes, social security contributions or regulations. In a broad definition, output which is not market-based – output which is self-produced or production which is performed informally to help out a neighbour – could also be included in the shadow economy (Karmann, 1990; Buehn et al., 2009) as this may also remain hidden from government authorities. Value added in connection with the production of goods and services for which the production, sale or possession is illegal, i.e. the manufacturing or sale of drugs, or smuggling, can also be counted as part of the shadow economy.

For the purposes of this paper, illegal uses of cash refer to those where the surrounding circumstances are not consistent with established law. Based on a common definition of the shadow economy in the economic literature (Schneider, 2015a), the term includes primarily the illicit use of cash as a means of payment for the market-based legal and illegal production of goods and services which are concealed from government authorities for the purposes of avoiding financial or other costs. As a result, non-market-based legal or illegal production in the taxonomy shown in Table 3 which, in particular, does not require the use of a payment medium, is disregarded.

Aside from this production-oriented perspective, other undesirable uses of cash are also conceivable. First, income from an illegal source could be hoarded. Second, cash can be used to conceal assets or income from assets, such as when income substitution benefits are claimed and at the same time assets held in cash are not declared. In general, cash can be used as a tool to facilitate corruption, money laundering or terrorist financing. The methods for determining the extent of the illicit use of cash discussed below are, however, generally linked to the production-oriented approach of the economic literature to determining the size of the shadow economy and are therefore not necessarily directly suitable for the comprehensive examination of the illegal uses mentioned here.

| Taxonomy of the shadow economy | | Table 2 |
| --- | --- | --- |
| | **Market-based** | **Non-market-based** |
| **Legal** | e.g. car repairs, trade services and household services | DIY work, helping out a neighbour |
| **Illegal** | Manufacturing, smuggling and sale of drugs | Manufacturing or smuggling drugs for personal use |

Sources: Bundesbank compilation as well as Feige (1989a), Smith (1994), Boockmann et al. (2010), Feld and Schneider (2010) and Schneider (2015a).

Conceptually, Germany's system of national accounts does take the named shadow economy activities into account – at least partially. According to the European System of Accounts (ESA 2010), activities relating to the production of goods and services should also be included "irrespective of being illegal or not-registered at tax, social security, statistical and other public authorities".[6] Sales without invoices, moonlighting and illegal production activities such as drug dealing and cigarette smuggling thus in principle contribute to Germany's gross domestic product (Taschowsky, 2015). Taking drug dealing and smuggling activities into account increases Germany's GDP by less than 0.1% (Taschowsky, 2015). Add-ons for completeness are also made in various places in the national accounts for other activities of the shadow economy (Federal Statistical Office, 2016). However, it is not known officially to what overall extent Germany's reported GDP includes shadow economy activities.

Despite the conceptual consideration of shadow economy activities, economic estimates regarding the size of the shadow economy are important because, first, the relevant statistical authorities publish the volume of additional estimates for

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**6**   As given in Eurostat (2014), Section 3.08, p. 54. The own-account production of goods by households includes, for instance, the own-account construction of dwellings, while domestic services such as cleaning the dwellings, which a household carries out itself, are excluded; see Eurostat (2014).

clandestine economic activities only in exceptional cases, and, second, these additional estimates may only show part of the activities in the shadow economy. Table 3 shows an overview of the estimates regarding the extent of the shadow economy in Germany. The definition of the shadow economy is not necessarily comparable across the various studies, meaning that each of the studies could record different amounts of economic activity. The procedures used are also subject to debate in the economic literature.[7] The various studies put the size of the shadow economy in Germany at between 2.4% and 16.6% of GDP. In terms of a GDP of around €3,300 billion in 2017, estimates for the scope of the shadow economy thus vary between approximately €80 billion and €550 billion. Overall, the estimates of the size of the shadow economy based on public surveys (Pedersen, 2003; Feld and Larsen, 2005, 2012) are much lower than the macroeconomic estimates (Schneider, 2005; Pickhardt and Sardà, 2006, 2011; Hassan and Schneider, 2016). The size of the shadow economy is possibly underestimated in studies based on public surveys, as respondents may be unwilling to disclose information. A widely-held opinion in the literature, on the other hand, is that macroeconomic procedures could overestimate the size of the shadow economy (Thießen, 2011; Kirchgässner, 2017). Even some of the criticisms outlined below of cash-based estimates regarding the extent of illicit cash use suggest that the size of the shadow economy cannot be estimated with precision using macroeconomic approaches. The wide range of estimation results available reflects the uncertainty associated with empirical analyses of the shadow economy.

Insofar as the estimates presented here provide at least a rough indication of the size of the shadow economy in Germany, underground economic activities are extensive in Germany. Continuing to follow the common assumption in the economic litera-

| Estimates of the extent of the shadow economy in Germany as a percentage of GDP | | | | Table 3 |
|---|---|---|---|---|
| Study | Method | 01-05 | 06-10 | 11-15 |
| Buehn et al., 2009[a] | MIMIC and currency demand approach | 16.2 | | |
| Feld and Larsen, 2005, 2012[b] | Public survey | 3.6 | 2.4 | |
| Hassan and Schneider, 2016 | MIMIC | 16.5 | 15.0 | 15.7 |
| Onnis and Tirelli, 2010 | Electricity approach | 10.9 | | |
| Pedersen, 2003 | Public survey | 4.1 | | |
| Pickhardt and Sardà Pons, 2006[c] | MIMIC and currency demand approach | 15.3 | | |
| Pickhardt and Sarda, 2011[d] | Cash-deposit ratio approach | 9.8 | 9.6 | |
| Schneider, 2005 | MIMIC and currency demand approach | 16.6 | | |
| Schneider, 2007 | MIMIC and currency demand approach | 16.1 | | |
| Schneider, 2015b | MIMIC | 16.2 | 14.5 | 12.6 |
| Schneider, 2017[e] | Adjusted MIMIC approach | | 10.4 | 10.4 |
| Schneider and Buehn, 2018[f] | MIMIC | 14.7 | 14.7 | 14.7 |

Notes: In each case, the average of the values given for the respective timeframe in the study mentioned is stated. Where a study employs more than one method, the data are based on a single selected approach. **a** Size of the shadow economy according to the H-DIY model. **b** Calculated as the ratio of the working hours worked illegally to the working hours in the regular economy. Value for 01-05 according to Feld and Larsen (2005), value for 06-10 according to Feld and Larsen (2012). **c** According to the joint model. **d** According to the modified G3 approach. **e** According to Table 2.5, average for 2009 to 2015. **f** Average for the period from 1996 to 2014. The cash-deposit ratio approach is dealt with in Section 3.3 and the currency demand approach is dealt with in Section 3.5. The other methods mentioned are not directly suited to obtaining information on illicit cash use and are therefore not explained in this paper.
Sources: Compiled by the authors.

ture that transactions in the shadow economy are predominantly settled in cash,[8] the size of the shadow economy, in addition to trade in intermediate products, would reflect the illegal cash transactions carried out. The illicit use of cash would therefore be frequent in Germany. This question of the illicit use of cash is to be examined further on.

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**7**  Critical discussions of estimates of the size of the shadow economy in general or of individual methods can be found, for instance, in Helberger and Knepel (1988), Thomas (1999), Caridi and Passerini (2001), Breusch (2004, 2005a, 2005b, 2005c), Ahumada et al. (2007), Schneider (2015a), Feige (2016) and Kirchgässner (2017).

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**8**  This assumption is central to some cash-based methods of estimating the size of the shadow economy; see, for example, Schneider (2015a). Feige (1979), for instance, takes a critical view of this assumption.

## 3.2 Direct estimates

The economic literature sometimes argues that existing information on foreign demand or the legitimate holding of cash domestically understates total cash in circulation and the circulation of large-denomination banknotes (Rogoff, 1998; Rogoff, 2015; Rogoff, 2016). To clarify the motivation for using direct estimates, Table 4 shows an international comparison of cash in circulation per inhabitant and the share of large-denomination banknotes in the total volume of cash in circulation.[9]

### 3.2.1 Direct estimates using the volume of cash in circulation per inhabitant

Looking at the regions in question, Switzerland recorded the highest figure for cash in circulation per inhabitant in US dollar terms (USD 9,516), followed by Hong Kong (USD 7,341), Japan (USD 7,214) and Singapore (USD 5,242). In some cases, regions with a relatively low population thus showed particularly striking figures for cash in circulation per capita; this is true of Switzerland, Hong Kong and Singapore. Even if it is not known whether large volumes of cash issued in these particular currencies are in circulation abroad, these high figures could partly be explained by foreign demand. If a currency has a small volume of cash in circulation overall, relatively low demand from abroad already suffices to generate a large figure for cash in circulation per inhabitant. This argument cannot be used to explain the strikingly high cash in circulation per inhabitant of USD 7,214 in Japan. High income combined with low interest rates may potentially be a factor contributing to relatively large cash holdings. In 2016, cash in circulation per inhabitant was USD 3,579 in the euro area and USD 4,671 in the United States. The economic literature devotes intensive study to the foreign circulation of euro and US dollar cash, in particular (Porter and Judson, 1996; Bartzsch et al., 2011a, 2011b; Feige, 2012;

Judson, 2012; European Central Bank, 2017; Bartzsch and Uhl, 2017, Deutsche Bundesbank, 2018). This foreign demand for euro and US dollar cash probably explains the relatively high per capita value of cash in circulation for the euro area

| Cash in circulation per inhabitant and share of large-denomination banknotes for 2016 | | | Table 4 |
|---|---|---|---|
| Country | Cash per capita in USD | Share of large-denomination banknotes in % | Lowest-value large denomination banknote |
| Australia | 2,379 | 43 | AUD 100 |
| Brazil | 346 | 39 | BRL 100 |
| Euro area | 3,579 | 48 | EUR 100 |
| Hong Kong | 7,341 | 45 | HKD 1,000 |
| India | 151 | 49 | INR 2,000 |
| Japan | 7,214 | 88 | JPY 10,000 |
| Canada | 1,788 | 51 | CAD 100 |
| Mexico | 565 | 6 | MXN 1,000 |
| Russia | 989 | 72 | RUR 5,000 |
| Saudia Arabia | 1,678 | 81 | SAR 500 |
| Sweden | 689 | 5 | SEK 1,000 |
| Switzerland | 9,516 | 74 | CHF 200 |
| Singapore | 5,242 | 57 | SGD 100 |
| South Africa | 131 | 32 | ZAR 200 |
| South Korea | 1,584 | 78 | KRW 50,000 |
| Turkey | 444 | 27 | TRY 200 |
| USA | 4,671 | 77 | USD 100 |
| United Kingdom | 1,429 | 21 | GBP 50 |

Notes: There are no clear rules for distinguishing between large, and small or medium-denomination banknotes so this distinction is somewhat arbitrary. As a rule, the threshold is selected in such a way that the smallest "large" banknote of the respective currency has a value as close as possible to €100.
Source: Compiled by the authors according to the Bank for International Settlements (2017).

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**9** Barthelemy (1988), Georgiou (2007) and Deutsche Bundesbank (2016) also discuss the use of direct approaches to estimate the scale on which cash is being used illicitly. The term direct estimates is used here to describe the above-mentioned procedure to estimate the scale on which cash is being used illicitly, as it draws on banknote circulation, which is directly observed, and data or estimates pertaining to the amount of cash held, which are available directly.

and the United States. As expected, across all the countries observed, there was a higher volume of cash in circulation in countries with greater economic power than in countries with a smaller economy, as demand for cash as a means of payment and as a store of value is a function of income.

The volume of banknotes in circulation per inhabitant in Germany is shown in Figure 5. At the end of 2017, the imputed value of the euro banknotes issued by the Bundesbank came to around €7,700 per inhabitant in Germany, although a considerable share of banknotes issued by the Bundesbank were in circulation abroad. Using the estimated volume of banknotes in circulation in Germany implies that banknote holdings per inhabitant stood at €2,500 at the end of 2016.

**Euro banknotes in circulation per inhabitant in Germany**  Figure 5

€ thousand, year-end data



Cumulative net issuance by the Bundesbank per inhabitant
Domestic circulation per inhabitant[1]

**1** Estimated domestic circulation.
Deutsche Bundesbank
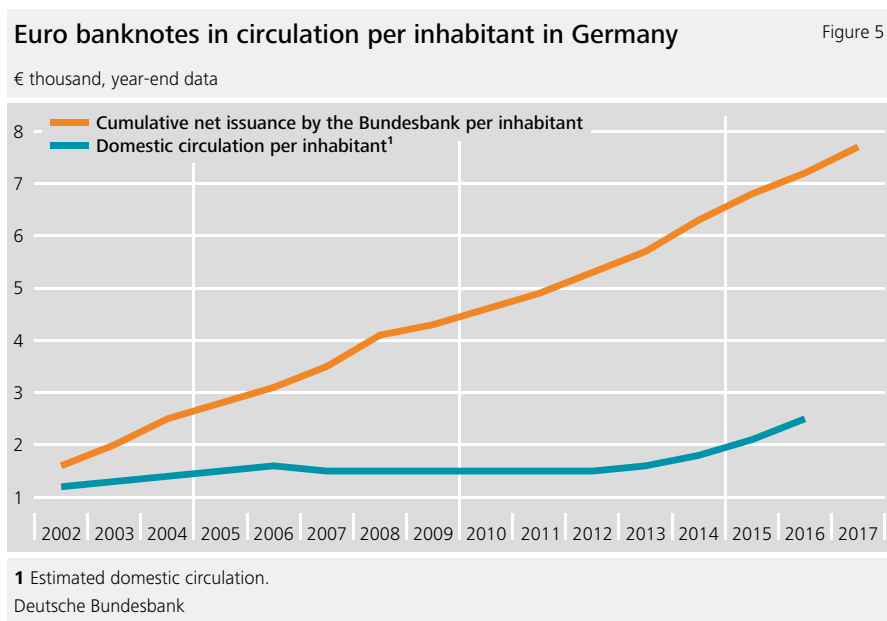
Statistical data on cash in circulation could be applied to determine the illegal use of cash as a residual if data were to exist on use of cash in the respective currency abroad and on the legitimate domestic use as a transaction currency and as a store of value. The European Central Bank (ECB) estimates that €340 billion worth of banknotes were in circulation outside the euro area at the end of 2016, which was equivalent to around 30% of the total volume of euro banknotes in circulation at that time (ECB, 2107). The estimates of domestic and foreign components of the euro banknotes in circulation presented in Section 2.2 suggest that at the end of 2016, a total of around 65% of the euro banknotes issued by the Bundesbank had found their way abroad. By this measure, euro banknotes worth an estimated €200 billion were in circulation in Germany. Judson (2012) estimates that roughly half of the US currency issued is held outside the United States. Feige (2012) estimates a significantly lower share (approximately 20%) of US currency abroad, however. Foreign circulation must be taken into consideration when determining the extent of illicit cash use.[10]

By way of an example, subtracting the estimated foreign circulation from the value of Bundesbank-issued euro banknotes gives around €200 billion or €2,500 per inhabitant at the end of 2016. Figures presented in Section 2.2. on credit institutions' cash holdings (€26 billion), households' estimated cash holdings for transaction purposes (€13 billion)[11] and retailers' estimated cash holdings (€2 billion) only partially account for this volume of cash in circulation. No explanation can be provided so far for the roughly €160 billion or €2,000 euro per inhabitant which remains after deducting these components.

**10** Some of the Bundesbank-issued euro cash in circulation abroad could be used illicitly there, too. This study, however, refers to the illegitimate domestic use of cash.
**11** This estimate of households' cash holdings for transaction purposes can, in part, even comprise illegal uses of cash as it is based on responses to the Bundesbank's payment behaviour study regarding the cash withdrawals (Deutsche Bundesbank, 2015). This provision of cash may partially serve illegal purposes.

On an international level, too, direct data on cash usage can only explain a small part of the (domestic) circulation of cash in the respective currency.[12] Vault cash held by American institutions subject to reserve requirements is stated as around USD 80 billion for December 2017.[13] A survey conducted for the United States showed that on average respondents had a total of USD 207 cash on their person or stored at home, in the car or in the office (Greene et al., 2016).[14] Bagnall et al. (2016) observed surveys on payment behaviour in Australia, Germany, France, Canada, the Netherlands, Austria and the United States. On balance, the average cash balance in respondents' wallets is equivalent to between USD 51 in the Netherlands and USD 148 in Austria. A study by the ECB argues that at the end of 2008 around one third of banknotes in circulation were held for transaction purposes, credit institutions held a further €60 billion, and 20% to 25% of the cash in circulation was held outside the euro area, leaving an unexplained remaining portion of between €250 billion and €300 billion (ECB, 2011).

As a rule, estimates for foreign demand for a currency and for the cash holdings of credit institutions, retailers and households can therefore not fully explain the volume of a currency in circulation.[15] On the one hand, these unexplained cash holdings could be held as a legal store of value and, on the other, for illegal purposes. Surveys in which households provide data quantifying how much cash they use as a store of value are relatively rare. In a study conducted in 2008 by the ECB in Belgium, Germany, France, Italy, Luxembourg, the Netherlands, Austria and Spain, 57% of respondents

stated that they kept just the amount of cash they needed for everyday purchases (ECB, 2011). Roughly one-third of the respondents who use cash as a store of value stated that they hold cash with a value of less than €1,000 as store of value, 2.8% of respondents indicated that they saved between €1,000 and €5,000 and 0.5% saved more than €5,000. 2.9% of respondents held cash but declined to provide any details on the amount. Using these results and a survey of enterprises conducted at the same time as a basis, the ECB determined that in 2008 households and companies in the euro area held at least €100 billion in cash, significantly less than the estimated unexplained sum of between €250 billion and €300 billion. From a security perspective, households are likely to be reluctant to provide information about private cash holdings. Moreover, the distribution of private cash holdings is likely to be very heavily concentrated on a few cash users. These cash users are rarely sampled in household surveys with typical samples of around 1,000 to 2,000 respondents and they may also show a particularly pronounced unwillingness to disclose information.

On balance, it is not possible to reliably separate the part of banknotes in circulation which is not circulating abroad or used for transaction purposes into legal and illegal holdings. Even if the value of currency legitimately used domestically as a store of value cannot be observed directly, general questions can be raised about whether a legal store of value in the high two digit or lower three-digit billion range is actually plausible in Germany. Figure 6 shows the share of cash in households' financial assets in Germany. The cash assets of German households are calculated from the volume of Bundesbank-issued euro banknotes by deducting direct estimates for foreign demand and the cash holdings of retailers and the statistical data on credit institutions' cash holdings. By comparison, the chart shows the share of hoarded banknotes in financial assets on the basis of the seasonal method.[16] Even if the chronology of the two time series is not identical, both

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**12**   This phenomenon has also been discussed in "Missing Currency" (Sprenkle, 1993) or "Currency Enigma" (Feige, 1989b, 1994).

**13**   Source: Board of Governors of the Federal Reserve System (US), Vault Cash, Total [TLVAULT], downloaded from FRED, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/TLVAULT, 15 May 2018.

**14**   Large holdings of cash (above roughly USD 2,600) were excluded when calculating this average.

**15**   Rogoff (1998, 2015, 2016) provides a comprehensive overview of currency demand and its components for a large number of currencies. On balance, the estimates presented for the foreign demand for banknotes of various currencies and the estimates presented for the legitimate holding of banknotes domestically do not, as a rule, fully account for the banknotes in circulation.
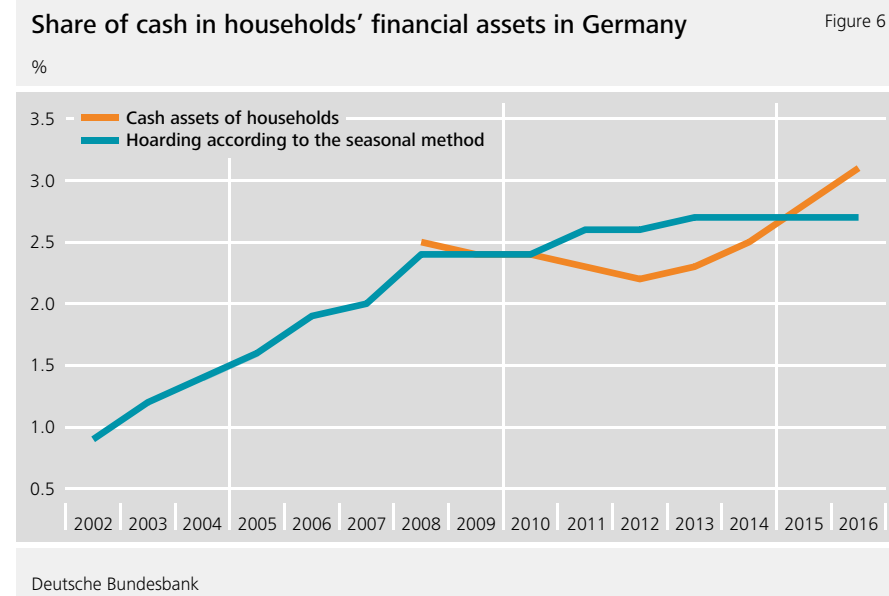
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**16**   Conceptually speaking, the stocks of hoarded banknotes calculated using the seasonal method are not fully comparable with the methodology for financial assets according to the financial accounts.

approaches indicate a roughly 2.5% to 3.0% share of cash in financial assets at the end of 2016. The figures for cash in circulation per inhabitant, as high as they might appear at first, can be put into perspective, as only a small part of total financial assets must be held in cash in order to explain them.

Tobin (1958) uses a portfolio-based theory to address the question of why economic agents hold non-interest-bearing forms of money such as cash when assets bearing interest are available too. The analyses presented in Tobin (1958) suggest that economic agents hold cash and other non-interest-bearing forms of money because the investment risk is lower than that of investments bearing interest. More generally, economic agents could hold a part of their assets in cash for reasons of liquidity and security (Deutsche Bundesbank, 2016). Cash is legal tender and therefore can generally be used in Germany at any time to settle a financial obligation, particularly if the technical requirements for making a cashless payment are not in place. For this reason, some consumers might form cash reserves in order to be able to cover expenses even in the event of unforeseen circumstances. Furthermore, certain investors might be concerned about the stability of the banking and financial system and set aside cash for this reason. Cash is secure central bank money that is generally not exposed to the risk of default. One example of the fact that substantial amounts of cash are held legally as a store of value can be seen from developments in the demand for cash during the escalation of the financial crisis following the Lehman Brothers crisis in September 2008. The Bundesbank's cumulative net issuance of €500 banknotes rose by around €20 billion between October 2007 and October 2008. To sum up, it cannot be excluded that significant volumes of cash are being held as a legal store of value. This means that the volume of cash in circulation cannot be used directly to establish the scale on which cash is being used for illegal purposes, either.



Share of cash in households' financial assets in Germany                Figure 6

%

— Cash assets of households
— Hoarding according to the seasonal method

Deutsche Bundesbank

### 3.2.2 Direct estimates using large-denomination banknotes in circulation

A further direct estimate of the illegal use of cash is based on demand for large-denomination banknotes. Column 3 in Table 4 on page 33 shows the share of large-denomination banknotes in the total volume of cash in circulation according to region, with column 4 defining the lower limit above which a banknote is classified as large-denomination. The percentage of large-denomination banknotes in circulation is very high in many regions, with $100 notes accounting for around 77% of US dollar currency in circulation, for example. In 2016, banknotes with a nominal value of €100 and higher accounted for a 48% share of euro currency in circulation and banknotes with a nominal value of 200 Swiss francs and higher for 74%.

While large-denomination banknotes account for a considerable share of cash in circulation in many currencies, a common thesis suggests that they are omitted in official payment systems. This potential contradiction is sometimes resolved with

reference to the illegal use of these banknote denominations. The share of high-value banknotes in all notes in circulation indicates a pronounced use of cash for illegal purposes overall, according to this view. The use of large-denomination banknotes has been examined in household surveys. In an ECB survey, the interviewees reported how often they were in possession of a €200 or €500 banknote. On balance, 41% of the respondents stated that they had never been in possession of one of these banknotes, while 25% reported having a €200 or €500 banknote in their possession more than once a year. A further 33% reported having one of these banknotes in their possession once a year or less frequently than once a year (ECB, 2011). In a Bundesbank survey, 36% of respondents stated that they had never held a €500 banknote in their hand. 23% had already come into contact with this denomination but do not use it. 35% of respondents use the €500 banknotes on rare occasions, 3% occasionally and 1% often.[17]

It therefore appears that large-denomination banknotes are generally not used by part of the general public, but they do crop up in business life. If large-denomination banknotes are used for payments, then potentially for rare, high-price transactions, in particular. Given the fact that transaction balances only make up around 5-10% of the Bundesbank's net issuance of euro banknotes, however, it is not to be expected that purpose of payment can explain the volume of large-denomination banknotes overall. The volume of large-denomination euro banknotes is more likely to be determined through foreign demand, legitimate use as store of value, or illicit use.

At the end of 2017, the joint share of the large €100, €200 and €500 denominations in the volume of banknotes in circulation stood at 55% for the components issued by the Bundesbank and 41% 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 part issued by the Bundesbank than for components issued by 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 ECB, which analysed cash usage in Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands and Spain, found that €200 and €500 banknotes are not used more intensively in Germany (European Central Bank, 2011).[18] This suggests that the reason for the large percentage of high-value banknotes in the Bundesbank's cumulative net issuance is likely to be the use of German-issued euro banknotes in other countries. Taking the French banknote circulation as a benchmark, Bartzsch et al. (2011b) use the seasonal method to determine that in 2009 around €95 billion of the net issuance of €500 banknotes by the Bundesbank was in fact held outside the euro area. This corresponded to around 80% of the total issuance of €500 banknotes by the Bundesbank at that time. There is therefore a greater proportion of large denominations in circulation outside the euro area than of banknotes of a lower denomination generally used for payments.

The domestic circulation of high-denomination banknotes cannot be broken down directly into legitimate function as a store of value and the illicit use of cash. High-denomination banknotes make it possible to store larger sums of money in a relatively small space. They are thus particularly useful for the store of value in cash and also for high-value legal and illegal transactions.

To sum up, there are difficulties when differentiating between the illicit use of cash and the legal storage of value using direct estimates, which means that the proportion of illicit use of cash cannot be quantified in a precise manner either.

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**17**  Some of the results of this survey are presented in Deutsche Bundesbank (2015b).

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**18**  22% of respondents in Germany reported having a €200 or €500 banknote in their possession more than once a year, compared with 25% of respondents on an average of the countries in the study.

### 3.3 Cash-deposit ratio approach

### 3.3.1 Basic concept behind cash-deposit ratio approach

The cash-deposit ratio approach for determining the scale of the underground economy dates back to Cagan (1958) and Gutmann (1977), with cash-deposit ratios generally defined as the ratio of cash in circulation to sight deposits. Those using the approach see the unexplained rises in the size of these cash-deposit ratios as an indication of the illicit use of cash.

Cagan (1958) observed marked increases in the cash-deposit ratios during World Wars I and II. With some reluctance, Cagan (1958) asserted that a higher income tax burden during World War II was attributable to the rise in cash-deposit ratios observed at that time. The US tax ratio actually rose from 2% in 1939 to 11% in 1945.[19] An increase in the tax rate might have boosted motivation to provide economic services without government knowledge and for this reason demand for cash could have risen relative to deposits.

Cagan (1958) subsequently uses this observation of the cash-deposit ratio. The ratio of cash in circulation to the total money supply, excluding the money holdings of incorporated businesses, was found to amount to 15.5% in June 1940. Using this ratio, unincorporated businesses and consumers would have been expected to hold USD 12.4 billion of cash in June 1945, but the actual figure was USD 23.2 billion. Since Cagan (1958) simultaneously argues that a number of other variables could not have affected the cash-deposit ratios over this period, he comes to the conclusion that at that time there was an unexplained excess demand for currency, which was mainly due to cash being used for illegal purposes.

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**19**  The tax ratio is calculated as personal current taxes as a percentage of personal income. Source: Bureau of Economic Analysis, National Income and Product Accounts Tables, Table 2.1. Personal Income and Its Disposition, downloaded on 4 May 2017. In the description of the development of tax rates on particularly high income and inheritances in Piketty (2014), an increase is also visible during World War II.

Cagan (1958) identifies that developments in interest payments and income and other variables such as black markets, the size of the US armed forces, travel activities and war-related change of residence cannot explain the rise in cash-deposit ratios during the World War II. From the variables under consideration, Cagan (1958) thus singles out the tax burden as main explanation. However, the higher cash-deposit ratios during both World Wars would also be consistent with increased use of cash as store of value, which could rise in times of war against a backdrop of general uncertainty.

Gutmann (1977) touches upon Cagan's cash-deposit ratio approach (1958) with the aim of also assessing the size of the shadow economy for other points in time.

### 3.3.2 Critical discussion of the cash-deposit ratio approach

One advantage of the approach is that all illicit use of cash is generally taken into consideration, in particular the use of cash for settlement in the shadow economy and cases of corruption and money laundering. As a condition for use of the cash-deposit ratio, it is, however, important that there was indeed a base year in which there was no illicit use of cash. Thomas (1999) argues that there has never been a period when a shadow economy did not exist.

In order to calculate illegal cash demand, the cash-deposit ratio approach still assumes that the ratio of currency in circulation to sight deposits would remain constant over time without the influence of illegal economic activities. However, Cagan (1958) cites a set of variables which could affect the cash-deposit ratio, the most important of which include the interest rate and the level of economic activity. Generally speaking, technological advances and in particular innovations being made in the world of payments and banking could over time contribute to changes in the ratio of currency in circulation to sight deposits. Specific examples of relevant determinants are an increasing volume of cashless wage payments as well as the emergence of ATMs. The cash-deposit ratio could, in principle, also rise as a result of an increase in legitimate use of cash as a store of value.

Pickhardt and Sardà (2011, 2012) observe that the cash-deposit ratio has declined in a number of industrial nations and argue that this implies implausible negative values for the size of the shadow economy. Figure 7 indeed confirms that variously defined cash-deposit ratios for Germany have generally declined, at least up to the launch of euro cash. Following the introduction of the euro, there was a rise in the cash-deposit ratios shown; however, this is not least because of the changed development in foreign demand for banknotes issued by the Bundesbank.

**Cash-deposit ratio in Germany\***  Figure 7



\* Cash-deposit ratios are defined as the ratio of currency in circulation to sight deposits or sight and time deposits. The dashed lines show the cash-deposit ratios calculated after deducting an estimate of the foreign demand for euro banknotes issued by the Bundesbank. The data observed in this analysis have breaks in the time series.
Deutsche Bundesbank

Partly motivated by the need to avoid the assumption of a constant ratio of currency in circulation to sight deposits, Pickhardt and Sardà (2011, 2012) examine the size of the shadow economy in Germany using a modified cash-deposit ratio. This modification no longer requires an assumption about the ratio of currency in circulation to sight deposits, but instead assumes that in Germany every increase in real

cash in circulation per inhabitant since the base year is due to the illicit use of cash.[20] The possibility of at least part of the increase in real cash in circulation per inhabitant in Germany being due to the legitimate hoarding of cash is therefore ruled out. The income and wealth of non-banks in Germany have risen since the base year 1960. This means, on the one hand, that more currency is required to carry out legitimate transactions, but on the other hand that a greater proportion of cash is presumably used as a store of value.

In an expansion of this modified cash-deposit ratio approach, Pickhardt and Sardà (2012) show how legitimate cash holdings affect estimates of the shadow economy's size. As it is not possible to estimate the size of legal and illegal cash hoarding, Pickhardt and Sardà (2012) estimate how large the shadow economy is in various scenarios. Depending on the size and composition of the hoarding stocks, the size of the shadow economy was between 2% and 9% of GDP in 2009. Various assumptions about the scale of legitimate cash hoarding thus have a significant influence on estimates of the size of the shadow economy.

On balance, as with the approaches described in Section 3.2, the cash-deposit ratio approach cannot differentiate between the illicit use of cash and the legitimate use of cash as a store of value. In addition to the other above-mentioned difficulties, this would caution against selecting this approach to estimate the extent of illicit cash use.

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**20**  In different variants of their approach, the authors adjust the cash in circulation in Germany for the period from 1960 to 2008 for the effect of inflation, demographic developments, one-off effects caused by the introduction of euro cash and for estimates of the foreign demand for euro banknotes issued by the Bundesbank. On balance, the share of illegal economic activity increases from zero to 18% up to 1987, before then falling to 11% by the end of the review period.

## 3.4 Transactions approach

Business life involves a multitude of different transactions between government, enterprises and consumers. This is the starting point of the transaction approach for determining the size of the underground economy as described by Feige (1979), who interprets irregularities in movements in the total value of transactions as an indication of underground economic activity.[21]

Data on the total value of the transactions in an economy are needed to apply this approach. Feige (1979) calculates the value of cashless transactions using available data on the value of demand deposits as well as the average velocity of these deposits. The value of cash transactions is not directly observable and has to be estimated approximately. The value of cash transactions can be determined by weighting the currency in circulation with an estimate of the velocity of cash (Feige, 1989a). To calculate the velocity of cash, Feige (1979) estimates that the average number of transactions that can be performed with one unit of currency is 125 before it is withdrawn from circulation and divides this figure by the average lifetime of this unit of currency. Feige (1979) calculates this average lifetime of one unit of currency as the ratio of currency in circulation to the value of the cash that is withdrawn from circulation within one year. Feige (1979) uses this information to calculate that, in 1978, underground transactions with an estimated value of USD 5,600 billion were performed, compared with legitimate transactions with a value of USD 21,700 billion. This results in the size of the underground economy amounting to 26% of the legitimate US economy in 1978.

Following the transaction approach of Feige (1979) solves, in particular, some problems of the cash coefficient approach (Feige, 1989a; Schneider, 2015a). For example, there is no need to assume that underground transactions are settled

solely in cash. Difficulties in applying the transaction method emerge chiefly in empirically determining the total value of the transactions. The total number of transactions in an economy not only covers buying new goods and services but also encompasses purchasing intermediate products and existing goods in addition to transactions that are of a purely financial nature (Feige, 1979; Langfeldt, 1989). Such purely financial transactions include transfer payments and portfolio shifts, for example. Key to this method, however, is the assumption of proportionality between the total value of the end products of an economy and the measured transaction volume (Frey and Pommerehne, 1984). Changes in the relative importance of the above-mentioned aspects argue against such an assumption of a constant ratio of the transaction volume and economic output. In practical applications of the transaction approach, users therefore try to adjust the transaction volume, as far as possible, for the effect of the cited factors (Feige, 1979, 1989a; Kirchgässner, 1983; Langfeldt, 1989; Smith, 1994). Feige (2016) notes, however, that the dynamics of the financial transactions and difficulties in capturing them mean that the transaction approach has no longer been used for the current period in the literature. Moreover, estimating the total value of the transactions conducted in cash is, in general, challenging (Cramer, 1986; Karmann, 1986; Boockmann et al., 2010; Krüger and Seitz, 2014; Schneider, 2015a). When determining a suitable velocity, estimates of the domestic transaction volume performed by weighting the volume of currency in circulation have to pay particular attention to the fact that a part of the cash in a given currency is being used as a store of value or might be located abroad.

To sum up, difficulties in empirically determining the relevant transaction volumes argue against applying the transaction method in order to determine the scale of the illicit use of payment media (Schneider, 1986; Schneider, 2015a; Feige, 2016; Schneider and Buehn, 2018).

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**21** This approach is discussed, for example, in Feige (1989a) and Schneider (2015a). An application of the transaction approach to Germany may be found in Langfeldt (1989).

### 3.5 Currency demand approach

### 3.5.1 Basic design and applications of the currency demand approach

The currency demand approach for analysing the shadow economy enhances traditional money demand models by the addition of variables that are designed to capture the impact of illegal activities on the demand for cash.[22] In the literature it is customary to incorporate a tax rate (Tanzi, 1983; Klovland, 1984; Schneider, 1986), although other variables such as the unemployment rate or indicators of criminality can be included in the empirical modelling (Drehmann and Goodhart, 2000; Ardizzi et al., 2014a, 2014b; Herwartz et al., 2016). Provided that the selected indicators explain parts of the currency demand, this ultimately points to an illegal use of cash.

A textbook application of the currency demand approach begins by modelling the currency demand $C_t$ as a function of transaction variables, an interest rate $i_t$ for measuring the opportunity costs of cash holdings as well as, possibly, other control variables $\Theta_t$.

$$(1) \qquad C_t = f_1(Y_{L,t}, Y_{I,t}, i_t, \Theta_t)$$

The particular feature in equation (1) consists of the fact that the currency demand is formulated explicitly as a function of legitimate economic output $Y_{L,t}$ as well as of illegal economic output $Y_{I,t}$. The scale of illegal economic output is unknown; indicators $x_{I,t}$ for the scale of illegal economic output are incorporated instead. It is customary in the literature to add a tax variable as an indicator of the shadow economy. This approach can be justified by the tax burden setting incentives to shift economic activities into the shadow economy.

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22   Surveys of the theoretical and empirical work on the demand for money may be found, for example, in Goldfeld and Sichel (1990) and Sriram (1999). The currency demand approach for determining the scale of the shadow economy is explained, for example, in Hofreither and Schneider (1987) as well as Schneider (2015a). Applications of the currency demand approach may be found, for instance, in Tanzi (1983), Klovland (1984) and Schneider (1986), and for Germany in Kirchgässner (1983), Langfeldt (1989), Karmann (1990), and Pickhardt and Sardà Pons (2006).

$$(2) \qquad C_t = f_2(Y_{L,t}, x_{I,t}, i_t, \Theta_t)$$

The aim of some applications of the currency demand approach is, in the next step, to decompose the entire currency demand $C_t$ into a legitimate part $C_{L,t}$ as well as an illegal part $C_{I,t}$. To do this, it is assumed there is no shadow economy for certain values of the indicators of illegal economic output, $x_{I,t}^*$. Assumptions that there would be no underground economy if the tax rate were zero or at an all-time low (Tanzi, 1980, 1983) are widespread in the literature. Legitimate cash holdings $C_{L,t}$ then follow in line with the assumption as

$$(3) \qquad C_{L,t} = f_2(Y_{L,t}, x_{I,t}^*, i_t, \Theta_t)$$

As a result, illegal cash holdings $C_{I,t}$ follow from this as

$$(4) \qquad C_{I,t} = C_t - C_{L,t}$$

The size of the underground economy could be calculated from this by weighting the illicit use of cash by the velocity of circulation of currency $v$. One possible way of calculating $v$ is

$$(5) \qquad v = \frac{Y_{L,t}}{D_t + C_{L,t}}$$

where $D_t$ comprises certain deposits. Naturally enough, calculating the velocity of circulation has to be based on the observed economic output, which implies having to make the critical assumption that the velocity of circulation of currency in the legitimate economy corresponds to that in the illicit economy. In line with the assumption, deposits $D_t$ continue to be used solely in a legitimate way, which is reflected, first, in the velocity of circulation being calculated in accordance with equation (5) and, second, in the shadow economy being calculated solely by weighting the illicit use of cash.

The papers by Tanzi (1980, 1983) are regarded as the first applications of the currency demand approach. Tanzi (1983) investigates, for the period from 1930 to 1980, the ratio of cash in circulation to the monetary aggregate M2 as a function of income per capita, an interest rate for fixed-term deposits, the ratio of wages and salaries to national income as well as an income tax variable. Tanzi (1983) argues that an increase in the tax burden heightens the incentives to undertake activities in the shadow economy and that, for this reason, the cash-deposit ratio should rise. In the estimated regression equations, all the ratios are indeed statistically significant and have the expected signs.

Depending on the specification, illicit cash holdings in 1980 amount to USD 16 billion and USD 22 billion respectively, which corresponds to 15% and 20% of the cash holdings in 1980 predicted by the model. The shadow economy amounts to 4% and 6% of gross national product (GNP) in 1980. Since the papers by Tanzi (1980, 1983) the currency demand approach has been applied in many variants. Table 5 contains an overview of selected applications of the currency demand approach for Germany and other economic areas.

## Selected applications of the currency demand approach · Table 5

| Study | Study design | Result |
|---|---|---|
| Tanzi (1983) | The US cash-deposit ratio (currency in circulation divided by the monetary aggregate M2) is modelled for the period from 1930 to 1980 as a log-linear function of various measures for the tax burden, real income per capita, an interest rate and the ratio of salaries and wages to national income. | The tax rate has a positive, statistically significant impact on the cash-deposit ratio. Depending on the specification, illicit cash holdings in 1980 amount to USD 16 billion and USD 22 billion respectively, which corresponds to 15% and 20% of the cash holdings in 1980 predicted by the model. |
| Kirchgässner (1983) | Variants after Tanzi (1983) and Klovland (1984) for Germany for the period from 1950 to 1980. | A measure for the marginal tax rate of an average wage earner has a positive, statistically significant effect in each case. The size of the underground economy, according to the approach of Tanzi (1983), amounted to 2% of gross national product (GNP) in 1960 and 10% of GNP in 1980 and, according to the approach of Klovland (1984), 2% of GNP in 1960 and 11% of GNP in 1980. |
| Klovland (1984) | Non-banks' cash holdings in Norway and Sweden are specified in an error correction model as the function of a price index, an income variable, an interest rate and various measures for the marginal tax burden. | In Norway the various measures for the marginal tax burden generate no significant effect; in Sweden the marginal tax burden is found to have a statistically significant effect on cash holdings. Depending on the specification, illicit cash holdings in Sweden amount to between SEK 9 billion and SEK 17 billion in 1982. This would correspond to between 23% and 43% of the banknotes and coins in circulation outside the Riksbank in 1982 amounting to SEK 41 billion. |
| Schneider (1986) | Real cash holdings in Denmark are modelled for the period from 1952 to 1982 in a dynamic, log-linear approach as the function of a transaction variable, an interest rate and various measures of the tax burden. | Various measures of the tax burden each generate a positive, statistically significant effect on real cash holdings. Depending on the specification, the size of the underground economy amounted to between 7% and 13% of GNP in 1982. |
| Pickhardt and Sardà Pons (2006) | Cash holdings in Germany in the period from 1980 to 2001 are specified as a log-linear function of GDP, a price index, a measure of the tax burden, as well as an interest rate. | The tax burden has a positive, statistically significant effect on cash holdings. The size of the shadow economy amounts to 9% of GDP in 1980 and 15% of GDP in 2001. |
| Ardizzi et al. (2014a, 2014b) | Analysis of cash lodgements into and cash withdrawals from bank accounts in a panel of 91 Italian provinces for the period from 2005 to 2008. Inclusion of indicators for a legal and an illegal component of the shadow economy. | The size of the legal component of the shadow economy in Italy is stated as 17.5% of GDP and the size of the illegal component as 10% of GDP. The volume of money laundering in Italy amounts to 6% of GDP or 20% of GDP including deposits relating to the legal component of the shadow economy. |

Source: Own compilation.

While some papers apply the currency demand approach with the aim of calculating the size of the underground economy, other papers focus on the significance of indicators of the shadow economy in currency demand models. Shadow economy indicators making a statistical contribution to explaining the currency demand may be interpreted as an indication of the illicit use of cash on an indeterminate scale. Viren (1992) studies the impact of innovations in the financial and banking sectors on the currency demand. The author also looks at the suspected relationship between the tax burden and the currency demand, but notes that the tax burden does not have the expected effect. Doyle (1999) investigates the effects of the tax burden on the currency demand in 15 countries. Overall, the tax burden is mostly either insignificant or shows the wrong sign. Drehmann and Goodhart (2000) investigate determinants of the ratio of currency demand to GDP in 18 OECD countries for the period from 1980 to 1998. Besides variables designed to model the general macroeconomic setting and technological developments, indicators of the shadow economy are included. According to the results, the selected indicator of criminality has no effect on the currency demand. The tax ratio shows a significant effect with the expected sign, although the authors report that small changes in the considered sample lead to an insignificant tax ratio. Herwartz et al. (2016) find for a panel of OECD countries that the unemployment rate and the percentage of self-employed persons, as indicators of the underground economy with a positive, statistically significant sign, make a contribution to explaining currency in circulation. Seitz et al. (2018) study the connection between banknote demand and the shadow economy in the context of a cointegration analysis with panel data for the euro area and a group of eight countries outside this region, including the United States, Canada, Japan and Switzerland. Nominal private consumption expenditure or nominal disposable income and a short-term interest rate as a measure for the opportunity costs of cash holdings serve a control variable. A distinction is made between small, medium and large banknote denominations. Ultimately, they are able to find a long-term equilibrium relationship between banknote demand and the underground economy only for the medium denominations. This, in turn, is due to the

smaller euro area economies. This means that what is generally apparent across the various papers is a mixed picture regarding the impact of indicators of the underground economy on currency demand.

### 3.5.2 Critical discussion of the currency demand approach

In the economic literature, some points of criticism about the currency demand approach are also cited.[23] One point of criticism relates to the assumption that it is exclusively cash which is used as a means of payment in the underground economy. Isachsen and Strøm (1985) report on the basis of a survey of the public in Norway that around 80% of secretly offered labour services are paid for in cash. The shadow economy cannot be equated with a cash economy without qualification.

If the currency demand approach is to be used to draw a conclusion about the size of the shadow economy, it is also necessary to assume that the velocity of circulation in the official economy corresponds to that in the underground economy. As there is a lack of direct information about the velocity of circulation of currency in the underground economy, this assumption is virtually unavoidable in the currency demand approach. It could be argued, however, that the velocity of circulation of currency in the shadow economy is slower than the velocity of circulation of currency in the official economy, as a larger part of the illegally acquired funds could be stored over the long term. On the other hand, it is possible to argue that the depth of added value in the shadow economy is relatively more pronounced than in the official economy, leading to a higher velocity of circulation of currency in the shadow economy.[24]

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**23** Discussions of selected applications may be found, for example, in Acharya (1984), Tanzi (1984, 1986), Feige (1986), Thomas (1986), Zilberfarb (1986) as well as Breusch (2005a, 2005d, 2006). The focus of the present paper is on a general discussion of the currency demand approach; see, for example, Hofreither and Schneider (1987), Schneider and Enste (2000), and Schneider (2015a). Not all the cited points of criticism apply to every variant of the currency demand approach. Some of the points of criticism cited here likewise apply to the cash-deposit ratio approach presented in Section 3.3 as well as the transaction approach considered in Section 3.4.

**24** The description in the text is based on Klovland (1984), who also discussed whether the velocity of circulation of currency is higher in the shadow economy or in the official economy.

Ahumada et al. (2007, 2009) analyse the assumption of identical velocities of circulation in the shadow economy and in the official economy. The authors look at the specific case of computing the velocity of circulation of money where the velocity of circulation, unlike in equation (5), is calculated as the ratio $Y_{L,t}/C_{L,t}$. For this case, the authors show that the currency demand approach depends on an income elasticity of the currency demand of one. If this elasticity deviates from 1, the currency demand approach produces misleading results regarding the size of the shadow economy. Pickhardt and Sardà (2011) correct the estimates of Kirchgässner (1983) using the currency demand approach in line with a correction formula proposed by Ahumada et al. (2007) and find as an outcome that the estimates for the size of the shadow economy are significantly smaller.[25]

An explicit calculation of the scale on which cash is being used illicitly depends on the key assumption that cash is used exclusively for legitimate purposes for certain reference values of the employed indicators. In this context it is usual, for example, to set the tax rate as an indicator of the underground economy to zero or to its historical minimum (Tanzi, 1980). But even with a zero tax rate, there could be other illicit uses of cash, especially as the tax burden is not the sole motive for the illicit use of cash. All things considered, selecting a reference value for which there are assumed to be exclusively legitimate uses of cash implies a certain arbitrariness when computing the scale of illicit cash use.

In many applications of the currency demand approach, the tax burden is used as an indicator of the shadow economy (Tanzi, 1983; Klovland, 1984; Schneider, 1986). The background to this is that the burden of taxes (and social security contributions) is seen as the key motive for offering services in the underground economy. There are, in fact, other conceivable motives for shifting economic activities into

what is known as the shadow economy. The fact that illegal economic activities may lead to criminal charges means that they obviously have to be conducted in secret. However, legal economic activities can also be offered in the shadow economy for reasons other than tax evasion. A further motive for economic activities being shifted into the shadow economy could be due, say, to regulations concerning economic activities in the official economy. The causes of the shadow economy are discussed in detail, for example, in Schneider (2015a) and in Schneider and Buehn (2018). Cebula and Feige (2012) note that, besides the tax burden, the unemployment rate also has a positive effect on the extent of tax evasion. Karmann (1990) looks at the causes of the underground economy also from the demand side and includes wage costs in the craft trades as an explanatory variable in a currency demand approach. For applications of the currency demand approach, this discussion means that a wider group of indicators of the illicit use of cash should be looked at.

One fundamentally important question is how any statistically significant correlation found between the currency demand and an indicator of the shadow economy can be interpreted.[26] How far this relationship may be regarded as proof of the illicit use of cash also depends on how far the selected indicator of the shadow economy is actually congruent with the concept to be measured. In particular, there could be another reason why indicators of the shadow economy that are usually selected, such as the unemployment rate or the tax rate, might affect cash holdings. Unemployed persons might feel a greater need for budget planning and keeping a check on spending and, therefore, use cash as a means of payment to a greater extent.[27] This would mean that any connection found between the unemployment rate and cash holdings would not necessarily be due to use in the shadow economy. The tax burden, too, could have an impact on the legitimate use of cash

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25 According to Kirchgässner (1983), the size of the shadow economy in Germany in 1980 amounted to 8.8% of GNP, while the corrected estimate produces a figure of 0.3%.

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26 This problem of the interpretation of a possible empirical link between explanatory variables and dependent variables applies generally to empirical studies.

27 The importance of cash as an instrument for keeping a check on spending is discussed, for example, in von Kalckreuth et al. (2014) and Deutsche Bundesbank (2016).

and therefore not be linked solely to the illegal use of cash. When judging the extent to which affected individuals forgo interest earnings as a result of holding cash, it is not only the nominal rate of interest that is relevant, but also interest income after taxes. Increases in the tax burden could reduce interest income from other investments and make investments in cash appear more attractive. This aspect calls into question how far any connection found between indicators of the underground economy and cash holdings can be seen as an indication of the illicit use of cash.

In the currency demand approach, all cash holdings are broken down into a legitimate and an illicit component, with legitimate cash holdings being explained by conventional variables of currency demand such as an interest rate and an indicator for the size of economic output. Nevertheless, the macroeconomic aggregates shown in economic accounting systems generally also include output of the underground economy (Caridi and Passerini, 2001; Taschowsky, 2015; Federal Statistical Office, 2016). This means that the estimating equation underlying the currency demand approach is misspecified in the sense that underground economic activities are also explained to a certain extent by official GDP. This means, in particular, that cash holdings cannot be split cleanly into a legitimate and an illicit component. When calculating the velocity of circulation of legitimate money, officially recorded GDP is, moreover, usually equated with legitimate economic output.

In conclusion, reference should be made to the challenge posed by taking account of all the motives for cash holdings when modelling the currency demand. Empirical studies are faced with the task of capturing the motives for foreign demand, domestic transaction balances as well as the domestic store of value. Sections 2.2 and 3.2 described how a large part of the euro and US dollar currency in circulation is located outside their respective currency areas. For applications of the currency demand approach to Germany that work with historical time series, it is also relevant that DM cash was in circulation on a considerable scale outside Germany. Seitz (1995)

estimates that, at the end of 1994, between 30% and 40% of the DM banknotes in circulation, or DM banknotes with a value of between DM 65 billion and DM 90 billion, were located outside Germany.

Aksoy and Piskorski (2006) note that US dollar currency in circulation adjusted for foreign demand shows a better predictive capability regarding inflation and economic output. In applications of the currency demand approach, this finding suggests that adjusting the used volume of cash in circulation for foreign demand is a reasonable step to take. Alternatively, the specified model of currency demand can be enhanced by including variables which capture the motive of foreign demand. One possibility of doing this is offered by the exchange rate (Seitz, 1995; Fischer et al., 2004; Bartzsch et al., 2015), as a change in the exchange rate in one currency also affects its attractiveness as a store of value abroad. The fact that cash of one currency might also be in circulation outside its currency area is, however, usually neglected in applications of the currency demand approach.[28] This means that some of the cash that is actually located abroad might be ascribed to the illicit use of cash, potentially resulting in an overestimation of the illicit use of cash at home.

A similar argument can be made regarding the legitimate store of value. In the currency demand approach, the econometric specification of the currency demand usually includes a transaction variable as well as an interest rate as a yardstick for the opportunity costs. Generally speaking, these variables are likely to model the motives for the legitimate storage of value to some extent as well, although this involves disregarding a number of determinants for the legitimate store of value in cash. Cash usually tends to be used more as a store of value as a result of other forms of investment being perceived as unsafe: this was shown, for example, by

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[28] The importance of foreign demand for estimates of the size of the underground economy is addressed, for example, in Frey and Pommerehne (1984), Isachsen and Strøm (1985), Feige (1997, 2011), Schneider (2015a), and Schneider and Buehn (2018).

the increased currency demand in the wake of the Lehman Brothers crisis in 2008. It is possible that this aspect is not entirely captured by standard formulations of the currency demand with a transaction variable and a measure for the opportunity costs of money holdings. The extent to which the currency demand approach can actually model all the motives for the legitimate store of value is therefore an open question: in the final analysis, part of the legitimate storage of value could be ascribed to the illicit use of cash.

A number of assumptions have to be met for the scale of the illicit use of cash and/ or the size of the underground economy to be quantified reliably using the currency demand approach. If major assumptions of this approach are violated, the obtained results could be misleading. If applied cautiously, however, the currency demand approach could be used to derive insights into the importance of illicit motives for the currency demand, and this approach is chosen below as the basis for our own empirical analyses

# 4 New analyses on the illicit use of cash

## 4.1 Overview

This chapter presents the authors' own estimations on the illicit use of cash in Germany. Methodologically speaking, these estimations generally fall under the currency demand approach. However, they take into account the criticism of this approach as outlined in Section 3.5.2 and thus go beyond it. One contribution is the panel analysis of regional cash deposits at Bundesbank branches, which can be found in Section 4.2. Section 4.3 contains regression estimations on the circulation of "German" banknotes according to various definitions.[29]

## 4.2 Regional analysis of cash deposits at Bundesbank branches

### 4.2.1 Motivation and research approach

The motives for using cash in Germany can be analysed on the basis of cash deposits made at the Bundesbank. The Bundesbank plays an integral part in the operational tasks of cash payments in Germany. These operational tasks are performed, not least, via the Bundesbank's 35 branches, the locations of which are shown in Figure 8 (as at 15 June 2018).[30] The Bundesbank brings euro banknotes and euro coins into circulation in Germany. Once the banknotes and coins have been issued by the central bank, they circulate between the banking industry, commercial enterprises and consumers. After being paid in at the Bundesbank or a credit institution, the banknotes and coins are checked for authenticity and fitness for circulation, either by the Bundesbank itself or by a credit institution, and then paid out again. The share of private banknote recycling (i.e. without the involvement of the Bundesbank), not taking into account manual recycling by trained cashiers in the banking

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29  Here, "German" banknotes are the euro banknotes brought into circulation by the Bundesbank. This is the Bundesbank's cumulative net issuance (withdrawals less deposits).

30  At present, the Bundesbank is setting up a new branch in Dortmund, which is designed to take on the tasks of the existing branches in Bochum, Dortmund, Düsseldorf, Essen and Hagen. Following completion, the Bundesbank will still have 31 branches. On 1 April 1992, the Bundesbank had 192 branches in operation (Deutsche Bundesbank, 1992).

Regional Offices and branches of the Bundesbank          Figure 8



Source: Deutsche Bundesbank.

industry, is estimated to be around 20%.[31] This means that the majority of Germany's cash is supplied by the Bundesbank.

Figure 9 shows the development over time of cash deposits and withdrawals at the Bundesbank from 1991 to 2015. The question being dealt with in this section is whether signs of illicit cash use can be observed in the form of unusual lodgement patterns at Bundesbank branches. In this context, earnings illegally generated by economic agents are not paid in directly to a Bundesbank branch but indirectly through commercial enterprises or the banking industry.

Deposits and withdrawals of cash          Figure 9



Deutsche Bundesbank
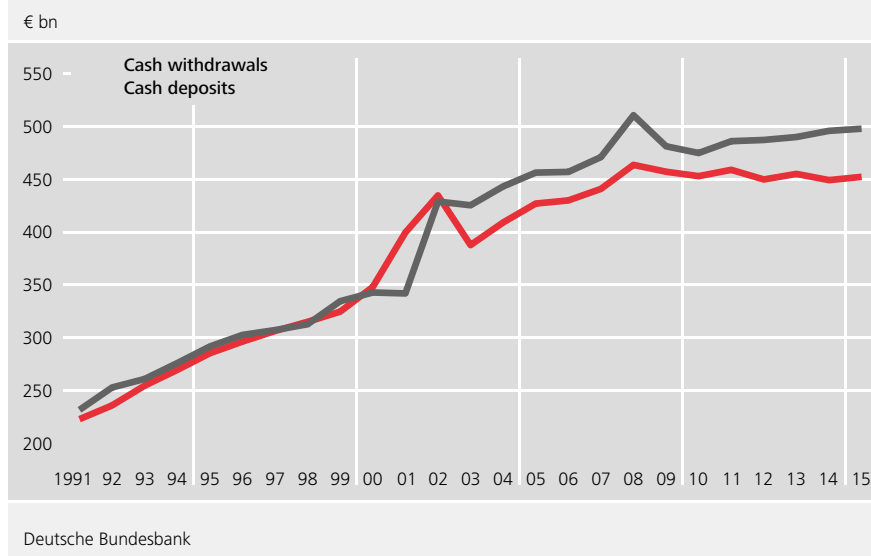
31   This share was calculated based on statistics on banknote processing at Bundesbank branches and on automated banknote processing by private handlers. The estimate refers to the second half of 2015.

To analyse the importance of illegal motives as a driver for cash demand, a panel dataset compiled specifically for this study is used. It comprises data on cash deposits at Bundesbank branches broken down by federal states from 1991 to 2015. The impact of a transaction variable and various indicators of illicit cash use on cash deposits are analysed in panel regressions. While many economic studies use the burden of tax and social security contributions as the only indicator, this study looks at several indicators of illicit cash use. Using a range of indicators at the same time could yield a fuller picture overall. A statistically significant and positive correlation found in the panel estimations between the selected indicators and cash deposits made at the Bundesbank could be seen as evidence of illicit cash use.

The indicators used initially comprise variables typically employed as indicators of the shadow economy in the economic literature. In particular, these include the unemployment rate, the ratio of taxes and social security contributions, the self-employment rate, the share of persons employed in the agricultural sector and the share of persons employed in the construction sector. Other indicators in this study provide information on the regional distribution of crime and stem from the Federal Criminal Police Office's Police Crime Statistics (Federal Criminal Police Office, 2016); these cover the total number of crimes, the number of offences involving brutality as well as crimes against personal freedom,[32] the overall number of theft-related offences and the number of drug-related crimes. Specifically, taking into account indicators on regional crime levels allows the study to look at activities in the shadow economy where the underlying good itself is illegal; on this, see the taxonomy of the shadow economy outlined in Table 2.

In the economic literature, empirical modelling of cash in circulation is more common (Tanzi, 1983; Klovland, 1984; Schneider, 1986; Bartzsch et al., 2015). Currency in circulation indicates the volume of cash held by economic agents, meaning that

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32 This covers, for example, offences involving robbery or bodily injury.

modelling it enables an analysis of the motives for holding cash. However, in reality, it is difficult to capture all motives for holding cash in one model framework. In particular, some approaches have difficulty capturing foreign demand, the motives for domestic hoarding and the motives for cash holdings for transaction purposes all at the same time. A viable alternative for measuring the use of cash are therefore cash deposits made with a central bank. These deposits of cash make for a suitable indicator of the scale of cash use as they reflect how much cash is used outside the central bank. Although deposits of cash comprise cash emanating from domestic payment transactions, from the dissolution of domestic hoards as well as from abroad, deposits on the whole are dominated by payment transactions. For instance, in 2017, banknotes with a value of around €470 billion were paid in at Bundesbank branches, of which only around €35 billion came from the international wholesale banknote market. Modelling deposits is therefore probably slightly less complicated than modelling cash in circulation given that hoarded cash and foreign demand are hard to model and likely to have less of an impact on the study.

There are further examples in the literature of modelling the use of cash at the regional level. Judson and Porter (2004) evaluate the regional demand for cash at 37 Federal Reserve Cash Offices. The authors find evidence of a transaction variable influencing the use of cash. Amongst other things, demographic structure and the scale of activities in the construction sector are also relevant. The latter result would be justified by the fact that some labour services and benefits in kind are paid for in cash in the construction sector. Ardizzi et al. (2014a) analyse a panel of cash deposits at credit institutions in various Italian provinces and show that, in addition to classic indicators of the shadow economy such as the level of employment in construction, other variables, which could potentially be connected to money laundering, are significant as well. Ardizzi et al. (2014b) analyse a panel of cash withdrawals from credit institutions in Italian provinces. Amongst other things, the authors use direct indicators for illicit cash use in the form of indicators of un-

covered tax evasion and in the form of variables which measure the levels of prostitution and drug-related crime. These variables have a significant influence on cash withdrawals. Ardizzi et al. (2016) follow on from earlier evaluations and analyse cash deposits to bank accounts in Italian municipalities to find out, in particular, whether there is a potential connection between cash deposits and any illegal activity. However, this study is the first macroeconomic analysis of cash deposits at Bundesbank branches.

### 4.2.2 Empirical modelling of cash deposits

For deposits made at Bundesbank branches it is assumed that the cash is used as means of payment, where the scale of cash use should be a function of a transaction variable. Real deposits per inhabitant in region $i$ at time $t$, $DEP_{it}$, can thus be modelled as

$$(6) \qquad DEP_{it} = \eta_{it} GDP_{it}(1 + x'_{it}\beta), \; i = 1, ..., N, t = 1, ..., T$$

where $GDP_{it}$ stands for real gross domestic product per inhabitant in region i at time t and $x'_{it}$ represents a vector with indicators of illicit cash use. $\eta_{it}$ is a parameter indicating how economic output in a region is translated into cash deposits. The parameter varies across regions and over time, capturing regional and temporal differences in the intensity of cash use. Gross domestic product is selected as the transaction variable here. It is assumed that the official measure of economic output, $GDP_{it}$, does not take into consideration all relevant activities. Rather, this measure must be multiplied by a factor of $(1 + x'_{it}\beta)$ in order to reflect a region's actual economic output – generated both by official and unofficial economic activities. $\beta$ is a coefficient vector which, on the one hand, scales the indicators of illicit cash use and, on the other hand, also allows different components of economic output in a region to be transferred into deposits in different ways, e.g. due to the fact that the shadow economy may be more cash-intensive than the official economy. The selected specification is static. A static specification seems appropriate here

given that, as expected, changes in the level of economic activity tend to be reflected by deposits made with the Bundesbank in the short term (as an indicator of the scale of cash payments) and not following a lengthy adjustment process, which would be modelled, for example, by dynamic specifications.

Based on approximations $\eta_{it} \approx e^{\alpha_i}e^{\lambda_t}$ and $log(1 + x'_{it}\beta) \approx x'_{it}\beta$ [33], the following equation is derived after taking logarithms and adding an error term :

$$(7) \qquad \log(DEP_{it}) = \alpha_i + \lambda_t + \log(GDP_{it}) + x'_{it}\beta + u_{it}, \; i = 1, ..., N, t = 1, ..., T$$

This is a static panel model with dummy variables representing regions and points in time; it is estimated using the least squares method. It is conceivable that the disturbance terms correlate between regions. For example, a CIT company may collect cash in one region and pay it back in at the nearest branch in a different region. We therefore use panel-corrected standard errors which are robust to panel heteroscedasticity and to contemporaneous correlation between panels (Beck and Katz, 1995). Moreover, an analysis of the estimated residuals suggests autocorrelation of the residuals, which is why the variables are first transformed using the Prais-Winsten approach (Prais and Winsten, 1954; see also Parks, 1967 and Kmenta, 1997).

With a few exceptions, cash deposited at the Bundesbank stems from commercial enterprises and credit institutions and has, as such, been generated from legal cash transactions. Illegal activities only indirectly result in deposits at the Bundesbank if economic agents put illegally generated income into circulation in the official economy and commercial enterprises and credit institutions, in turn, forward these cash takings to the Bundesbank. In accordance with the preliminary theoretical

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**33** It is assumed that the shadow economy is small in relation to the official economy, which is why this approximation holds.

considerations, the significant influence of indicators $x_{it}$ suggests that official GDP underestimates the relevant economic output and that a shadow economy is also at play. By extension, statistically significant indicators of the shadow economy with a positive sign would indirectly indicate illegal cash transactions in the economy.

A common approach in the literature is to ascertain the quantitative extent of illicit cash use with the help of a model simulation based on the estimated model equations (Tanzi, 1983; Schneider, 1986; Ardizzi et al., 2014a). In line with a calculation formula proposed by Tanzi (1983), the share of cash deposits which can indirectly be traced back to the shadow economy is quantified. First, the value for the dependent variable projected by the model is calculated for each region and each point in time. This calculation is then repeated under the assumption that the shadow economy indicators take the value zero in order to work out what the value of cash deposits would be per region and point in time without the shadow economy. Based on these two values, the share of cash deposits indirectly attributable to the shadow economy can be calculated per region and point in time. Absolute values are obtained by weighting real cash deposits per inhabitant and region with the corresponding share.

The calculated values for the extent of illicit cash use may depend strongly on the assumptions made and should thus be interpreted with caution. Specifying a reference value for shadow economy indicators for which it is assumed that there is no shadow economy is something of an arbitrary exercise. Moreover, the indicators of the shadow economy used should not impact on cash deposits for any other reason. In the applied simulation, the influence of these alternative transmission channels would likewise be attributed to the shadow economy.

Table 6 contains a description of the data used in the analysis.[34] However, Figure 8 shows that the Bundesbank currently no longer operates a branch in each federal state. The federal states of Bremen and Lower Saxony, Berlin and Brandenburg as well as Hamburg and Schleswig-Holstein are therefore grouped together.[35]

**34** A national GDP deflator is used to adjust prices (Source: Deutsche Bundesbank). The information regarding population by region is taken from the federal states' national accounts.
**35** This aggregation also removes the individual observations for the cities of Bremen, Berlin and Hamburg, which given their status of city states might otherwise have had to be modelled separately. The dataset encompasses one-off effects such as those from the introduction of the euro. In addition, the importance of private cash recycling has continued to rise over the past few years. The dummy variables for regions and points in time included in the empirical model should capture these special developments at least in part.

## Description of data

Table 6

| Variable | Description | Data source |
|---|---|---|
| Cash deposits at Bundesbank branches | Real cash deposits at Bundesbank branches by region and per inhabitant in € | Deutsche Bundesbank |
| Gross domestic product | Transaction variable; real GDP per inhabitant in € | Statistical offices of central and state government |
| Tax and social contributions ratio | Indicator of the shadow economy; share of taxes on income and wealth and social security contributions in households' primary income | Statistical offices of central and state government |
| Persons employed in the agricultural sector | Indicator of the shadow economy; share of persons employed in agriculture, forestry and fishing in the total number of employed persons | Statistical offices of central and state government |
| Persons employed in the construction sector | Indicator of the shadow economy; share of persons employed in construction in the total number of employed persons | Statistical offices of central and state government |
| Unemployment rate | Indicator of the shadow economy; share of unemployed persons in the civilian dependent labour force | Federal Employment Agency |
| Self-employment rate | Indicator of the shadow economy; share of persons who are self-employed and assisting in family-run businesses in the total number of employed persons | Statistical offices of central and state government |
| Crimes in total | Indicator of criminality; total number of offences per 1,000 inhabitants | Federal Criminal Police Office, Police Crime Statistics |
| Offences involving brutality / crimes against personal freedom | Indicator of criminality; number of offences involving brutality and crimes against personal freedom per 1,000 inhabitants | Federal Criminal Police Office, Police Crime Statistics |
| Theft | Indicator of criminality; total number of offences involving theft per 1,000 inhabitants | Federal Criminal Police Office, Police Crime Statistics |
| Drug-related crimes | Indicator of criminality; number of drug-related offences per 1,000 inhabitants | Federal Criminal Police Office, Police Crime Statistics |

Source: Compiled by the authors.

In the first instance, the regression equation according to equation (7) comprises real GDP per inhabitant in the form of a transaction variable, with the preliminary theoretical consideration suggesting a coefficient of one for GDP per inhabitant. In addition, equation (7) contains various indicators of the shadow economy. An indicator for components of the shadow economy where the activity carried out is generally speaking legal can be found in the ratio of taxes and social security contributions, the unemployment rate, the self-employment rate and the shares of persons employed in the agricultural sector and in the construction sector. The burden of taxes and social security contributions is generally regarded as a key motive for transferring economic activities to what is known as the shadow economy (Feld and Schneider, 2010). The tax burden is used as an indicator of the shadow economy in many macroeconomic studies on the shadow economy (Tanzi, 1983; Klovland, 1984; Schneider, 1986; Pickhardt and Sardà Pons, 2006). The marginal burden of taxes and social security contributions is relevant in determining whether additional legal economic activities are performed in either the official economy or the shadow economy. If population characteristics such as the income structure show regional differences, this also results in variations in the burden of taxes and social security contributions which can be used to identify the impact of the fiscal burden on cash deposits. However, given that there is no information on the marginal tax burden, the ratio of tax and social security contributions is used as an indicator here. This ratio is likely to correlate with the theoretically relevant indicator but might not fully reflect every change in the marginal burden.

Another indicator used to gauge illicit cash use is the unemployment rate (Schneider, 2005, Deutsche Bundesbank, 2009a; Buehn, 2011; Herwartz et al., 2016). The idea is that unemployed persons are more likely to have the opportunity to offer their labour services in the shadow economy. Another motive here could be that there are limits to earning an official income while unemployed or that doing so could lead to a reduction in the benefits received from the unemployment insurance fund. However, unemployment could generally also influence the volume of cash

deposits for a different reason. If it is the case that unemployed persons use cash more frequently than people in employment – in other words, if their payment behaviour differs – the unemployment rate could also have an impact on regional volumes of cash deposits for this reason. Likewise, using the self-employment rate as an indicator of the shadow economy (Herwartz et al., 2016) can be justified by the fact that self-employed persons may have a greater scope of opportunity to perform activities in the shadow economy than those who are not self-employed. However, regions with a high level of self-employment may have a particularly large amount of small enterprises which might use cash to a greater extent as a means of payment to do business. This could potentially explain a statistically relevant and positive effect of the self-employment rate on cash deposits. The share of persons employed in the agricultural sector and the share of persons employed in the construction sector (Ardizzi et al., 2014a) are also used as indicators of illicit cash use as employees in these sectors may have an especially large number of opportunities to perform activities pertaining to the shadow economy. However, an argument against using the share of employment in agriculture could be that the agricultural sector is of no major importance from a macroeconomic stance; it is therefore questionable whether the shadow economy in this sector could lead to significant cash deposits at the Bundesbank. The agricultural and construction sectors may also be particularly cash intensive for other reasons, for example because features of cash are also valued in officially recorded transactions in these economic sectors. The bottom line is that cash can be used on a delivery-versus-payment basis, which does not require a technical infrastructure.

Various indicators of regional crime levels are taken from police crime statistics, i.e. i) total number of offences per 1,000 inhabitants, ii) number of offences involving brutality as well as crimes against personal freedom per 1,000 inhabitants, iii) number of offences involving theft per 1,000 inhabitants and iv) number of drug-related crimes per 1,000 inhabitants. Drug-related crimes appear to serve as a particularly suitable indicator of illicit cash use as drugs can be traded for cash at both the retail

and the wholesale level. Furthermore, the regional distribution of drug-related crime could also help approximate the regional distribution of associated offences such as organised crime or money laundering. The indicators used for criminality are likely to reflect its scale and regional distribution. Moreover, the GDP contains only a small estimate for crime-related value added in the form of drug dealing and cigarette smuggling (Taschowsky, 2015) due to which overlaps with the transaction variable are probably minor. A potential drawback is the fact that the data source is geared towards criminal law provisions and not economic categories. It is also possible that money laundering takes place independently of regional crime distribution; in other words, income from criminal activities in one region may be disbursed in another. In addition, there may be a considerable blind spot that is not taken into account by police crime statistics. As a rule, crime could also diminish the use of cash in the event that consumers perceive higher levels of uncertainty, causing them to scale back their cash holdings and make more of their payments in cashless form.

It is conceivable that cash deposits and gross domestic product are non-stationary. The estimating equation contains dummy variables for each point in time; adopting them into a balanced panel model is equivalent to transforming the variables by deducting the average across regions at each point in time (Baltagi, 2009). This transformation may cause stationarity. Unit root tests suggest that the transformed variables are stationary.[36]

### 4.2.3 Results

Table 7 shows the results of the panel estimations. The figures presented in the table's columns are the results of the estimations for various models, which all

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[36] According to the unit root test of Levin et al. (2002). This test was selected based on a simulation study (Hlouskova and Wagner, 2006). We test the null hypothesis that the panels follow a unit root procedure against the alternative hypothesis, where the panels are stationary. The test is applied to the variable that is transformed at each point in time by deducting the mean value.

differ in terms of the indicators for illicit cash use included in the estimating equation. First, the total of nine various indicators are analysed individually. In addition, Table 7 shows the results of two models in which multiple indicators are included at the same time. The reason for this two-step procedure is the possible presence of multicollinearity between the indicators. The effects of the indicators examined here are not of direct interest, but rather of interest inasmuch as the indicators are proxy variables for the unobserved shadow economy. If there is a high correlation between the individual indicators and the unobserved shadow economy, it stands to reason that they also correlate to a high degree with each other. In view of this, the indicators for the shadow economy are first modelled individually, as the presence of multicollinearity could make it more difficult to interpret the point estimators. In turn, the models in which the indicators are collectively included have the advantage that they are not affected by any misspecification should variables that are actually of relevance be left out. Analysing the range of indicators in this manner should paint a detailed picture of the significance of the shadow economy for cash deposits at the Bundesbank.

While point estimators and their level of significance are shown in the upper part of Table 7, various statistics that are suitable for evaluating the models are presented in the lower part of the table. The explained variance – $R^2$, calculated here as the squared correlation of the projected values for the dependent variables with the actual values for the dependent variables – is around the 0.8 mark in all cases and should be regarded as high. In the previous section, it was shown that some of the indicators relate to the shadow economy where the goods produced and services rendered are, as a general rule, legal, while others cover value added derived from criminal activities in the stricter sense. Tests on the collective significance of the variables of these two groups of indicators are shown in Table 7. Lastly, the table also contains an estimated average percentage share of cash deposits attributable to the shadow economy in the period from 1994 to 2015, as well as an absolute value in € billion for the cash deposits stemming from the shadow economy in 2015.

## Results of panel estimations
Table 7

| Model | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Log of real GDP per inhabitant | 1.20*** (4.18) | 1.32*** (4.95) | 0.97*** (4.11) | 1.28*** (4.73) | 1.05*** (4.23) | 1.24*** (4.88) | 1.24*** (4.81) | 1.22*** (4.87) | 1.14*** (4.62) | 1.01*** (4.12) | 1.03*** (3.58) |
| Tax and social contributions ratio | - 0.26 (- 0.17) | | | | | | | | | | - 0.15 (- 0.11) |
| Persons employed in the agricultural sector | | 7.87 (1.28) | | | | | | | | | 5.56 (0.82) |
| Persons employed in the construction sector | | | - 3.70*** (-3.03) | | | | | | | | - 3.54* (- 1.86) |
| Unemployment rate | | | | 0.64 (0.54) | | | | | | | 0.44 (0.40) |
| Self-employment rate | | | | | 4.76** (2.45) | | | | | 4.07** (2.20) | - 0.02 (- 0.01) |
| Crimes in total | | | | | | - 0.002 (- 1.56) | | | | | - 0.006* (- 1.95) |
| Offences involving brutality/ offences against personal freedom | | | | | | | - 0.002 (- 0.13) | | | | 0.03 (1.39) |
| Theft | | | | | | | | - 0.003 (- 1.39) | | | 0.006 (1.39) |
| Drug-related crimes | | | | | | | | | 0.05** (2.09) | 0.04* (1.78) | 0.04* (1.68) |
| Number of observations | 299 | 299 | 299 | 299 | 299 | 299 | 299 | 299 | 299 | 299 | 299 |
| "R²" | 0.79 | 0.79 | 0.81 | 0.79 | 0.80 | 0.80 | 0.79 | 0.80 | 0.80 | 0.81 | 0.82 |
| Joint significance: shadow economy | 0.03 | 1.64 | 9.19*** | 0.29 | 6.03** | n.a. | n.a. | n.a. | n.a. | 4.85** | 8.51 |
| Joint significance: criminality | n.a. | n.a. | n.a. | n.a. | n.a. | 2.45 | 0.02 | 1.93 | 4.36** | 3.17* | 5.76 |
| Share (%) of cash deposits indirectly explained by illicit cash transactions | - 2.7 | 3.7 | - 7.3 | 1.8 | 12.2 | - 5.1 | - 0.5 | - 2.9 | 3.9 | 13.9 | - 1.5 |
| Derived volume of illicit cash transactions in 2015 (€ billion) | - 12.9 | 13.3 | - 25.9 | 4.5 | 50.2 | - 24.0 | - 2.2 | - 11.8 | 20.7 | 61.4 | - 7.4 |

Notes: The analysis covers a panel of regions for the period from 1993 to 2015. The log of real cash deposits per inhabitant serves as the dependent variable. *** significant at 1%. ** significant at 5%. * significant at 10%. Definitions of the variables are given in Table 6. R² is calculated as the squared correlation between the dependent variable and the values predicted by the model. In the case of the joint significance tests, the calculated test statistic values are shown; t-values in brackets.
Source: Authors' own calculations.

GDP has a statistically significant influence as a transaction variable in all of the models examined in Table 7. In all instances, the coefficient is very close to 1 and not statistically different from this value, with the result that the coefficient theoretically expected for the transaction variable is also the one actually determined – a 1% rise in a region's GDP thus equals a 1% rise in cash deposits at the Bundesbank.

Of the indicators for illicit cash use, only the share of persons employed in the construction sector, the self-employment rate and drug-related crimes are statistically significant. However, the share of persons employed in the construction sector has a negative impact on cash deposits, meaning that, according to the results, a rise in employment in construction leads to a decline in cash deposits. In principle, it is conceivable that regions in which a particularly low number of persons are registered as employed in the construction sector would also have many persons moonlighting, i.e. their employment is not reported in the official statistics. This argument could explain the negative sign observed. In this case, however, the cause of the unexpected sign appears to be a one-off effect of German reunification. Following reunification, the share of persons employed in the construction sector in the east German federal states was very high, while cash deposits in eastern Germany – possibly as a result of the decades-old barter economy in the German Democratic Republic and its economy's initially weaker performance – were fairly low. In the years that followed, the share of persons employed in the construction sector contracted, while cash deposits grew quickly. In fact, the share of persons employed in the construction sector has a statistically significant, positive effect if the sample analysed is limited to the west German federal states.

The self-employment rate is significant in both statistical and economic terms. A rise of 1 percentage point in the self-employment rate leads to a 4.8% increase in cash deposits. The average share of cash deposits stemming indirectly from the shadow economy calculated for model (5) was 12.2%, while the derived volume of illicit cash transactions stood at €50.2 billion in 2015.

In terms of the indicators selected for the impact of criminality on cash deposits, only drug-related crimes stand out. The model-based analyses suggest that, on average in 2015, 3.9% of cash deposits at the Bundesbank – cash deposits with a value of €20.7 billion – were indirectly attributable to criminal activities. The picture is rounded off by the collective models shown in Table 7. Model (10), which uses the two significant indicators "self-employment rate" and "drug-related crimes", may be considered a benchmark here.

Overall, the results are mixed. Only a few of the indicators for illicit cash use have a statistically significant, positive impact on cash deposits at Bundesbank branches, meaning that, ultimately, it is not possible to paint a clear picture of the significance of illicit cash use in Germany.

In principle, using the framework presented in this paper, it is also possible to calculate cash deposits indirectly attributable to the shadow economy as a percentage of overall cash deposits on both a year-by-year and region-by-region basis. However, it should be noted with respect to this disaggregated analysis that the estimates for individual years and individual regions will probably be less reliable than those for the overall average share of illicit cash deposits, e.g. owing to random fluctuations across regions and over years not being offset in the disaggregated approach. Table 8 presents this share of illicit cash deposits by year based on collective model (10) from Table 7, while Figure 10 shows how this share has changed over time. Altogether, illicit cash deposits as a percentage of overall cash deposits have remained fairly constant, disregarding a spike in 2003 and 2004. All in all, it appears that the share of illicit cash deposits was somewhat smaller at the start of the sample in 1994 and 1995 than in the years thereafter. Based on collective model (10), the share of illicit cash deposits has remained fairly constant at around 14% since 2007.

**Share of cash deposits attributable to the shadow economy, by year**

Table 8

| Year | Share (%) | Standard deviation | Number of observations |
|------|-----------|--------------------|------------------------|
| 1994 | 12.1 | 2.1 | 13 |
| 1995 | 12.6 | 2.7 | 13 |
| 1996 | 13.3 | 2.6 | 13 |
| 1997 | 13.6 | 2.3 | 13 |
| 1998 | 13.3 | 1.8 | 13 |
| 1999 | 13.2 | 1.6 | 13 |
| 2000 | 13.3 | 2.0 | 13 |
| 2001 | 13.6 | 1.8 | 13 |
| 2002 | 14.4 | 1.0 | 13 |
| 2003 | 15.0 | 1.5 | 13 |
| 2004 | 16.5 | 1.2 | 13 |
| 2005 | 15.7 | 1.7 | 13 |
| 2006 | 14.7 | 1.2 | 13 |
| 2007 | 13.8 | 1.9 | 13 |
| 2008 | 13.4 | 1.9 | 13 |
| 2009 | 14.3 | 2.1 | 13 |
| 2010 | 14.1 | 1.7 | 13 |
| 2011 | 14.6 | 1.6 | 13 |
| 2012 | 13.8 | 1.7 | 13 |
| 2013 | 13.5 | 1.6 | 13 |
| 2014 | 14.5 | 1.4 | 13 |
| 2015 | 13.5 | 1.8 | 13 |
| Total | 13.9 | 2.0 | 286 |

Note: Calculated on the basis of collective model (10); see Table 7. Share of cash deposits at Bundesbank branches that can be indirectly attributed to the shadow economy as a percentage of overall cash deposits.
Source: Authors' own calculations.

**Share of cash deposits attributable to the shadow economy, by year***

Figure 10
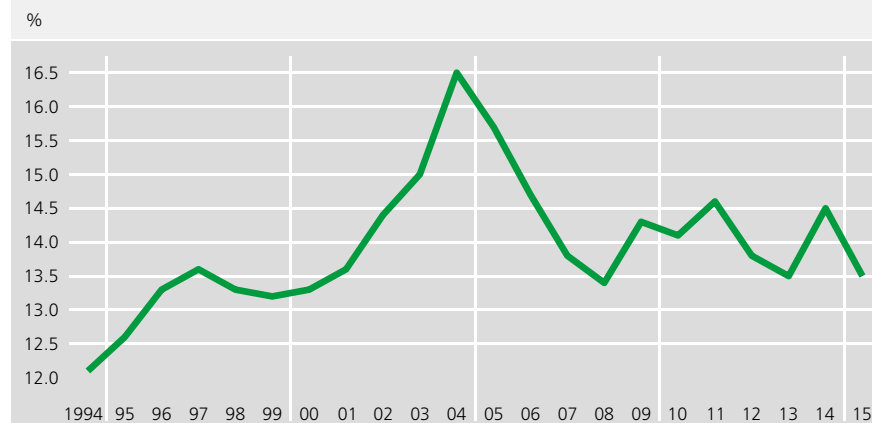
%



**\*** Calculated on the basis of collective model (10); see Table 7. Share of cash deposits at Bundesbank branches that can be indirectly attributed to the shadow economy as a percentage of overall cash deposits.
Deutsche Bundesbank

Table 9 shows the share of cash deposits attributable to the shadow economy by region. As was also the case in the year-by-year analysis, the share of illicit cash deposits broken down by region is fairly close to the average across all regions. The regional breakdown reveals no clear north-south or east-west differences. According to the model-based analyses, the share of illicit cash deposits is especially low in Saarland (11.5%), and particularly high in the region comprising the federal states Hamburg and Schleswig-Holstein (15.7%).

| Share of cash deposits attributable to the shadow economy, by region | | | Table 9 |
|---|---|---|---|
| Region | Share (%) | Standard deviation | Number of observations |
| Berlin/Brandenburg | 15.6 | 1.9 | 22 |
| Baden-Württemberg | 13.9 | 1.1 | 22 |
| Bavaria | 15.6 | 1.0 | 22 |
| Bremen/Lower Saxony | 14.3 | 0.9 | 22 |
| Hesse | 14.0 | 1.2 | 22 |
| Hamburg/Schleswig-Holstein | 15.7 | 1.2 | 22 |
| Mecklenburg-West Pomerania | 12.7 | 2.2 | 22 |
| North Rhine-Westphalia | 13.4 | 0.8 | 22 |
| Rhineland Palatinate | 15.4 | 1.3 | 22 |
| Saarland | 11.5 | 1.7 | 22 |
| Saxony | 13.1 | 2.0 | 22 |
| Saxony-Anhalt | 12.2 | 1.8 | 22 |
| Thuringia | 13.9 | 2.1 | 22 |
| Total | 13.9 | 2.0 | 286 |

Note: Calculated on the basis of collective model (10); see Table 7. Share of cash deposits at Bundesbank ranches that can be indirectly attributed to the shadow economy as a percentage of overall cash deposits. Source: Authors' own calculations.

To interpret the new results, it is interesting to compare the estimated size of the shadow economy with our own estimates of illicit cash transactions to the tune of €60 billion. These estimates are based purely on deposits at the Bundesbank. If the fact that a portion of cash is processed and recirculated by private cash handlers is also taken into account, the volume of illicit cash transactions derived from cash

deposits at the Bundesbank and credit institutions amounts to €75 billion.[37] This estimate of illicit cash deposits is not conceptually comparable with estimates of the size of the shadow economy. It is not possible to simply use the estimated volume of illicit cash deposits to derive an estimate of the size of the shadow economy, because it is not known how often cash changes hands in the shadow economy before it is deposited via retailers or credit institutions at the Bundesbank. The figure of €75 billion for the volume of illicit cash deposits can be interpreted only as a lower bound for the size of the cash-based shadow economy in Germany. Much like other estimates of the shadow economy's size, this estimated lower bound is also subject to above-average uncertainty and should therefore be interpreted with a degree of caution.

### 4.3 Modelling and simulating euro banknote circulation

In the following, the relationship between the real circulation of "German" banknotes and the (unobserved) shadow economy is studied.[38] Demand for these banknotes is estimated for the small, medium and large denominations respectively, as well as for domestic circulation. Here, seven different alternative proxy variables (indicators) for the shadow economy are used. In methodological terms, this procedure is associated with the currency demand approach described in Section 3.5. The present study attempts to largely take into account the criticisms surrounding this approach (see Section 3.5.2). Only the extent to which proxy variables for the shadow economy make a statistical explanatory contribution is explored here (partial effects). This is a less ambitious aim than quantifying the exact scale of illegal

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**37** The share of private banknote recycling stood at 20.3% in the second half of 2015. Private banknote recycling is usually carried out by credit institutions, which recirculate banknotes via cash recycling machines (CRMs), for example. Banknotes that are accepted by credit institutions and passed on to the Bundesbank for processing are merely transitory items for the credit institutions and are recorded as deposits at the Bundesbank. The estimated share of private banknote recycling presented here does not take account of the fact that banknotes may also be recirculated by qualified bank tellers.
**38** Here, "German" banknotes are the euro banknotes brought into circulation by the Bundesbank. This is the Bundesbank's cumulative net issuance (outpayments less inpayments).

banknote usage using the currency demand approach.[39] A further criticism of the currency demand approach is that it does not adequately capture the various different motives behind shadow economic activities. It is often the case that only the tax and social security contributions ratio is considered as an indicator for the shadow economy. In the present analysis, the employment rates in the agricultural and construction sectors, the unemployment rate, the self-employment rate, the total number of crimes and the number of drug-related crimes are also used as indicators. One-off effects such as the financial crisis of 2008 and the decision of the ECB Governing Council on 4 May 2016 to halt the production and distribution of the €500 banknote are still modelled. When using the currency demand approach, it is important to consider all motives for holding cash – particularly foreign demand, if at all relevant. The motives taken into account in this study are outlined in Section 4.3.1. Demand outside the euro area is depicted by an exchange rate, whilst demand from the rest of the euro area is captured using a residential property price indicator. Alternatively, domestic circulation is used as a dependent variable. This then corresponds to the circulation of German-issued euro banknotes, adjusted for total estimated foreign demand (outside of the euro area and in the rest of the euro area).

The study confines itself to the results of the extensive regression estimations, which illustrate a significant relationship between banknote demand and the shadow economy and are ultimately of interest.[40] In the following section, the data for the econometric analysis as well as the determinants of and estimation methods for banknote demand are explained, see also Bartzsch, Seitz and Setzer (2015, Section 4). This is followed by four sections presenting the results of various models and a summary with concluding remarks.

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**39** Although an attempt was made to determine the value of banknotes in domestic banknote circulation used for shadow economic purposes by means of a dynamic simulation, no meaningful results could be obtained.
**40** Documentation of the cointegration analyses for estimations of banknote demand is available from the authors upon request.

### 4.3.1 Banknote demand: data, determining factors and estimation methods
A total of five different motives driving banknote demand were identified: 1) shadow economy-related (illegal) motives, 2) transaction motives, 3) the desire for a store of value, 4) the availability of alternative payment instruments, and 5) foreign demand. The following sections explain which variables are used to empirically map these motives.

The focus of this analysis is on the shadow economy as an explanatory variable for banknote demand. Transactions in the shadow economy are presumably often conducted in cash so that payments can remain secret (Schneider, 2002). An increase in shadow economic activities should therefore result in higher currency demand. The shadow economy phenomenon has exceedingly varied characteristics. As alternative approaches, different proxy variables which broadly correspond to those in Table 6 in Section 4.2.2 are used for these characteristics: 1) tax and social security contributions ratio, i.e. wage tax and social security contributions as a percentage of households' disposable income, 2) employment rate in the agricultural sector, i.e. the number of persons employed in the agricultural sector as a percentage of all persons in employment, 3) employment rate in the construction sector, i.e. the number of persons employed in the construction sector as a percentage of all persons in employment, 4) unemployment rate, i.e. the number of unemployed persons as a percentage of the civilian labour force, 5) self-employment rate, i.e. the number of self-employed persons as a percentage of all persons in employment, 6) crimes in total, i.e. the total number of recorded crimes, 7) drug-related crimes, i.e. the number of recorded drug-related crimes. The suitability of all of these variables as proxy variables for the differing attributes of the (unobserved) shadow economy is discussed at length in Section 4.2.2.

A rising transaction volume is accompanied by increasing banknote demand. Total private consumption, retail sales and gross domestic product serve as transaction variables in traditional studies of banknote demand. In view of the large number of

cashless payments in the economy, however, these are only rough proxy variables. Therefore, a variable was instead selected that includes the components of the real domestic consumption of households and non-profit institutions serving households, which are predominately paid in cash (real cash consumption). Real cash consumption comprises the following components of the domestic consumption of households and non-profit institutions serving households, as shown in the national accounts: 1) restaurants and hotels, 2) clothing and footwear, 3) recreation and culture, 4) food, as well as 5) other purposes such as healthcare, education, personal care and personal effects.

Aside from their function as a payment medium, banknotes also serve as a store of value. This is particularly true of large-denomination banknotes, and, to a certain extent, medium denomination banknotes too. As banknotes do not bear interest, interest rate levels present themselves as a measure of the opportunity costs associated with holding banknotes. Banknote demand declines as opportunity costs rise. The interest rate for three-month funds in the money market and the yield on ten-year Federal bonds (Bunds), for instance, can be used as measures of the latter. In line with the approach taken by Friedman (1977), a measure is selected for the entire yield curve.[41] This curve is estimated for German Federal securities with a maturity of between three months and 30 years using Svensson's (1994) expanded version of Nelson and Siegel's (1987) method. For further details, see Deutsche Bundesbank (1997).

Cash is in competition with alternative payment instruments. According to the Bundesbank's most recent survey on payment behaviour (Deutsche Bundesbank, 2017), cashless payment instruments are predominantly used to settle higher amounts (€50 and above). However, cash is still used to settle 96% of smaller payment amounts of up to €5 and for the bulk of payments of up to €50. The use of

debit cards is increasing. Compared with 2011, their share of turnover rose by around six percentage points to 34% in 2017. In principle, card payments can be expected to have a negative influence on banknote demand, as girocards and credit cards are used as substitutes for cash payments. In this vein, Amromin and Chakravorti (2009) found evidence of reduced demand for smaller-denomination banknotes on account of increased debit card usage in the OECD countries. However, bank cards are also used to withdraw money from ATMs. On the one hand, lower transaction costs for withdrawing cash reduce the demand for cash. On the other hand, however, they also make it easier to access cash, thus boosting demand. The impact of card payments on currency demand is therefore unclear. In this analysis, the increasing preference for cashless payments is depicted by domestic card turnover (girocard and credit card). However, these figures are only available as annual data. The quadratic match-sum method was therefore used to convert them into quarterly data. Aside from the familiar girocards and credit cards, new payment instruments now exist, such as contactless card payments, new payment methods for internet purchases and the use of mobile payments.[42] Although the use of contactless card payments and smartphone payments is increasing, consumers' payment habits are changing only slowly. Contactless card payments currently make up 1% of turnover at the point of sale. Very few payments are made by smartphone and with customer or prepaid cards at present. Moreover, new payment instruments are also competing with existing cashless payment instruments. Therefore, no proxy variable for innovative payment methods has been added as a regressor.[43]

As shown in Section 2.2, the cumulative net issuance of (euro) banknotes by the Bundesbank (German-issued banknotes) differs from the (estimated) domestic

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**41** Seitz (1998) also recommends the use of such an opportunity cost variable.

**42** An overview of alternative payment instruments can be found in Deutsche Bundesbank (2012b).
**43** In principle, a time trend can be used as a rough approximation for the process of financial innovation.

circulation on account of large cross-border inflows and outflows of banknotes. It makes sense to break down the circulation of German-issued banknotes abroad into demand from the rest of the euro area and demand from countries outside the euro area. There is also demand for German-issued (euro) banknotes in other euro area countries, as they are a perfect substitute for the banknotes issued by other Eurosystem central banks. In other words, banknote demand in one euro area country can be met through inflows of banknotes from another euro area country. The transaction-related share of this demand is depicted using housing prices, i.e. the ECB's residential property price indicator excluding Germany. Anecdotal evidence suggests that properties are also commonly paid for in cash in some of these countries.[44] If buyers are domiciled in Germany, this results in banknotes being exported from Germany. These buyers may be Germans, or alternatively EU citizens from the rest of the euro area now residing in Germany who purchase properties in their home countries with banknotes brought with them from Germany. Such transactions are likely to be predominantly settled with large-denomination banknotes. The other component of foreign demand comes from countries outside the euro area. In the absence of a variable that directly displays demand from many different countries, the real effective exchange rate of the euro against the currencies of the EER-12 is chosen as a proxy variable for foreign banknote circulation outside the euro area. For more information, see also Fischer et al. (2004). An appreciation of the euro should make it more attractive and should therefore be accompanied by greater demand for euro cash in non-euro area countries.

As an alternative to including the regressors "exchange rate" and "ECB's residential property price indicator for the euro area excluding Germany" in banknote demand

estimations, German-issued banknotes in circulation were adjusted for the estimated foreign circulation. Domestic circulation estimated in this way corresponds to the cumulative net issuance of banknotes by the Bundesbank less the cumulative net deliveries of euro banknotes to countries outside the euro area by international banknote wholesalers in Germany less the estimated German net exports of banknotes taken abroad by travellers. The regressions for the estimated domestic circulation can be found in Section 4.3.5.

It would seem reasonable to assume that the coefficients of the above-described explanatory variables differ from each other for the individual banknote denominations. For instance, the transaction motive is particularly significant for small and medium-value denominations. For large denominations, by contrast, having a store of value is presumably the strongest motive. Additionally, substitutional effects can be expected between banknotes of similar value. For this reason, the following alternative dependent variables are used for the estimates: the real stocks (cumulative net issuance by the Bundesbank) of small, medium and large denominations. Another approach involves using real domestic banknote circulation[45] as a dependent variable.[46] The denominations are classified as follows: €5-€20 banknotes as small denominations, €50 and €100 banknotes as medium denominations and €200 and €500 banknotes as large denominations. This classification system was chosen as ATMs do not tend to issue larger denominations and are predominantly used to replenish transaction balance holdings.[47] The large denominations are thus unlikely

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44   For information pertaining to Spain, see Stücklin (2017). Flannigan and Parsons (2018) estimate demand for large denomination banknotes in Australia, Canada and the United Kingdom, respectively, using ARDL models. Their chosen regressors include, amongst others, property prices as a proxy variable for household wealth. Using this approach, they identify a significant (positive) wealth effect for demand for the Canadian $100 bill.

45   Domestic banknote circulation is the difference between cumulative net issuance and total foreign circulation, as estimated in Section 2.2.
46   "Real stock" refers to the deflated stock in terms of value. It is obtained by dividing the nominal stock (cumulative net issuance in terms of value or banknote circulation in terms of value) by the deflator of domestic cash consumption by households and non-profit institutions serving households.
47   For a cash study of several countries using a similar classification scheme in which the transaction motive is distinguished from the desire to have a store of value, see Amromin und Chakravorti (2009). The authors identify medium banknote denominations by establishing which denominations are predominantly withdrawn from ATMs. Denominations exceeding this value are classed as "large", while those falling short (including coins) are classed as "small".

to be used to conduct regular transactions. Furthermore, the €50 banknote is likely to be the smallest denomination used (amongst other purposes) as a store of value.
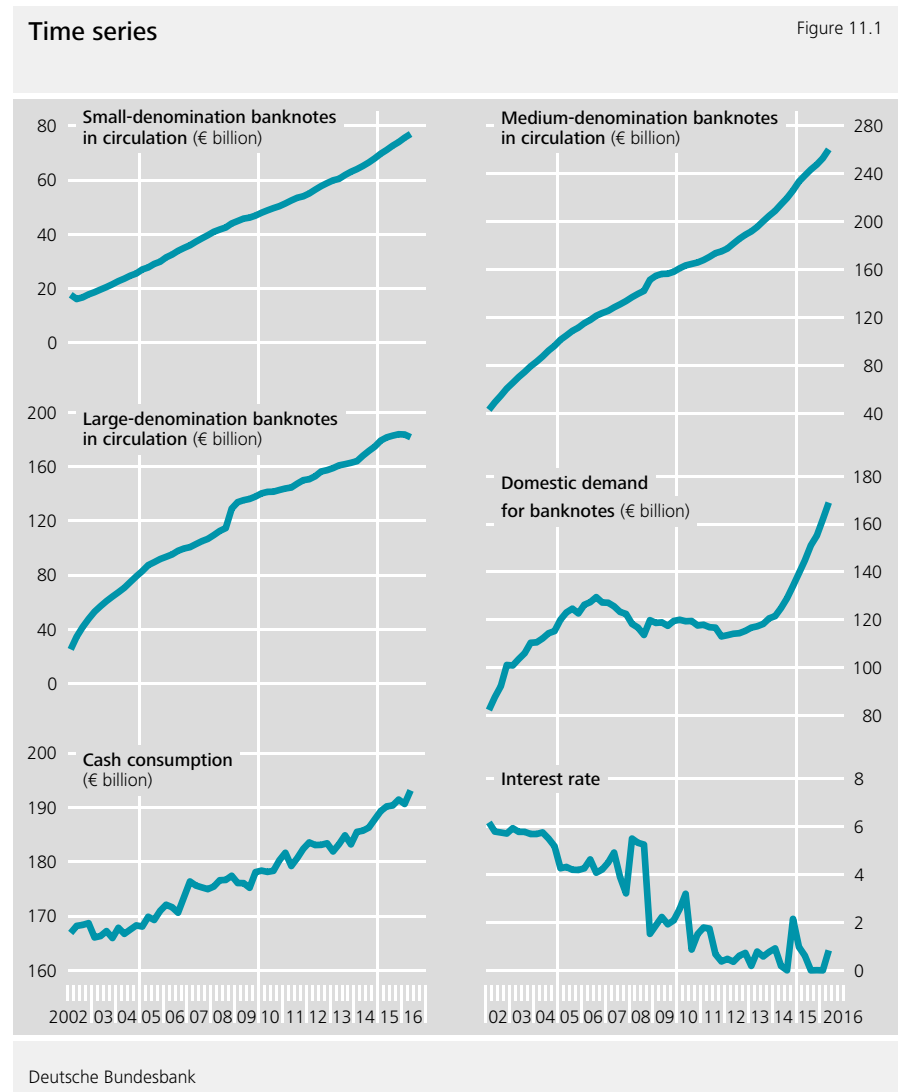
As discussed above, a further criticism of the currency demand approach is that one-off effects are not taken into account. In this analysis, by contrast, one-off effects are indeed modelled. The financial crisis of 2008 is shown, as is the decision of the ECB Governing Council on 4 May 2016 to halt the production and distribution of the €500 banknote. The impact of the financial crisis on banknote circulation is modelled using the following dummy variables. One dummy variable takes the value of 1 in the fourth quarter of 2008, but is otherwise equal to zero. It models the increase in banknote circulation in this quarter following the escalation of the financial crisis. The ensuing scaling back or further restocking of this hoard is modelled with dummy variables for the subsequent quarters. On 4 May 2016, the Governing Council of the ECB decided to discontinue the production and issuance of the €500 banknote towards the end of 2018. As a result of this decision and the previous months of public debate surrounding the issue, the circulation of the €500 banknote declined from the first quarter of 2016. In some cases, switches to €200 and €100 banknotes also took place. The effect of this on large and medium denominations is modelled using two quarterly dummy variables.

Quarterly data were used. Time series which were only available in the form of monthly or annual data were converted to quarterly data. The dataset essentially comprises the period from the first quarter of 2002 to the second quarter of 2016. The data used to estimate banknote demand are, as usual, adjusted for seasonal and calendar effects, to the extent that the time series display any such effects. The estimates are made using a real specification; in other words, long-term price homogeneity is assumed. The data are described in Table 10. A graphic representation of the time series can be found in Figure 11.

## Description of data

Table 10.1

| Variable | Description | Stationary transformation for the regression estimations |
|---|---|---|
| Circulation of small-denomination banknotes | Real circulation of €5, €10 and €20 banknotes issued by the Bundesbank in € billion (seasonally adjusted). Sources: Deutsche Bundesbank and authors' own calculations. | Logarithmic first difference (logarithmic growth rate) |
| Circulation of medium-denomination banknotes | Real circulation of €50 and €100 banknotes issued by the Bundesbank in € billion (seasonally adjusted). Sources: Deutsche Bundesbank and authors' own calculations. | Logarithmic first difference (logarithmic growth rate) |
| Circulation of large-denomination banknotes | Real circulation of €200 and €500 banknotes issued by the Bundesbank in € billion (seasonally adjusted). Sources: Deutsche Bundesbank and authors' own calculations. | Logarithmic first difference (logarithmic growth rate) |
| Domestic banknote circulation | Real (estimated) domestic circulation of euro banknotes in € billion (seasonally adjusted). Sources: Deutsche Bundesbank and authors' own calculations. | Logarithmic first difference (logarithmic growth rate) |
| Cash consumption | Real cash consumption in € billion (seasonally adjusted). Sources: Federal Statistical Office and authors' own calculations. | Logarithmic first difference (logarithmic growth rate) |
| Interest rate | Shift parameter derived from the estimated yield curve, which stands for the generally prevailing interest rate level. Source: Deutsche Bundesbank. | First difference |
| Card turnover | Domestic card turnover from girocards and credit cards in € billion. Sources: PaySys Consultancy GmbH and authors' own calculations. | Logarithmic first difference (logarithmic growth rate) |
| Exchange rate | Real effective exchange rate of the euro against the currencies of the EER-12. Source: Deutsche Bundesbank. | Logarithmic first difference (logarithmic growth rate) |
| Property prices in the rest of the euro area | ECB's residential property price indicator for the euro area excluding Germany. Source: European Central Bank. | Logarithmic first difference (logarithmic growth rate) |
| Tax and social security contributions ratio | Wage tax and social contributions as a percentage of households' disposable income (seasonally adjusted). Sources: Deutsche Bundesbank, Federal Statistical Office and authors' own calculations. | |

## Description of data

Table 10.2

| Variable | Description | Stationary transformation for the regression estimations |
|---|---|---|
| Employment rate in the agricultural sector | Number of persons employed in the agricultural sector as a percentage of all persons in employment (seasonally adjusted). Sources: Deutsche Bundesbank, Federal Statistical Office and authors' own calculations. | |
| Employment rate in the construction sector | Number of persons employed in the construction sector as a percentage of all persons in employment (seasonally adjusted). Sources: Deutsche Bundesbank, Federal Statistical Office and authors' own calculations. | |
| Unemployment rate | Number of unemployed persons as a percentage of the civilian labour force (seasonally adjusted). Source: Federal Employment Agency. | |
| Self-employment rate | Number of self-employed persons as a percentage of all persons in employment (seasonally adjusted). Sources: Deutsche Bundesbank, Federal Statistical Office and authors' own calculations. | |
| Crimes in total | Total number of recorded crimes. Sources: police crime statistics and authors' own calculations. | Logarithmic first difference (logarithmic growth rate) |
| Drug-related crimes | Number of recorded drug-related crimes. Sources: police crime statistics and authors' own calculations. | Logarithmic first difference (logarithmic growth rate) |

## Time series

Figure 11.1



Deutsche Bundesbank

## Time series

Figure 11.2



**Card turnover** (€ billion)

**Exchange rate**

**Residential property price indicator for the rest of the euro area**

**Tax and social security contributions ratio** (%)

**Ratio of persons employed in the agricultural sector** (%)

**Ratio of persons employed in the construction sector** (%)

Deutsche Bundesbank

## Time series

Figure 11.3



**Unemployment rate** (%)

**Self-employment rate** (%)

**Crimes in total**

**Drug-related crimes**
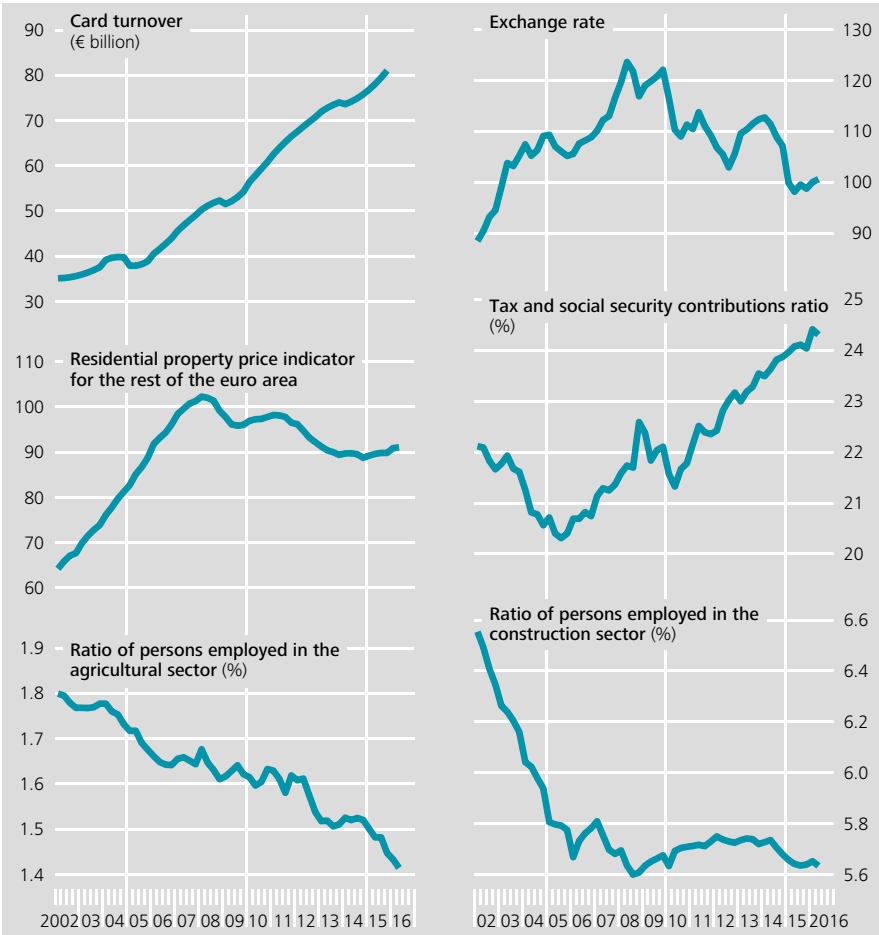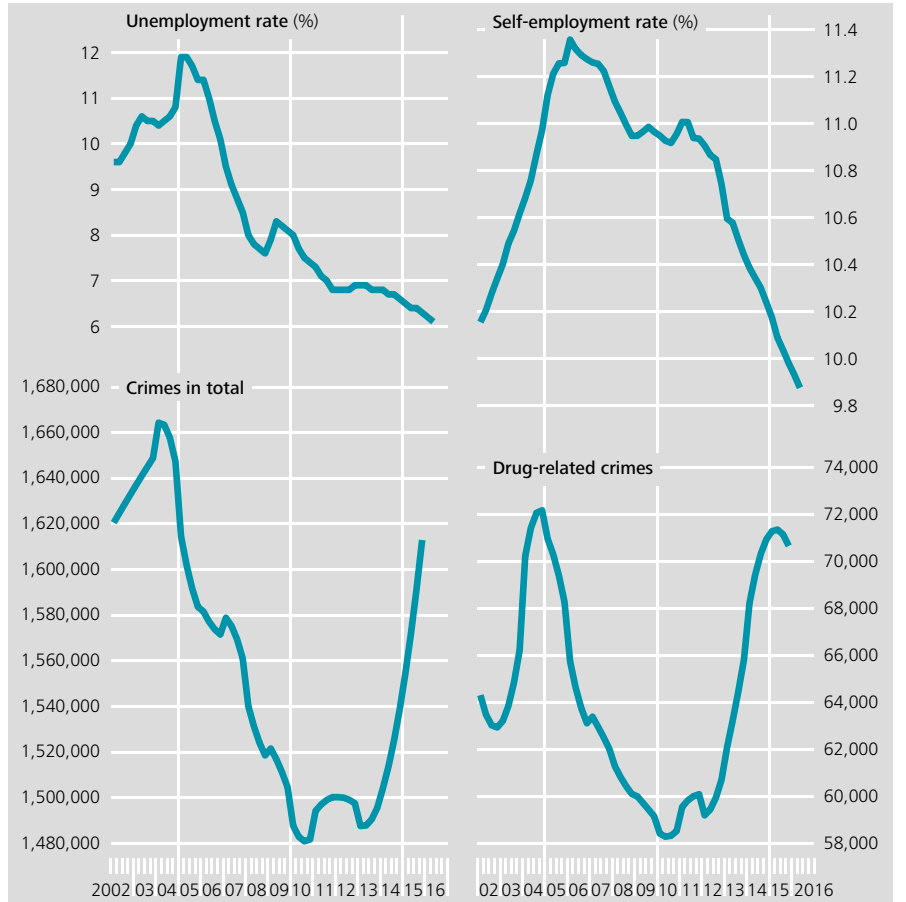
Sources: Federal Employment Agency, Deutsche Bundesbank, European Central Bank, PaySys Consultancy GmbH, police crime statistics, Federal Statistical Office and authors' own calculations.

Deutsche Bundesbank

Finally, the estimation methods employed in Sections 4.3.2 to 4.3.5 are described. A distinction should be made between the two non-stationary proxy variables for the shadow economy "crimes in total" and "drug-related crimes" on the one hand and the remaining five stationary proxy variables for the shadow economy on the other. Here, the first group is referred to as "shadow economy – illegal" and the second group as "shadow economy – legal production". Alternatively, different combinations of control variables are added to each of the eight combinations of endogenous variables and "shadow economy – illegal".[48] Each of these sets of variables are then tested for cointegration. In the event that no cointegration relationship is identified within the system of equations, i.e. no vector error correction model is found, the cointegration analysis is performed with individual equations.[49] If no cointegration relationship is found there either, dynamic regression models, more specifically autoregressive distributed lag (ARDL) models, are estimated for banknote demand using the general-to-specific approach.[50] To avoid the problem of omitted variables, two proxy variables for the shadow economy were included as regressors in the starting specification of the models; one from the "shadow economy – legal production" group and one from the "shadow economy – illegal" group.[51] Finally, the ARDL models estimated in this manner are transferred from the

reduced-form equation to the static long-run equation.[52] The long-run multipliers of the shadow economy variables in terms of banknote circulation, which are ultimately of interest, can be ascertained from this equation.[53] No cointegration analysis is performed for the proxy variables from the "shadow economy – legal production" group on account of their stationarity. The starting specifications of the ARDL models take the following general form:

$$(8) \quad y_t = c + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 y_{t-3} + \alpha_4 y_{t-4} + x_t' \beta_1 + x_{t-1}' \beta_2$$
$$+ \gamma_1 z_{prod,t} + \gamma_2 z_{prod,t-1} + \gamma_3 z_{illegal,t} + \gamma_4 z_{illegal,t-1} + u_t, \quad t = 1,\ldots,T.$$

Here, $y_t$ stands for the demand for banknotes as an endogenous variable, $c$ is the constant term, $x_t$ designates the vector of the control variables, $z_{prod,t}$ represents a shadow economy variable from the "shadow economy – legal production" group, $z_{illegal,t}$ represents a shadow economy variable from the "shadow economy – illegal" group, and $u_t$ is the residual. The alphas, betas and gammas are the corresponding coefficients. The control variables include all the exogenous variables with the exception of the shadow economy variables. The variables are fed into the regression after being transformed into stationary variables as described in Table 10.

The regression estimations described in the following sections are summarised in Table 11 for banknote circulation according to denomination and in Table 12 for

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**48**  The control variables include all the exogenous variables (determining factors of banknote demand) with the exception of the proxy variables for the shadow economy.

**49**  Documentation of the cointegration analyses is available from the authors upon request.

**50**  Distortions resulting from omitted variables can be avoided with the use of the general-to-specific approach. A comprehensive overview of this approach can be found in Campos et al. (2005).

**51**  In principle, it makes sense to add all of the shadow economy variables into the regressions together to avoid potential problems resulting from omitted variables. However, problems stemming from multicollinearity can subsequently arise. If the individual proxy variables are highly correlated with the shadow economy, this means that they are also highly correlated with each other. As a result, the estimation of the coefficients can be very imprecise. On account of the relatively low number of observations (fewer than 60), it was decided not to incorporate all of the shadow economy variables into the starting specifications of the regressions as a whole, but rather to include just two in each case. A well-specified ARDL model could not be estimated for the demand for large-denomination banknotes using the starting specifications of model (8). For this denomination, therefore, only one of the seven shadow economy variables was added per regression. As a result, seven regression models were estimated, the starting specifications of which only differ in terms of the shadow economy variable.

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**52**  The static long-run equation is also known as a long-run static equilibrium solution. The system is defined as having reached its equilibrium point when the variables have become stable or stationary (steady state) and no longer change. Where variables are defined as growth rates, these are steady state growth rates.

**53**  It can be deduced from the reduced form of the model how the dependent variable in the current period $t$ would react to a change (assumed here to be persistent) in a current exogenous variable (impact multiplier). Over the autoregressive structure of the model, the dependent variable changes during the subsequent periods $t+1$, $t+2$, etc. The corresponding changes are known as dynamic multipliers. The sequence of these dynamic multipliers converges towards the long-run multiplier over time. This shows the long-term effect that a persistent change of one exogenous variable has on the dependent variable.

domestic circulation. These tables contain the ARDL models estimated on the basis of equation (8), the corresponding static long-run equations and the results of the diagnostic tests of the dynamic regression models. The explanatory variables are grouped into the following blocks: deterministic control variables, lagged endogenous variables, stochastic control variables and proxy variables for the shadow economy. The endogenous variables, i.e. the dependent variables or rather the to be explained variables, are listed in the first line of Table 11.

### 4.3.2 Structural models for demand for small-denomination banknotes

The two shadow economy variables "unemployment rate" and "crimes in total" have a highly significant positive impact on the logarithmic growth rate in real circulation of small-denomination banknotes, see model (1) in Table 11. They are also the only regressors. The model passes the diagnostic tests. The null hypotheses of uncorrelated, homoscedastic and normally distributed residuals are not rejected. The Ramsey RESET test does not indicate any misspecification in the model. The adjusted $R^2$ value of 0.69 is satisfactory, but is considerably lower than in models (2) to (5) for medium-denomination and large-denomination banknotes. This could be a result of the difficulty in modelling the domestic migration of these banknotes.[54]

Since the ARDL model (1) does not contain any lagged endogenous variables, it results directly (i.e. with no further transformation) in the associated static long-run equation that is ultimately of interest here. The long-run multiplier of the logarithmic growth rate of the total number of crimes in relation to the logarithmic growth rate of real circulation of small-denomination banknotes has a value of 0.70. This is to be interpreted as follows: if there is a sustained rise of 1 percentage point in the logarithmic growth rate of the total number of crimes, the logarithmic growth rate

of real circulation of small-denomination banknotes rises by 0.7 percentage point over the long term. In order to classify this result, it is helpful to take a look at the development of both time series. In the estimation period, the logarithmic growth rate of the total number of crimes fluctuated within a range of -2.0% to 1.3%. In the estimation period, the logarithmic growth rate of real circulation of small-denomination banknotes was within an interval of 1% to 6%, but was within a narrower range of around 1% to 2.5% from 2009. The long-run multiplier of the shadow economy variable "crimes in total" in relation to the circulation by value of small-denomination banknotes can therefore be considered economically significant.

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54   "Domestic migration" refers to the migration of euro banknotes within the euro area. The Bundesbank's large share of the issuance of small-denomination banknotes is indicative of considerable export of these banknotes to the rest of the euro area.

## Results of the regression estimations for the individual denominations

Table 11.1

| Endogenous variable | Small-denomination banknotes in circulation | Medium-denomination banknotes in circulation | | Large-denomination banknotes in circulation | |
|---|---|---|---|---|---|
| ARDL model | (1) | (2) | (3) | (4) | (5) |
| Constant term | - 0.03*** | - 0.11* | - 17.31*** | - 0.08*** | - 0.28*** |
| Dummy variable for Q4 2008 | | 0.04*** | | 0.10*** | 0.11*** |
| Dummy variable for Q1 2009 | | | | - 0.03*** | - 0.02** |
| Dummy variable for Q2 2009 | | | | - 0.03*** | |
| Dummy variable for Q3 2009 | | - 0.02*** | | | |
| Dummy variable for Q4 2009 | | - 0.02*** | | | |
| Dummy variable for Q2 2016 | | | | | - 0.02** |
| Endogenous variable lagged by one period | | | | 0.54*** | 0.45*** |
| Endogenous variable lagged by four periods | | 0.34*** | | | |
| House prices in the euro area excluding Germany | | | 1.31*** | | |
| Card turnover | | -0.19*** | 1.07*** | | |
| Card turnover lagged by one period | | | | - 0.18** | |
| Euro exchange rate lagged by one period | | | | 0.09** | |
| Unemployment rate | 0.007*** | | | | |
| Employment rate in the agricultural sector | | | | 0.06*** | |
| Employment rate in the construction sector | | - 0.04** | | | |
| Employment rate in the construction sector lagged by one period | | 0.06*** | | | 0.05*** |
| Crimes in total lagged by one period | 0.70*** | | | | |
| Drug-related crimes | | | 1.10*** | | |

## Results of the regression estimations for the individual denominations

Table 11.2

| Endogenous variable | Small-denomination banknotes in circulation | Medium-denomination banknotes in circulation | | Large-denomination banknotes in circulation | |
|---|---|---|---|---|---|
| Static long-run equation for the regression model | (1) | (2) | (3) | (4) | (5) |
| Constant term | - 0.03*** | - 0.17** | | - 0.17*** | - 0.51*** |
| Dummy variable for Q4 2008 | | 0.07*** | | 0.22*** | 0.20*** |
| Dummy variable for Q1 2009 | | | | - 0.08*** | - 0.04** |
| Dummy variable for Q2 2009 | | | | - 0.06*** | |
| Dummy variable for Q3 2009 | | - 0.02*** | | | |
| Dummy variable for Q4 2009 | | - 0.03*** | | | |
| Dummy variable for Q2 2016 | | | | | - 0.03** |
| Card turnover | | - 0.29*** | | - 0.38** | |
| Euro exchange rate | | | | 0.21** | |
| Unemployment rate | 0.007*** | | | | |
| Employment rate in the agricultural sector | | | | 0.12*** | |
| Employment rate in the construction sector | | 0.033** | | | 0.09*** |
| Crimes in total | 0.70*** | | | | |

**Cash use in Germany**
New analyses on the illicit use of cash
100

**Cash use in Germany**
New analyses on the illicit use of cash
101

### Results of the regression estimations for the individual denominations

Table 11.3

| Endogenous variable | Small-denomination banknotes in circulation | Medium-denomination banknotes in circulation | | Large-denomination banknotes in circulation | |
|---|---|---|---|---|---|
| Diagnostic tests | (1) | (2) | (3) | (4) | (5) |
| Number of observations | 55 (Q3 2002-Q1 2016) | 51 (Q2 2003-Q4 2015) | 53 (Q3 2002-Q3 2015) | 55 (Q3 2002-Q1 2016) | 56 (Q3 2002-Q2 2016) |
| Adjusted R² | 0.69 | 0.92 | 0.99 | 0.96 | 0.96 |
| Prob (F-statistic) | 0.00 | 0.00 | | 0.00 | 0.00 |
| Breusch-Godfrey autocorrelation test: LM (12) [p value] | 19.87 [0.07] | 15.55 [0.21] | | 11.19 [0.51] | 12.96 [0.37] |
| Jarque-Bera test of normal distribution: JB [p value] | 5.62 [0.06] | 4.81 [0.09] | | 0.08 [0.96] | 1.85 [0.40] |
| White-Test of heteroscedasticity: Obs*R² statistic [p value] | 5.21 [0.39] | 7.37 [0.97] | | 25.23 [0.09] | 14.31 [0.28] |
| Ramsey RESET test: F-statistic [p value] Likelihood ratio [p value] | 1.52 [0.23]. 3.25 [0.20] | 0.52 [0.60]. 1.28 [0.53] | | 2.73 [0.076]. 6.30 [0.043] | 0.41 [0.67]. 0.96 [0.62] |

Notes: *** significant at 1%. ** significant at 5%. * significant at 10%.
With the exception of model (3). the variables undergo stationary transformation as described in Table 10. Unlike the other models. model (3) is not an ARDL model. but a cointegration equation. As a result. model (3) is already available in the form of a static long-run equation. All of the variables in that model are logged and non-stationary.
Source: Authors' own calculations.

The long-run multiplier of the shadow economy variable "unemployment rate" in relation to the logarithmic growth rate of real circulation of small-denomination banknotes in the static long-run equation has a value of 0.007. This is to be interpreted as follows: if there is a sustained rise of 1 percentage point in the unemployment rate, the logarithmic growth rate of real circulation of small-denomination

banknotes rises by 0.7 percentage point over the long term.[55] In order to classify this result, another look should be taken at the development of both time series. In the estimation period, the unemployment rate fell from 10.5% to 6.1%, temporarily rising from 10.8% to 11.9% in the first quarter of 2005 (see Figure 11). The long-run multiplier of the shadow economy variable "unemployment rate" in relation to the real circulation of small-denomination banknotes is therefore likely to be economically significant.

### 4.3.3 Structural models for demand for medium-denomination banknotes

A long-run equilibrium relationship (cointegration relationship) with the shadow economy variable "drug-related crimes" (and other variables) was found for the demand for medium-denomination banknotes. Dynamic regression models show a statistically significant influence on demand for medium-denomination banknotes only for the shadow economy variable "employment rate in the construction sector", see models (2) and (3) in Table 11. In line with the results of surveys on payment behaviour, card payments play a role in the demand for medium-denomination banknotes. The theoretical uncertainty regarding the sign of the card payments coefficient is reflected in the estimations.

A cointegration relationship (long-run equilibrium relationship) with the variables "card turnover", "drug-related crimes" and "residential property price indicator for the euro area excluding Germany" was found for real demand for medium-denomination banknotes; see model (3) in Table 11. All of the coefficients are highly significant and the positive signs are consistent with the theory and/or can be theoretically justified. The elasticity of real demand for medium-denomination banknotes in relation to the residential property price indicator for the rest of the euro area

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[55] It should be noted that the unemployment rate is quoted in percentage points while the logarithmic growth rate of real circulation of small-denomination banknotes is quoted as a percentage. If, for example, the latter rises from 0.01 or 1% to 0.017 or 1.7%, this constitutes a rise of 0.7 percentage point.

Cash use in Germany
New analyses on the illicit use of cash
102

Cash use in Germany
New analyses on the illicit use of cash
103

has a value of 1.3. If this indicator increases by 1%, real demand for medium-denomination banknotes rises correspondingly – and slightly disproportionately – by 1.3%. Real demand for medium-denomination banknotes is positively dependent on card turnover with an elasticity of 1. The positive effect of easier access to ATMs apparently outweighs the negative effects of card payments as a substitute for cash payments and lower transaction costs for obtaining cash. If there is a sustained rise of 1% in the number of drug-related crimes, the real circulation of medium-denomination banknotes also rises by just over 1% over the long term. In other words, as is the case for card turnover, the elasticity of real circulation of medium-denomination banknotes in relation to the number of drug-related crimes has a value of 1. This positive, proportionally elastic influence of the number of drug-related crimes on real demand for medium-denomination banknotes can be considered economically significant.

According to dynamic regression model (2) in Table 11, the logarithmic growth rate of real circulation of medium-denomination banknotes is explained by its value lagged by four periods, the logarithmic growth rate of card turnover, as well as the current value of the "employment rate in the construction sector" and the value lagged by one period. The three dummy variables depict the rise in real demand for medium-denomination banknotes as a result of the financial crisis in the fourth quarter of 2008 as well as the complete reduction of this additional demand in the second half of 2009. The adjusted $R^2$ value of 0.92 is high and the model passes the diagnostic tests. The null hypotheses of uncorrelated, homoscedastic and normally distributed residuals are not rejected. The Ramsey RESET test does not indicate any misspecification in the model. Unlike in cointegration model (3), real demand for medium-denomination banknotes falls as card turnover rises. Here, the negative effect of card payments as a substitute for cash payments and the lower transaction costs for obtaining cash therefore outweigh the positive effect of easier access to ATMs. Due to the differing signs, the model cannot be used to ascertain whether a (sustained) rise in the employment rate in the construction sector leads to an increase

in the logarithmic growth rate of real circulation of medium-denomination banknotes, as would be expected in theory. Insight into this is first provided by the static long-run equation.

According to the equation, the long-run multiplier of the shadow economy variable "employment rate in the construction sector" in relation to the logarithmic growth rate of real circulation of medium-denomination banknotes has a value of 0.033. This coefficient is significant and has a positive sign, as would be expected in theory. This is to be interpreted as follows: if there is a sustained rise of 1 percentage point in the employment rate in the construction sector, the logarithmic growth rate of real circulation of medium-denomination banknotes rises by 3.3 percentage points over the long term.[56] In order to classify this result, it is helpful to take a look at the development of both time series. In the estimation period, the employment rate in the construction sector fell from 6.2% to 5.6% (see Figure 11) and the logarithmic growth rate of real circulation of medium-denomination banknotes was within an interval of 0% to 7%. On balance, the long-run multiplier of the shadow economy variable "employment rate in the construction sector" in relation to real circulation of medium-denomination banknotes can therefore be considered economically significant. The long-run multiplier of card turnover with a value of -0.29 is to be interpreted as follows: if there is a rise of 1 percentage point in the logarithmic growth rate of card turnover, the logarithmic growth rate of real demand for medium-denomination banknotes falls by 0.29 percentage point.

### 4.3.4 Structural models for demand for large-denomination banknotes

There is a statistically significant relationship between real demand for large-denomination banknotes and the shadow economy for the shadow economy variables

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**56** It should be noted that the employment rate in the construction sector is quoted in percentage points while the logarithmic growth rate of real circulation of medium-denomination banknotes is quoted as a percentage. If, for example, the latter rises from 0.01 or 1% to 0.043 or 4.3%, this constitutes a rise of 3.3 percentage points.

Cash use in Germany
New analyses on the illicit use of cash
104

Cash use in Germany
New analyses on the illicit use of cash
105

"employment rate in the agricultural sector" and "employment rate in the construction sector"; see models (4) and (5) in Table 11. As in the case of the medium denominations, the regression estimates for real demand for large-denomination banknotes have greater explanatory power than the estimates for the small denominations, as foreign demand can be modelled more effectively. In line with the results of surveys on payment behaviour, card payments play a role in the demand for large-denomination banknotes. According to dynamic regression model (4), the logarithmic growth rate of real circulation of large-denomination banknotes is explained by its value lagged by one period, the value of the logarithmic growth rate of card turnover lagged by one period, the value of the exchange rate lagged by one period, as well as the employment rate in the agricultural sector. The dummy variables for the fourth quarter of 2008 to the second quarter of 2009 depict the rise in real demand for large-denomination banknotes as a result of the financial crisis in the fourth quarter of 2008 as well as the partial reduction of this additional demand in the first half of 2009. As a result of the financial crisis, the logarithmic growth rate of real demand for large-denomination banknotes rose by an additional 10 percentage points over the short term (from 2% in the third quarter of 2008 to 12% in the fourth quarter of 2008). The positive signs of the coefficient of the employment rate in the agricultural sector and of the exchange rate are consistent with the theory. As is also the case in the dynamic regression model for demand for medium-denomination banknotes, the coefficient (of the logarithmic growth rate) of card turnover is negative. The negative effect of card payments as a substitute for cash payments and the lower transaction costs for obtaining cash again outweigh the positive effect of easier access to ATMs. The adjusted $R^2$ value of 0.96 is high and the model passes most of the diagnostic tests. The Ramsey RESET test for general misspecification does not produce a clear result, however.[57]

The long-run multiplier of the shadow economy variable "employment rate in the agricultural sector" in relation to the logarithmic growth rate of real circulation of large-denomination banknotes is to be interpreted as follows: if there is a sustained rise of 1 percentage point in the employment rate in the agricultural sector, the logarithmic growth rate of real circulation of large-denomination banknotes rises by 12 percentage points over the long term.[58] In order to classify this result, it is helpful to take a look at the development of both time series. In the estimation period, the employment rate in the agricultural sector fell from just under 1.8% to just over 1.4% (see Figure 11) and the logarithmic growth rate of real circulation of large-denomination banknotes was within an interval of 0% to 3%, disregarding both the strong growth in the initial quarters of the estimation period, which were still being affected by the introduction of euro cash, and the strong growth in the fourth quarter of 2008 (compared to the preceding quarter) as a result of the financial crisis. In particular, the long-run multiplier of the shadow economy variable "employment rate in the agricultural sector" in relation to the logarithmic growth rate of real circulation of large-denomination banknotes is even slightly higher than the (short-term) impact of the financial crisis in the fourth quarter of 2008, which, according to the regression estimation, caused this growth rate to rise by an estimated 10 percentage points. It is therefore certain that the long-run multiplier is economically significant. However, this result is subject to the potential misspecification in the underlying reduced-form model, as discussed above. Furthermore, the effect is also not entirely attributable to shadow economic motives, as cash is typically used in the agricultural sector for legal payments as well. The long-run multiplier of the logarithmic growth rate of card turnover is (in absolute terms) around twice as high as the long-run multiplier of the exchange rate.

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[57]  The null hypothesis that the model is not misspecified is in fact not rejected by the F statistic (at the 5% level), but by the likelihood ratio.

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[58]  It should be noted that the employment rate in the agricultural sector is quoted in percentage points while the logarithmic growth rate of real circulation of large-denomination banknotes is quoted as a percentage. If, for example, the latter rises from 0.01 or 1% to 0.13 or 13%, this constitutes a rise of 12 percentage points.

Cash use in Germany
New analyses on the illicit use of cash
106

Cash use in Germany
New analyses on the illicit use of cash
107

Dynamic regression model (5) displays the estimated relationship between the growth rate of real circulation of large-denomination banknotes and the employment rate in the construction sector as a proxy variable for the shadow economy. The adjusted $R^2$ value of 0.96 is high and the model passes all of the diagnostic tests. The employment rate in the construction sector is introduced into the regression with its value lagged by one period. It is highly significant and, as expected in theory, positive. According to the regression estimation, the additional growth in real circulation of large-denomination banknotes as a result of the financial crisis amounted to 11 percentage points in the fourth quarter of 2008. It is estimated that the discontinuation of the €500 banknote caused the logarithmic growth rate of real circulation of large-denomination banknotes to decline by 2 percentage points.

The long-run multiplier of the shadow economy variable "employment rate in the construction sector" in relation to the logarithmic growth rate of real circulation of large-denomination banknotes is to be interpreted as follows: if there is a sustained rise of 1 percentage poipct in the employment rate in the construction sector, the logarithmic growth rate of real circulation of large-denomination banknotes rises by 9 percentage points over the long term.[59] In order to classify this result, it is again helpful to take a look at the development of the time series. From the third quarter of 2002 to the first quarter of 2006, the employment rate in the construction sector fell from around 6.4% to around 5.7% and then remained more or less constant (see Figure 11). In addition, the long-run multiplier for the shadow economy variable "employment rate in the construction sector" in relation to real circulation of large-denomination banknotes is almost as large as the short-term impact of the financial crisis in the autumn of 2008. It is therefore certain that this long-run multiplier is economically significant.

In comparison to the small denominations, the regression estimates for real demand for larger-denomination banknotes have greater explanatory power in terms of a higher coefficient of determination. Foreign demand can be modelled more effectively for these denominations. In line with the results of surveys on payment behaviour, card payments play a role in the demand for medium-denomination and large-denomination banknotes.

### 4.3.5 Structural models for domestic demand for banknotes
In addition to the models for the demand by denomination for euro banknotes issued by the Bundesbank described in Sections 4.3.2 to 4.3.4, domestic demand for banknotes (real domestic circulation) is modelled in this section.[60] This serves two purposes. First, it takes account of the difficulty in appropriately depicting foreign circulation in regressions. To some extent, the exchange rate is likely to represent a good means of capturing the circulation of German-issued euro banknotes outside the euro area. By contrast, the demand for German-issued euro banknotes in the rest of the euro area (excluding Germany) is difficult to depict.[61] Second, domestic circulation as a regional component of German-issued banknotes in circulation is already a topic of interest in and of itself. In this context, particular attention should be paid to the relationship between domestic circulation and the shadow economy. In order to do so, partial effects will be estimated in this section as they were in the three previous sections. Real domestic circulation, which is used as the dependent variable, corresponds – before deflation – to the difference between the value of the cumulative net banknote issuance by the Bundesbank and the (total) foreign circulation of German-issued euro banknotes estimated in

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59   It should be noted that the employment rate in the construction sector is quoted in percentage points while the logarithmic growth rate of real circulation of large-denomination banknotes is quoted as a percentage. If, for example, the latter rises from 0.01 or 1% to 0.10 or 10%, this constitutes a rise of 9 percentage points.

60   As the Bundesbank meets all of the demand for banknotes and Germany is a net exporter of euro banknotes, domestic demand for euro banknotes corresponds to domestic circulation of euro banknotes.

61   The total domestic migration of euro banknotes in the euro area – and not only German net exports – is difficult to estimate.

Section 2.2.[62] Unlike total banknote circulation (cumulative net issuance by the Bundesbank), domestic banknote circulation cannot be decomposed into (small, medium and large) denominations, as the relevant estimates are not available.

There is a statistically significant relationship between domestic demand for banknotes and the shadow economy for the shadow economy variable "tax and social security contributions ratio"; see also model (6) in Table 12. In this dynamic regression model, the logarithmic growth rate of real domestic banknote circulation is explained by its lagged values, the logarithmic growth rate of cash consumption lagged by one period, the logarithmic growth rate of card turnover lagged by one period, the change in interest rates, and the tax and social security contributions ratio, which serves as a proxy variable for the shadow economy. All of the regressors are (at least) statistically significant. As traditional motives for banknote demand, transactions and hoarding now play a role. However, in the regression estimations by denomination, it is likely that these motives are obscured by foreign circulation. As is also the case in the dynamic regression models for demand for medium-denomination and large-denomination banknotes, the coefficient (of the logarithmic growth rate) of card turnover is negative. The negative effects of card payments as a substitute for cash payments and the lower transaction costs for obtaining cash again outweigh the positive effect of easier access to ATMs. A rise of 1 percentage point in the logarithmic growth rate of card turnover leads to a decline of 0.3 percentage point in the logarithmic growth rate of real domestic demand for banknotes. The impact of the logarithmic growth rate of real cash consumption is, with a value of 0.55 (in absolute terms), almost twice as large. The positive sign is con-

sistent with the theory.[63] A change in interest rates has, in accordance with the theory, a negative impact on the logarithmic growth rate of real domestic banknote circulation. The highly significant impact of the tax and social security contributions ratio on the logarithmic growth rate of real domestic demand for banknotes is, at half a percentage point (in absolute terms), exactly the same as the impact of interest rates and is considerably less than proportional. The adjusted $R^2$ value of 0.71 is satisfactory and the model passes all of the diagnostic tests.

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**62**   The regressors for foreign circulation can therefore be omitted. This procedure is equivalent to introducing the foreign circulation estimated in Section 2.2 as an additional regressor in the estimation equation for the total circulation of German-issued banknotes and restricting its coefficient to a value of 1.

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**63**   There are economies of scale in the holding of cash when the economic agents reduce their cash holdings in relation to their transactions (or income) with increasing transaction volume (or income). This is the case if the transaction elasticity or income elasticity of cash demand is less than 1; see Boeschoten (1992, pp. 23-24). The coefficient cited here (with a value of 0.55) represents a derivative of the logarithmic growth rate of real domestic banknote circulation based on the logarithmic growth rate of real cash consumption. This derivative does not correspond to transaction elasticity, which is defined as the quotient of these growth rates. On this basis, no conclusions regarding economies of scale in domestic cash demand can be drawn here.

### Results of the regression estimations for domestic circulation   Table 12.1

| ARDL model | (6) |
| --- | --- |
| Constant term | - 0.10*** |
| Dummy variable for Q4 2008 | 0.4*** |
| | |
| Endogenous variable lagged by one period | 0.21** |
| Endogenous variable lagged by two periods | 0.22** |
| Endogenous variable lagged by four periods | 0.35*** |
| | |
| Cash consumption lagged by one period | 0.55** |
| Card turnover lagged by one period | - 0.30** |
| Interest rate | - 0.005** |
| | |
| Tax and social security contributions ratio | 0.005*** |
| | |
| Number of observations | 52 (Q2 2003-Q1 2016) |
| Adjusted $R^2$ | 0.71 |
| Prob (F-statistic) | 0.00 |
| Breusch-Godfrey autocorrelation test: LM (12) [p value] | 15.89 [0.20] |
| Jarque-Bera test of normal distribution: JB [p value] | 1.77 [0.41] |
| White test of heteroscedasticity: Obs*$R^2$ statistic [p value] | 34.84 [0.52] |
| Ramsey RESET test: F-statistic [p value] Likelihood ratio [p value] | 0.94 [0.40], 2.32 [0.31] |

### Results of the regression estimations for domestic circulation   Table 12.2

| Static long-run equation for the regression model | (6) |
| --- | --- |
| Constant term | - 0.46* |
| Dummy variable for Q4 2008 | 0.19 |
| | |
| Cash consumption | 2.42 |
| Card turnover | - 1.35* |
| Interest rate | - 0.02 |
| | |
| Tax and social contributions ratio | 0.022** |

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%.
As described in Table 10, the variables in the ARDL model (6) undergo stationary transformation.
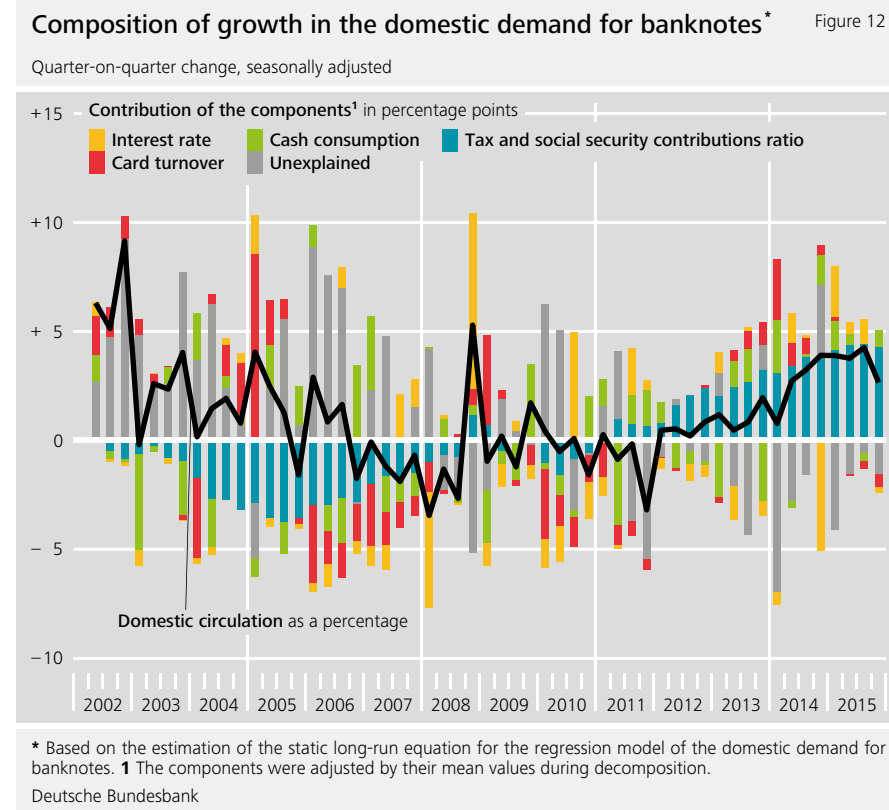Source: Authors' own calculations.

The long-run multiplier of the shadow economy variable "tax and social security contributions ratio" in relation to the logarithmic growth rate of real domestic bank-note circulation has a value of 0.022. This is to be interpreted as follows: if there is a sustained rise of 1 percentage point in the tax and social security contributions ratio, the logarithmic growth rate of real domestic circulation rises by around 2.2 percentage points over the long term.[64] In order to classify this result, it is helpful to take a look at the development of both time series. In the estimation period, the tax and social security contributions ratio fluctuated within a range from 20.3% to 24.4% (see Figure 11) and the logarithmic growth rate of real domestic circulation of euro banknotes was within an interval of -3.5% to 5.3%. On balance, the long-run multiplier of the shadow economy variable "tax and social security contributions

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64   It should be noted that the tax and social security contributions ratio is quoted in percentage points while the logarithmic growth rate of real domestic circulation is quoted as a percentage. If, for example, the latter rises from 0.01 or 1% to 0.032 or 3.2%, this constitutes a rise of 2.2 percentage points.

**Cash use in Germany**
New analyses on the illicit use of cash
112

**Cash use in Germany**
New analyses on the illicit use of cash
113

ratio" in relation to real domestic banknote circulation can therefore be considered economically significant.

In addition to estimating the influence of the shadow economy on domestic banknote demand in the form of partial effects, i.e. by reference to regression coefficients, an attempt was made to determine the value of banknotes in domestic circulation used for shadow economic purposes by means of a dynamic simulation. For this purpose, the shadow economy variable was set at zero in the entire estimation period in ARDL model (6) from Table 12 and the resulting real domestic banknote circulation was simulated in terms of value. This was compared with the domestic banknote circulation estimated in regression model (6) in order to determine the contribution of tax evasion to domestic banknote circulation since the beginning of the estimation period, i.e. since the second quarter of 2003. No meaningful results could be obtained using this approach, however.

Instead, the quantitative contributions of the different influencing variables are compared by decomposing the growth in domestic banknote circulation (see Figure 12). The development of the growth rate of domestic banknote circulation can be split into three phases. It was positive from the launch of euro cash until the end of 2006, then mostly negative until the end of 2011, and has been positive again since then with a tendency to rise. Since 2012, the tax and social security contributions ratio has made the largest contribution to growth in domestic circulation, followed by the growth rates of cash consumption and card payments. This finding highlights the economic significance of the tax and social security contributions ratio in the domestic demand for banknotes.



**Composition of growth in the domestic demand for banknotes*** — Figure 12

Quarter-on-quarter change, seasonally adjusted

Contribution of the components[1] in percentage points
- Interest rate
- Card turnover
- Cash consumption
- Unexplained
- Tax and social security contributions ratio

Domestic circulation as a percentage

**\*** Based on the estimation of the static long-run equation for the regression model of the domestic demand for banknotes. **1** The components were adjusted by their mean values during decomposition.
Deutsche Bundesbank

Finally, the dynamic regression model for domestic banknote circulation with the proxy variable "tax and social security contributions ratio" (model (6) in Table 12)

should, wherever possible, still be compared with the other empirical works on the relationship between currency demand and the shadow economy in Germany.[65] Unlike in the present study, previous estimates of the shadow economy in Germany using the currency demand approach have almost exclusively used measures of the tax burden as a proxy variable for the shadow economy.[66] One exception is Karmann (1990), who, in addition to using a measure of the tax burden (to estimate the supply side of the shadow economy), also uses a measure of the consumer burden through the prices of regular services (to estimate the demand side of the shadow economy). None of the previous empirical works on the relationship between currency demand and the shadow economy in Germany take foreign demand into consideration. These studies all refer to the D-Mark era, a period in which foreign demand is already likely to have played an important role. In this vein, Seitz (1995), using various estimation approaches, comes to the conclusion that in the mid-1990s, 30% to 40% of the total volume of DM cash was in circulation outside Germany.

Kirchgässner (1983, equation (2) on p. 205) applies Klovland's (1980) method by estimating a regression for the real demand for currency per capita using annual data from 1952 to 1980.[67] As well as using an endogenous variable lagged by one period, he also uses the usual explanatory variables: real per capita income, the

interest rate on time deposits, the inflation rate[68] and, as a measure of the tax burden, the marginal tax rate, lagged by one period, on the average employee wage. All coefficients have the expected sign, but the coefficients of the income variable and of the inflation rate are not statistically significant. The coefficient of the proxy variable for the tax burden is highly significant. On balance, Kirchgässner's model is similar to dynamic regression model (6) for domestic banknote circulation from Table 12. The key difference lies in the fact that the transaction variable in Kirchgässner's model is not statistically significant. This is noteworthy, since, at that time, card payments did not yet play a role. One possible explanation could be that the domestic transaction motive is masked because foreign demand is not taken into consideration.[69]

Applying Tanzi's (1980) method, Langfeldt (1989, equation (5) in Table 8.2) regresses the real currency in circulation on its value lagged by one period, the real gross national product as a transaction variable, the three-month interest rate in the money market as an opportunity cost variable, the tax and social security contributions ratio as well as the relationship between the cost-of-living index and the implicit gross national product deflator. He uses annual data from 1952 to 1980. Apart from the transaction variable and the price relationship, all other coefficients are statistically significant (with the correct sign). Hence, Langfeldt's model is very similar to that of Kirchgässner (1983). The observations on Kirchgässner's model thus also apply to Langfeldt (1989).

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**65**  No comparison of coefficients in the different models is undertaken here, given that such a comparison is only possible for nested models. Two models are nested if one model can be reduced to the other model by means of linear restrictions on parameters. This is not the case here. The coefficients of the common variables are often examined to see whether they are significant in both models and whether their value differs between the models. Such comparisons are erroneous for the following reasons. Firstly, they do not take into account that the coefficients in one model are not independent of those in the other model. Secondly, both models cannot be true at the same time, unless they are equivalent. In nested models, comparing the coefficients is equally challenging (Clogg et al.,1995, p. 1263). Clogg et al. (1995) show how nested models can be tested to see whether the coefficients of the common variables differ between the models.

**66**  See Kirchgässner (1983), Langfeldt (1989), and Pickhardt and Sardà (2006).

**67**  Using demand per capita should eliminate the influence of changes in population size.

**68**  As well as the nominal interest rate, which corresponds to the sum of the real interest rate and expected inflation rate, the (actual) inflation rate is a further measure of the opportunity costs associated with holding cash. In contrast to non-financial assets, the value of financial assets falls when inflation increases. Inflation, therefore, reflects real investment alternatives. It is not easy to distinguish between the influences of the nominal interest rate and the inflation rate on the demand for currency. Fischer et al. (2004) hence include the volatility of the inflation rate, in addition to the nominal interest rate, in their regressions.

**69**  Much the same applies to the present study. The classic motives of banknote demand, i.e. the transaction motive and the store-of-value motive, are only significant in the regression of domestic circulation, but not in the estimations by denomination. The latter probably do not adequately capture foreign demand in the form of the domestic migration of banknotes in the euro area.

Cash use in Germany
New analyses on the illicit use of cash
116

Cash use in Germany
New analyses on the illicit use of cash
117

With the exception of the estimation period (from 1952 to 1987), Karmann's (1990, equation (1) on p. 191) currency demand equation differs from Kirchgässner (1983) only in two points. First, he selects the cash coefficient from cash and the monetary aggregate M2 as a dependent variable. Second, the variable for the tax burden is lagged by two periods. All coefficients are significant and their signs are consistent with the theory.

Pickhardt and Sardà (2006, Table 3 on p. 1711) use annual data from 1980 to 2001 to estimate the scope of the shadow economy in Germany by combining the currency demand approach with the MIMIC approach. They model banknote demand statically and select a nominal specification. In doing so, they regress the nominal currency in circulation on real GDP, a price index, a proxy variable for the tax burden and a nominal interest rate.[70] German reunification and the introduction of euro cash are taken into account as one-off effects through the use of dummy variables. All coefficients are statistically highly significant with the exception of the non-significant interest rate coefficient. The latter is consistent with the currently generally low interest-rate sensitivity of currency demand.[71] Unlike in the present study, Pickhardt and Sardà (2006) take neither foreign demand nor card payments into account.

### 4.3.6 Summary and conclusions

This paper examines the real demand for euro banknotes issued by the Bundesbank (German-issued banknotes in circulation). In this context, regressions were estimated for the circulation of small, medium and large denominations respectively, as well as for domestic circulation. According to the estimation, real demand for small denominations depends solely on shadow economic motives. This result should be interpreted with caution since the problem of omitted variables is likely to exist in the estimation. The Bundesbank's large share in the issuance of small denominations in the Eurosystem is indicative of a considerable net export of these banknotes from Germany to the rest of the euro area. Owing to a lack of suitable proxy variables, this domestic migration could, however, not be modelled.[72] In comparison to the small denominations, the regression estimations of real demand for medium and large denominations have greater explanatory power in terms of a higher coefficient of determination. Foreign demand can be modelled more effectively for these denominations, using an exchange rate, amongst other things. In line with the results of surveys on payment behaviour, card payments play a role in the demand for medium and large denominations. The theoretical uncertainty of the sign of the card payments coefficient is reflected in the estimations. An estimation of the domestic circulation time series, which uses existing data on the export of banknotes via foreign travel and by banknote wholesalers, serves as an alternative to modelling the (considerable) circulation of larger denominations abroad. Traditional motives for banknote demand, which are probably obscured by circulation abroad in the regression estimations by denomination, are now significant. These include the store of value motive modelled with an interest rate variable, as well as the transaction motive which is depicted through cash consumption.

The main focus of this analysis is on the long-term relationship between banknote demand and the shadow economy (illicit use of cash). It does not address the

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**70** Like Kirchgässner (1983), Langfeldt (1989) and Karmann (1990), Pickhardt and Sardà (2006) use a semi-log specification in levels. These authors thereby implicitly assume the stationarity of all variables or – if the regression model is static, as is the case in Pickhardt and Sardà (2006) – a cointegration relationship. Langfeldt's (1989) model is a stock-flow adjustment model, in which real currency in circulation is determined in each period by the share $\beta$ through its value in the preceding period and by the share $(1 - \beta)$ through the exogenous variables. Accordingly, the parameters of the model are not estimated freely, but rather in a restricted manner. By contrast, Kirchgässner (1983) estimates his regression in an unrestricted manner. Pickhardt and Sardà (2006) use a SUR estimator to estimate a system comprising the currency demand equation and the MIMIC model. This increases the efficiency of their estimation.

**71** In the present study, although the interest rate variable is statistically significant, the interest rate effect is low. If the interest rate rises by 1 percentage point, the (logarithmic) growth rate of real domestic banknote circulation, which stood within an interval of -3.5% to 5.3% in the estimation period, falls by 0.5 percentage point; see model (6) in Table 12. In other countries, too, the interest rate sensitivity of currency demand is low; see for example Swiss National Bank (2018, p. 6).

**72** "Domestic migration" refers to the migration of euro banknotes within the euro area.

shadow economy as a whole, but rather its different forms. The latter are depicted using seven alternative proxy variables.[73] For banknote demand in its various definitions only one or two of the seven shadow economy variables examined here respectively play a role; see the summary of the regression analysis in Table 13. What stands out is the employment rate in the construction sector, which has a significant influence on the demand for both medium and large-denomination banknotes. Otherwise, the demand for small, medium and large-denomination banknotes, as well as domestic demand for banknotes, each depend on different shadow economy variables. Unlike the panel econometric analysis of deposits at Bundesbank branches, the self-employment rate is the only shadow economy variable which has no influence on the demand for banknotes. The considerable decline in the self-employment rate since the end of 2012, accompanied by a simultaneous rise in the dependent variable "growth rate of real domestic banknote circulation", leads to a negative correlation of these variables.[74] However, it is not a causal economic relationship. The significant decline in the self-employment rate since the end of 2012 is likely to be due to the exceptionally favourable labour market situation in connection with the prolonged economic upturn in Germany. This enabled self-employed persons with the relevant preferences to make a transition to paid employment. Correspondingly, the strong rise in the number of employed persons subject to social security contributions since the end of 2012 was accompanied by a considerable decline in the number of self-employed persons. The shadow economic motives for banknote demand grow in significance as the

denomination size increases. While the impact of the shadow economy on the demand for small denominations is low, its impact on the demand for large denominations is roughly as large as the short-term effect of the financial crisis at the end of 2008.

| Long-term effects of the shadow economy on the value of banknotes in circulation | Table 13 |
| --- | --- |
| **Sustained rise in the proxy variable for the shadow economy** | **Long-term effect on the real circulation of German-issued euro banknotes** |
| Unemployment rate increases by 1 percentage point | Growth rate of the circulation of small denominations increases by **0.7 percentage point\*\*\*** |
| Growth rate of the total number of crimes increases by 1 percentage point | Growth rate of the circulation of small denominations increases by **0.7 percentage point\*\*\*** |
| Number of drug-related crimes increases by 1% | Circulation of medium denominations increases by **1.1%\*\*\*** |
| Employment rate in the construction sector increases by 1 percentage point | Growth rate of the circulation of medium denominations increases by **3.3 percentage points\*\*** |
| Employment rate in the agricultural sector increases by 1 percentage point | Growth rate of the circulation of large denominations increases by **12 percentage points\*\*\*** |
| Employment rate in the construction sector increases by 1 percentage point | Growth rate of the circulation of large denominations increases by **9 percentage points\*\*\*** |
| Tax and social security contributions ratio increases by 1 percentage point | Growth rate of domestic circulation increases by **2.2 percentage points\*\*** |

Notes: \*\*\* statistically significant at 1%, \*\* statistically significant at 5%. Economically significant effects are displayed in bold. Small denominations: €5-€20 banknotes, medium denominations: €50 and €100 banknotes, large denominations: €200 and €500 banknotes.
Source: Authors' own calculations.

In addition to estimating partial effects, the quantitative contributions of the various influencing variables were identified by decomposing the growth in real domestic banknote circulation. This confirmed the economic significance of the tax and social security contributions ratio.

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73 An indicator which represents the common factor of the proxy variables for the shadow economy can be used as a regressor for modelling the shadow economy as a whole. This is based on the assumption that there is no perfect measure of the shadow economy or that all such measures are subject to measurement errors. In this context, a distinction should be made between the production-orientated, stationary proxy variables for the shadow economy on the one hand and the non-stationary crime variables on the other. Alternatively, the shadow economy as a whole can be depicted by the simultaneous incorporation of all seven proxy variables for the shadow economy as regressors. Arguments against this method are the relatively low number of observations and potential problems owing to multicollinearity.
74 If the estimation period is limited to the second quarter of 2003 until the fourth quarter of 2012, the coefficient of the self-employment rate is no longer significant.

Cash use in Germany
Conclusion and discussion
120

Cash use in Germany
Conclusion and discussion
121

# 5 Conclusion and discussion

This study examines the significance of illegal motives for cash demand in Germany from a macroeconomic perspective. As such, it makes a valuable contribution to the current discussion of potential illegal uses of cash. The study approaches this question of the illegal use of cash by way of a literature review as well as empirical testing. The authors' empirical studies consist of a panel econometric analysis of deposits of cash at Bundesbank branches as well as a time series econometric analysis of cumulative net issuance of euro banknotes by the Bundesbank.

Illegal uses of cash refer to those where the surrounding circumstances are not consistent with established law. In the economic literature, illegal uses of cash are mostly studied in connection with estimates of the size of the shadow economy. Estimates put the size of the shadow economy in Germany between around €80 billion and €550 billion. Based on the assumption that transactions in the shadow economy are predominantly settled in cash, that amount in addition to trade in intermediate products represents the annual volume of illegal cash transactions in Germany.

Overall, the literature review reveals that macroeconomic procedures for studying illegal uses of cash encounter difficulties, inter alia, in adequately accounting for foreign demand and legitimate use of currency as a store of value. It is therefore likely that a number of macroeconomic approaches cannot reliably quantify the volume of illegal cash use. The currency demand approach, which, in an expanded form, serves as the basis for this paper's empirical studies, is best suited to estimating illegal cash use. If applied prudently, and if the relevant motives for holding cash are considered, this approach can deliver insights into the importance of illegal motives for cash demand. As a matter of course, the empirical study of the shadow economy is especially challenging, as the illegal activities analysed take place in secret. Accordingly, all results are subject to an above average degree of uncertainty and should only be interpreted cautiously.

The authors apply the currency demand approach first in the panel econometric analysis of cash deposits at Bundesbank branches. These cash deposits are a suitable indicator for the economic scale of cash use, as the Bundesbank is heavily involved in the operational settlement of cash payment transactions in Germany. Cash is deposited at the Bundesbank mainly by commercial enterprises and credit institutions, meaning the cash stems from legal transactions as a rule. However, cash takings in the shadow economy enter the official cash cycle via commercial enterprises and credit institutions, which means that cash deposits at the Bundesbank can deliver indirect insights into the importance of illegal motives. One particular advantage of looking at cash deposits rather than cash in circulation is that a major share of these deposits stem from the use of cash as a means of payment. Modelling cash deposits is thus less challenging, because only the transaction motive for cash demand has to be considered alongside the shadow economic motive.

The importance of illegal motives for cash demand is analysed using regressions of cash deposits on various indicators of illegal cash demand. The results are mixed. Of the series of nine indicators analysed, only the self-employment rate and an indicator of the scale of drug-related crime exhibit a statistically significant influence with the expected sign. According to a model-based analysis, cash deposits at the Bundesbank in the amount of €60 billion in 2015 can be indirectly traced back to illegal cash transactions. If private cash recycling is also considered, the total volume of illegal cash deposits at the Bundesbank and credit institutions comes to €75 billion. These estimates are not directly comparable, in conceptual terms, with estimates of the size of the cash-based shadow economy in Germany in the amount of up to €550 billion. However, the estimated illegal cash deposits of €75 billion can be interpreted as a lower bound for the size of the cash-based shadow economy in Germany.

The regression estimates of banknote demand come to similar, mixed results as the panel analysis of deposits at Bundesbank branches. When it comes to the partial

**Cash use in Germany**
Conclusion and discussion
122

**Cash use in Germany**
List of references
123

effects on banknote demand, shadow economic influences can only be proven for one to two of the seven alternative proxy variables used for the shadow economy. Aside from the employment rate in the construction sector, which plays a role in demand for medium and large-denomination banknotes, no indicator stands out. The importance of shadow economic influences rises as the denominations become larger. In addition to the estimation of partial effects, a dynamic simulation attempted to determine the value of banknotes held in Germany on account of tax evasion. No meaningful results could be obtained, however. Unlike in the present study, previous estimates of the shadow economy in Germany using the currency demand approach have almost exclusively used measures of the tax burden as a proxy variable for the shadow economy, they have disregarded external demand, and they have also failed to analyse cash demand by denomination.[75]

To sum up, the study suggests that estimates of the scale of illegal cash use are subject to an above average degree of uncertainty. Explicitly, the study does not consider the question of whether restrictions on cash usage could help to reduce the size of the shadow economy. On balance, however, it indicates that even advocates of cash restrictions should apply great caution when interpreting the very high macroeconomic estimates of the size of the shadow economy.

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[75]  See Kirchgässner (1983), Langfeldt (1989), and Pickhardt and Sardà (2006).

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Cash use in Germany
List of references
130

Cash use in Germany
List of references
131

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List of references
138

**Cash use in Germany**
List of references
139

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