Demand for euro banknotes issued by the Bundesbank: current developments

The volume of euro banknotes in circulation issued by the Bundesbank has continued to grow strongly over the past few years and amounted to €884 billion at the end of 2021. While the additional demand for banknotes issued by the Bundesbank predominantly originated from abroad up to 2014, domestic demand has since been the key determinant.

At the end of 2019, immediately prior to the onset of the coronavirus pandemic, the cumulated net issuance of euro banknotes by the Bundesbank came to €750 billion. According to estimates, this figure comprised domestic demand totalling €305 billion and foreign demand in the amount of €445 billion. An estimated €245 billion of the domestic demand was accounted for by holdings held as a store of value and €60 billion by transaction balances used for purchasing goods and services. However, the importance of the transaction motive is considerably greater than these figures suggest, as transaction balances are used in multiple transactions within a year and therefore finance a much greater volume of cash spending.

Demand for banknotes grew strongly during the coronavirus crisis. While the Bundesbank's net issuance of euro banknotes amounted to €59 billion in 2019, this figure was €71 billion in 2020 and still came to €63 billion in 2021. Since foreign demand was weak during the coronavirus pandemic owing to travel restrictions, the above-average rise in banknotes in circulation over the past two years was driven almost exclusively by domestic demand for banknotes as a store of value, the volume of which increased to €370 billion in the fourth quarter of 2021. As in previous crises, people placed their trust in cash during the coronavirus crisis, too. The increased demand for banknotes was met successfully without any difficulties as the cash supply was assured at all times.
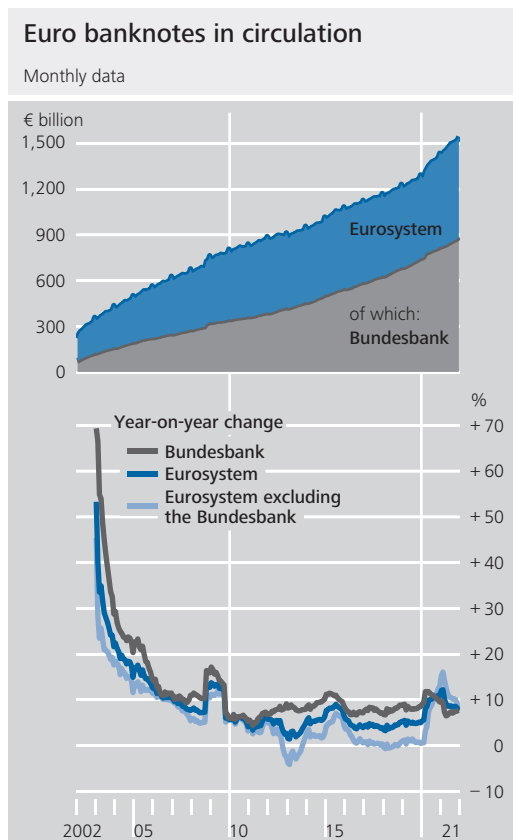
Introduction

Euro banknotes are used as a means of payment and store of value. The European Central Bank (ECB) and the national central banks of the Eurosystem are collectively responsible for the issuance of euro banknotes. In Germany, it is the Bundesbank's task to ensure the desired volume of euro cash is in circulation and that it is of high quality. This article examines the current demand for banknotes issued by the Bundesbank and discusses, in particular, the impact of the coronavirus crisis on German-issued banknotes in circulation – i.e. the cumulated net issuance of euro banknotes by the Bundesbank – in 2020 and 2021.[1] Observed developments will be analysed in this article, amongst other things, using a breakdown of banknote demand into the following components – foreign demand, domestic store of value and domestic transaction balance – as well as using a structural time series model for the circulation of €50 banknotes in Germany.

Euro banknotes in circulation

Monthly data

Sources: ECB and Bundesbank calculations.
Deutsche Bundesbank

Demand for euro banknotes issued by the Bundesbank until the onset of the coronavirus pandemic

Developments in the volume of euro banknotes in circulation over roughly the first 15 years are well documented in earlier articles.[2] This section aims to continue to describe these developments up until the end of 2019. At the end of January 2002, shortly after euro cash had been introduced, euro banknotes in circulation issued by the Eurosystem totalled €221 billion. By the end of December 2019, i.e. the last year-end figure before the pandemic, the volume of euro banknotes in circulation had grown to a total of roughly €1,293 billion (see the adjacent chart).[3] The cumulated net issuance of euro banknotes by the Bundesbank increased at a particularly rapid pace compared with total euro banknotes in circulation, growing from €73 billion to around €750 billion from the introduction of euro cash to the end of December 2019. The chart shows that, given otherwise similar developments, the growth rate of German-issued euro banknotes in circulation was usually above the corresponding growth rate for the Eurosystem. This growth differential is explained by the traditionally high foreign demand for euro banknotes issued by the Bundesbank.

Dynamic development of euro banknotes brought into circulation by the Bundesbank

1 The cumulated net issuance of euro banknotes by the Bundesbank corresponds to the arithmetical volume of banknotes in circulation, i.e. the sum of cash withdrawals from the Bundesbank less the sum of lodged banknotes. Euro banknotes issued by the Bundesbank are referred to below as German-issued euro banknotes. It should be noted in this context that these euro banknotes are not necessarily located in Germany and that a considerable part of them are, in fact, abroad.
2 For the period from the introduction of euro cash at the beginning of 2002 to the end of 2009, see Deutsche Bundesbank (2009a, 2011a). For the period from the start of 2010 to the end of 2017, see Deutsche Bundesbank (2018a).
3 This article focuses on developments in the volume of euro banknotes in circulation. At the end of December 2019, a total of 135.1 billion euro coins with a value of €30.0 billion were in circulation, of which – in arithmetical terms – 39.9 billion euro coins with a value of €9.1 billion had been issued by the Bundesbank. As the volume of euro coins in circulation is small in terms of value, growth in euro banknotes in circulation is also informative with regard to developments in the value of the demand for euro cash.

The share of domestic demand for German-issued euro banknotes has been growing for years, driven by demand as a store of value

As shown in the upper adjacent chart, it is estimated that, in terms of value, roughly 60% of German-issued euro banknotes in circulation were located abroad at the end of 2019: 40% outside the euro area and 20% elsewhere in the euro area. Thus, the estimated foreign demand totalled €445 billion at the end of 2019, €145 billion of which was accounted for by other euro area Member States and €300 billion by the rest of the world. Although the share of foreign demand for euro banknotes rose from 25% to roughly 70% between the end of 2004 and the end of 2013, it has been diminishing since then. Correspondingly, the share of domestic demand for German-issued euro banknotes in circulation has risen steadily from just under 30% at the end of 2013 to just over 40% at the end of 2019. This is due to the strong increase in the (estimated) domestic balances held as a store of value in this period (see the lower adjacent chart). The low opportunity costs of holding cash owing to persistently low interest rates are likely to have played a key role here.[4] For instance, the three-month EURIBOR rate declined from 0.33% in May 2014 to -0.01% in May 2015 and fell further to -0.4% by the end of 2019. The estimated transaction balance rose from around €50 billion to €60 billion from the end of 2013 to the end of 2019; however, its share in the volume of banknotes in circulation decreased from 11% to 8%.

Developments in euro banknotes in circulation during the coronavirus pandemic

Impact of the coronavirus pandemic on German-issued banknotes in circulation

The easiest way to show the impact of the outbreak of the pandemic in early 2020 on German-issued banknotes in circulation is by comparing net banknote issuance in the crisis years of 2020 and 2021 with that of 2019 – the last year before the onset of the crisis. We will subsequently also examine the lodgements of banknotes with and

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4 There is evidence of a statistically significant, negative relationship between domestic banknote demand in Germany and the generally prevailing interest rate level. See Deutsche Bundesbank (2019), Section 4.3.5.

Regional distribution of the euro banknotes issued by the Bundesbank
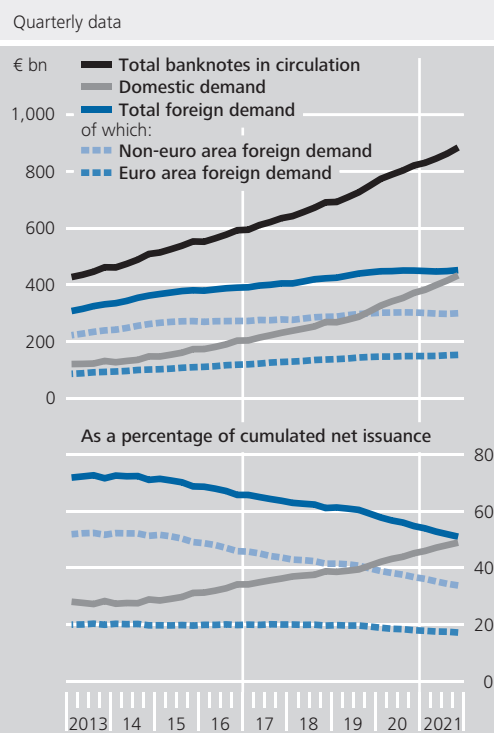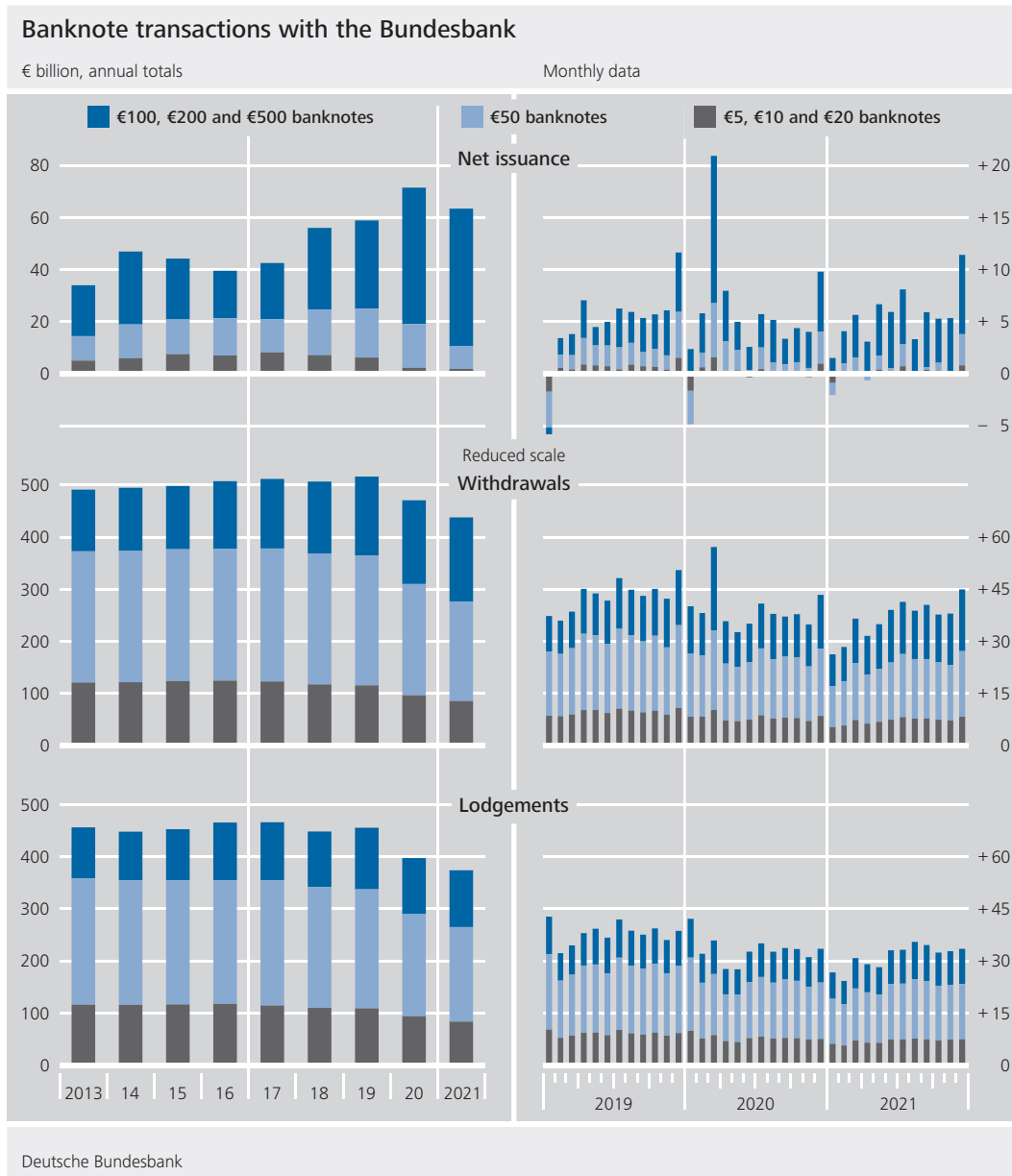
Quarterly data

Sources: Bartzsch, Rösl and Seitz (2011a) and Bundesbank calculations.
Deutsche Bundesbank

Domestic demand for the euro banknotes issued by the Bundesbank
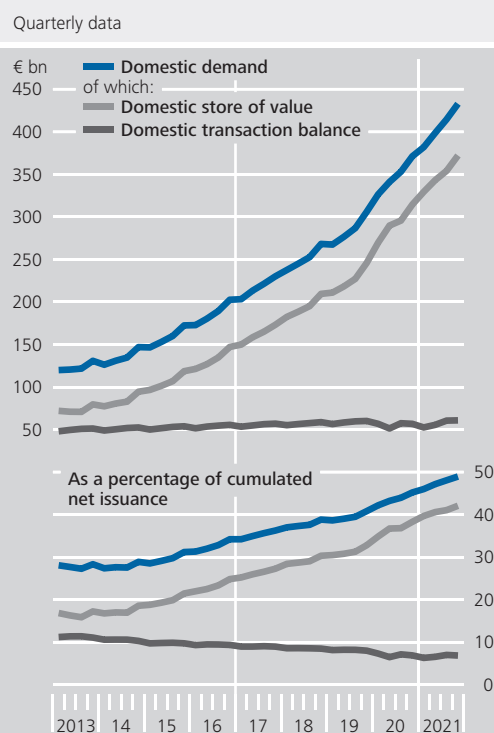
Quarterly data

Sources: Bartzsch, Rösl and Seitz (2011a and 2011b) and Bundesbank calculations.
Deutsche Bundesbank

Banknote transactions with the Bundesbank

Deutsche Bundesbank

withdrawals of banknotes from the Bundesbank, from which net issuance is derived. This comparison is even more meaningful as it distinguishes in each case between small-denomination banknotes (€5, €10 and €20 banknotes), the medium-denomination banknote (€50 banknote) and large-denomination banknotes (€100, €200 and €500 banknotes[5]). The denomination size sheds light on the use of banknotes. Small-denomination banknotes are typically used for transaction purposes and large-denomination banknotes as a store of value.[6] Demand for €50 banknotes stems from both of these motives. Net issuance in 2019, 2020 and 2021 is shown in the upper panel of the chart above.

Net issuance grew comparatively strongly in 2020, with the net issuance of €21 billion in March 2020 playing a key role in this context. The increase seen in March 2020 is largely attributable to €100 and €200 banknotes, even though the net issuance of other denominations

in that month also rose significantly. As an explanation for this, it stands to reason that consumers and professional cash handlers built up considerable cash holdings for precautionary reasons at the start of the first lockdown in March 2020.[7] For instance, at €48.1 billion, credit institutions' cash holdings were around 30% higher in March 2020 than in the previous year. Concerns regarding potential logistical restrictions on the supply of cash during lockdown were probably behind this precautionary motive. Precautionary savings became less important after it became apparent that the cash cycle worked during the pandemic, too. As the year progressed, developments were driven by cash holdings used as a store of value due to the lack of spending opportunities and supply difficulties as a result of the pandemic. By contrast, as from April 2020, the month in which the reduction of precautionary cash holdings began, net issuance of small denominations was below the previous year's figure. Looking at 2020 as a whole, net issuance of small-denomination banknotes was around 64% lower than the level seen in the previous year. This was due to the significant decline in the use of cash at the point of sale as a result of limited opportunities to spend cash – in retail, restaurants and at fairs, for example – owing to the pandemic. Nevertheless, almost 60% of everyday purchases were still made using cash in 2020.[8]

At €71 billion, the rise in banknotes in circulation in 2020 – the first year of the coronavirus pandemic – was around 21% higher than the figure for 2019 on balance. The increase in banknotes in circulation in 2021 – totalling around €63 billion – was weaker than in the previous year given weak growth in the net issuance of €50 banknotes, but was still just under 7% greater than the increase posted in 2019. Growth in the volume of small-denomination banknotes was also weak in 2021. The second lockdown between November 2020 and May 2021 is likely to have left its mark here.

Further insights are gained by looking at the withdrawals and lodgements of banknotes that underlie net issuance, as shown in the chart on p. 70 (middle and lower panels). First, it is noticeable that both withdrawals and lodgements were significantly lower in 2020 and 2021 than the prior-year figures.[9] This means that there was a contraction in the banknote cycle during the pandemic, owing to the considerable decline in cash spending by consumers as a result of the economic downturn.[10] This contraction can predominantly be seen in small denominations and the €50 banknote. This also points to a decline in the demand for banknotes for transaction purposes during the pandemic.

The sharp rise in net issuance in March 2020 was accompanied by a steep increase in withdrawals of large-denomination banknotes. During the two pandemic years of 2020 and 2021, withdrawals of large denominations exceeded the figures for 2019, whereas the corresponding figures for lodgements fell short. This suggests a rise in the demand for banknotes as a store of value during the pandemic.

Breakdown of banknote circulation into its components

In order to determine and quantify the impact of the pandemic more precisely, the circulation

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7 The first lockdown in response to the coronavirus crisis was between March and May 2020 and the second lockdown lasted from November 2020 to May 2021. From September 2021, varying degrees of restrictions on public life linked to vaccination status (known in Germany as the "3G", "2G" and "2G-Plus" rules) were in effect.
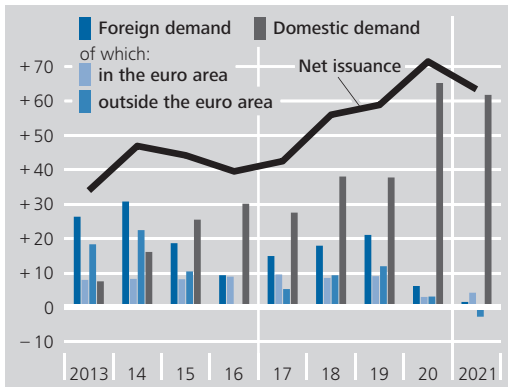**8** See Deutsche Bundesbank (2021a).
9 At around €58 billion, the decline in lodgements in 2020 was sharper than the decrease in withdrawals (around €46 billion). As a result, the rise in banknotes in circulation in 2020 was around €12 billion higher than that of 2019, as mentioned above.
10 The banknote cycle maps out the banknote payment flows between the Bundesbank, credit institutions, consumers and retailers. The Bundesbank issues banknotes to the banking system via its branches, which, in turn, makes the banknotes available to customers for withdrawal over the counter (OTC) or from ATMs. The banknotes are used by consumers for their cash spending at retailers (and elsewhere), and are then deposited at the Bundesbank's branches by retailers, either directly or via the commercial banks. The banknote cycle primarily reflects the active circulation of banknotes, i.e. the banknotes used to make payments at the point of sale. For further information on this topic, see the box on pp. 75 ff.

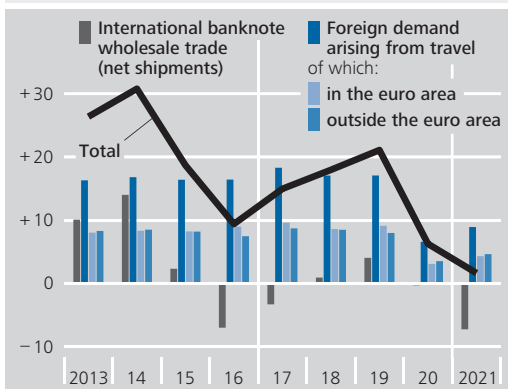## Regional components of the euro banknotes issued by the Bundesbank

€ billion, year-on-year change

Sources: Bartzsch, Rösl and Seitz (2011a) and Bundesbank calculations.
Deutsche Bundesbank

Foreign demand for the euro banknotes issued by the Bundesbank

€ billion, year-on-year change

Sources: Bartzsch, Rösl and Seitz (2011a) and Bundesbank calculations.
Deutsche Bundesbank

due to the extraordinarily sharp rise in the domestic demand for banknotes. The contribution of foreign demand was still positive, yet stood at a historically low level. To explain these developments, foreign demand and domestic demand are broken down into their components in even more granular fashion.

The estimated foreign demand consists of (net) deliveries of euro banknotes to non-euro area countries by international banknote wholesale traders (net shipments) and the direct net exports of euro banknotes via the travel sector.[11] As shown in the lower adjacent chart, foreign demand rose only slightly in 2020. At €6 billion, this increase was considerably lower than in previous years. While net outflows resulting from travellers taking banknotes between Germany and other countries were significantly weaker than in 2019 (albeit still positive), net shipments were even slightly negative in 2020. In 2021, net shipments fell by a considerable €7 billion; the slight rise in net outflows of banknotes from travel was unable to offset this decrease. Total foreign demand thus grew even more slowly in 2021 than in the preceding year. Overall, the growth in foreign demand decelerated significantly during the coronavirus pandemic. The reason for this is likely to be the decline in travel caused by the coronavirus pandemic, with travellers exporting fewer banknotes from Germany and demand in international banknote wholesale trading falling as well.[12]

Weak growth in foreign demand for euro banknotes during the pandemic

Substantial rise in German-issued euro banknotes in circulation in 2020 due to exceptionally strong domestic demand for banknotes

of German-issued banknotes is broken down into its components below. Foreign demand is looked at with its sub-components "non-euro area foreign demand" and "euro area foreign demand", as is domestic demand with its sub-components "domestic transaction balance" and "domestic store of value". The estimated regional distribution can be seen in the upper chart on p. 69 and its year-on-year change is shown in the upper chart above. In 2020, the first year of the pandemic, the volume of German-issued euro banknotes in circulation rose more sharply than ever before, at around €71 billion, excluding the period in which euro cash was introduced in 2002. This was solely

11 See Bartzsch et al. (2011a), Section 3.1, and Deutsche Bundesbank (2011a). As international banknote wholesale traders obtain euro banknotes from the Bundesbank, net shipments are taken from the Bundesbank's accounts. The net exports of euro banknotes via the travel sector are recorded regularly by the Bundesbank when it compiles the balance of payments statistics.
12 Travel is a substantial reason behind demand in international banknote wholesale trade as the latter supplies, inter alia, bureaux de change with banknotes for use in tourism. In periods of economic uncertainty abroad, the motive to use cash as a store of value also plays a key role, as seen, for example, when net shipments rose sharply during the escalation of the financial crisis in the fourth quarter of 2008.

Sharp increase in domestic demand for euro banknotes in 2020 and 2021 almost exclusively due to demand for store-of-value purposes

The domestic demand for banknotes consists of the transaction balances for the purposes of consumer spending[13] and the balances held as a store of value.[14] The estimates of both of these components are shown in the lower chart on p. 69 and their year-on-year change is depicted in the adjacent chart. They illustrate that the strong domestic demand for banknotes since the outbreak of the coronavirus pandemic has been almost exclusively due to the store-of-value motive. Standing at approximately €70 billion, domestic store of value grew as strongly in 2020 as in the two preceding years combined. This is by far the biggest increase since the introduction of euro cash.[15] Domestic store of value likewise increased substantially in 2021, the second year of the pandemic, albeit not to the same extent as in 2020. This sharp rise in the store of value was due mainly to the restrictions on opportunities for spending on account of the measures adopted to contain the pandemic. This led to the household saving rate experiencing an exceptionally strong rise from 10.8% in 2019 to 16.1% in 2020 and remaining at a high level in 2021 as well, at 15.0%.[16] It is also likely that the persistent low interest rate environment has continued to play a role.[17]

Weak development in the domestic demand for banknotes for transaction purposes during the coronavirus crisis

After the estimated domestic transaction balances had risen prior to the coronavirus crisis from just over €40 billion at the end of 2002 to €60 billion at the end of 2019, they are estimated to have fallen by around €3 billion in 2020. This decline followed directly on from the slump in private consumption expenditure. As this recovered in 2021, transaction balances contributed positively to the growth in domestic demand once more, as was typical before the pandemic.

Amplified trend during coronavirus pandemic of circulation of German-issued banknotes increasingly driven by domestic demand for store-of-value purposes

On the whole, the trend outlined at the beginning of this article of the growing importance of domestic store of value for the dynamics of banknote circulation has been amplified during the pandemic. As shown in the table on p. 74, cash held as a store of value now makes up a share estimated to be just over 40% of the Bundesbank's total cumulated net issuance.

Domestic demand for the euro banknotes issued by the Bundesbank

€ billion, year-on-year change
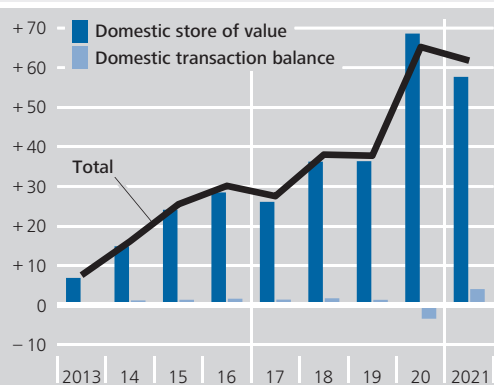
Sources: Bartzsch, Rösl and Seitz (2011a) and Bundesbank calculations.
Deutsche Bundesbank

13 The estimation of the transaction balances is based on the estimated starting balance at the beginning of 2002 derived from the growth of D-Mark and euro banknotes in Germany during the introduction of euro cash. This starting balance was then extrapolated using the growth rate of nominal private consumption expenditure; see Bartzsch et al. (2011b), Section 2.2.6.
14 Domestic store of value is determined by deducting the estimated foreign demand and the estimated domestic transaction balance from the total number of banknotes in circulation. For simplicity, this residual is referred to here as domestic store of value rather than domestic non-transaction balances. It comprises all banknote stocks that have not been destined for transactions or cash spending. Besides the stocks held as a store of value, this also includes precautionary cash holdings, cash held by banks to avoid negative interest rates and lost banknotes. Precautionary cash holdings are used as provisions for unforeseen opportunities for spending and unforeseen bottlenecks in the availability of cash.
15 Domestic store of value stood on average at around €70 billion in the period from 2003 to 2013, peaking at €80 billion. This long period of sideways movement was followed by a phase of strong growth starting in 2014 and lasting up to the present day. In the period from the start of 2014 until the end of 2019, store of value increased from just under €80 billion to around €245 billion. Average annual growth stood at €28 billion over this period.
16 The household saving rate is defined in the financial accounts as disposable income not used for consumption over total disposable income. Changes in households' cash holdings are part of their acquisition of financial assets or savings and thus influence their saving rate. According to financial accounts data, the share of cash in households' total acquisition of financial assets in 2020 (amounting to €388 billion) was 15.7%. In the same year, households' financial assets stood at €6,950 billion and the share of cash in these assets was 4.7%. See Deutsche Bundesbank (2021b).
17 There is evidence of a statistically significant, negative relationship between domestic banknote demand in Germany and the generally prevailing interest rate level. See Deutsche Bundesbank (2019), Section 4.3.5.

Estimated values of the components of the circulation of German-issued banknotes at the end of Q4 2021

Component	€ billion	Percentage share of total banknotes in circulation
Total foreign demand (estimated)	451	51
of which in the euro area	152	17
of which outside the euro area	299	34
Total domestic demand (estimated)	433	49
of which transaction balance	61	7
of which store of value	372	42
Banknotes in circulation (cumulated net issuance)	884	100

Sources: Bartzsch, Rösl and Seitz (2011a and 2011b) and Bundesbank calculations.

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Total domestic demand makes up just under 50%. The box on pp. 75 ff. shows that domestic transaction balances are turned over multiple times within a year and therefore finance a substantially higher volume of cash consumption. The importance of domestic transaction balances is thus considerably greater than their small share of just 7% in banknote circulation would suggest. Around 50% of banknotes in circulation are abroad, the majority outside the euro area.

Time series analyses using the circulation of €50 banknotes as an example

Structural time series model to describe and explain banknote circulation using €50 banknotes as an example

In addition to breaking it down into components, banknote circulation can also be studied using methods for time series analysis. These allow the determinants of banknote circulation to be identified and for banknote circulation to be projected as well. This is demonstrated below using an example of what is known as a structural time series model, which was developed to project the number of €50 banknotes in circulation issued by the Bundesbank for banknote requirement planning purposes.[18] This banknote denomination is particularly suitable for observation as it is sought after for both transaction and store-of-value purposes.

As shown below, it is therefore influenced by a large number of explanatory variables. Structural time series models break down a time series into its unobservable statistical components such as trend and season. As in regression models, explanatory variables can also be incorporated. The model set up for the circulation of €50 banknotes is outlined in the box on pp. 78 f. The result of the maximum likelihood estimation for the estimation period from January 2002 to September 2020 is summarised in the table on p. 79.

Trend is most important component in circulation of German-issued €50 banknotes; since 2010 increasing trend growth

The outcome of the estimation is satisfactory. Most effects are highly significant and the model is able to explain 74% of the variation in the circulation of the €50 banknote. The residuals are homoscedastic and normally distributed; some higher lags, however, exhibit serial correlation. The estimations are shown in the chart on p. 80. In the uppermost subchart, the actual circulation of the €50 banknote is compared to the estimated sum of trend, regression effect and intervention effects. The trajectory of the time series is well-replicated. The seasonal peaks in December are captured by the seasonal effects shown separately in the fourth subchart from the top. A deterministic seasonal pattern was identified, meaning that the seasonal pattern is the same every year. The seasonal high in December is explained by Christmas shopping, which leads to additional demand for €50 banknotes in December amounting to an estimated 62 million notes. The remaining deviations between the actual circulation of the €50 banknote and that estimated by the model are shown in the irregular component in the lowermost subchart. The regression effect in the fifth subchart from the top represents the calendar effect of the Easter holidays. In most years, these fall in the same month, which is reflected in sharp fluctuations

18 Structural time series models constitute a general class of time series models; see Harvey (1989) and Commandeur and Koopman (2007). This model class also includes ARIMA models as special cases. ARIMA models describe the current observation of the variable of interest as the weighted sum of its lagged realisations and an unobservable random shock.

Domestic transaction balances of banknotes and cash consumption

According to the estimates outlined here, the majority of the demand for banknotes issued by the Bundesbank is attributable to the high domestic demand for banknotes for use as a store of value as well as the strong foreign demand. In absolute terms, domestic transaction balances had also been trending upwards before the outbreak of the coronavirus crisis, growing from just over €40 billion at the end of 2002 to €60 billion at the end of 2019. Despite this rise – which was temporarily interrupted in 2020 during the coronavirus pandemic – only 7% of German-issued banknotes in circulation at the end of 2021 were held domestically for transaction purposes, i.e. for paying for goods and services. This low share may seem surprising at first glance. However, it is explained by the fact that transaction balances are frequently turned over and thus relatively small balances are sufficient for funding cash expenditure for goods and services (cash consumption). Cash consumption is therefore the appropriate measure for determining the significance of the transaction motive. The relationship between transaction balances as a measure of cash holdings and cash consumption as a measure of cash flows is described by the following quantity equation:

Domestic transaction balances * velocity of circulation = household cash consumption.[1]

Domestic transaction balances are estimated as part of the decomposition of German-issued banknotes in circulation. They consist mainly of the transaction balances of households and the cash balances of credit institutions.[2] Credit institutions hold cash primarily to supply it to their customers, i.e. in a way, they represent external transaction balances of consumers.[3] Nevertheless, the sharp rise in credit institutions' cash holdings that began in 2016 is attributable to the fact that they have, in part, shifted liquid assets away from the deposit facility, which is remunerated at a negative interest rate, and towards banknotes. This is therefore a special monetary policy effect.

Households' cash consumption, i.e. consumer cash expenditure for goods and services, is a key metric of the cash cycle.[4] It is estimated by deducting the following items from households' domestic consumption expenditure:

– regular payments, such as for housing or electricity;

– card payments at the point of sale, excluding credit card payments in online trade;

– expenditure in traditional mail order and online trade.[5]

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1 The quantity equation (also transaction equation) provides information about the relationship between money and goods transactions within an economy. It is based on the assumption that all transactions are settled using a determinable money supply (in the form of coins, banknotes or book money). The quantity equation is defined as follows: $M * v = P * T$, or money supply * velocity of circulation = price level * transactions. The velocity of money circulation v denotes how frequently the money supply M is used to make payments within a given period.
2 See Bartzsch and Uhl (2017), Section 3.2. The estimated cash holdings of trade are thus negligibly small.
3 See Allen (1998).
4 See Deutsche Bundesbank (2011b).
5 The national accounts data on household final consumption expenditure in Germany are adjusted for regular payments based on our own estimations. The data on card payments at the point of sale are taken from the payment card statistics of PaySys Consultancy GmbH. The estimation of credit card payments in online trade is based on data from the payment card statistics of PaySys Consultancy GmbH and from the EHI Retail Institute. The data on expenditure in traditional mail order and online trade are from Bundesverband E-Commerce und Versandhandel Deutschland e.V. (bevh).

Households' cash expenditure and its determinants

€ billion

Households' domestic consumption expenditure[1]
Card payments at the point of sale[2]
Expenditure in traditional mail order and online trade
Cash expenditure

Year-on-year change

2009 10 11 12 13 14 15 16 17 18 19 20
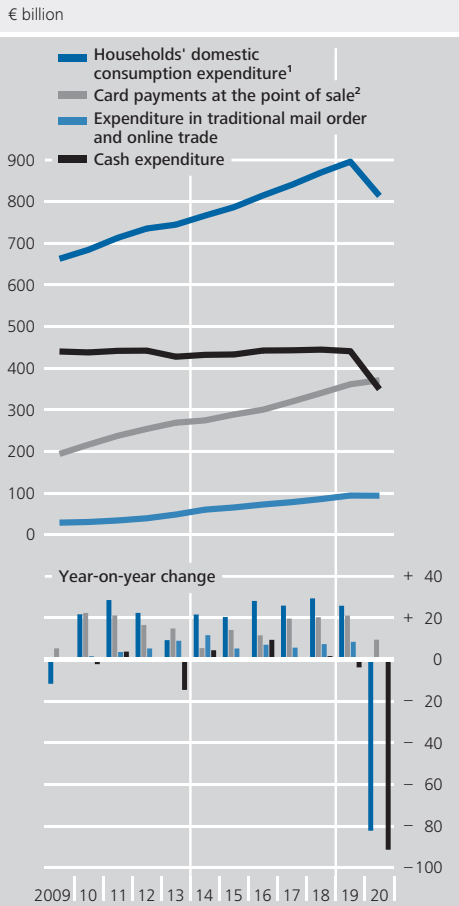
Sources: Bundesverband E-Commerce und Versandhandel Deutschland e. V. (bevh), EHI Retail Institute, PaySys Consultancy GmbH, Federal Statistical Office, and Bundesbank calculations. **1** Adjusted for regular payments. **2** Excluding credit card payments in online trade.

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The corresponding time series are depicted in the chart above.[6] Until 2019, estimated cash expenditure remained quite stable at around €440 billion, despite the increasing prevalence of card payments. The declining proportion of cash payments at the point of sale was thus compensated by rising consumption. In 2020, cash expenditure dropped sharply. The changes in the time series are shown in the lower part of the same chart. They show that, in 2020, adjusted household final consumption expenditure in Germany fell exceptionally sharply by just over €80 billion over the course of the pandemic-related economic downturn. Households' cash expenditure fell by an even larger amount, dropping by just over €90 billion. This difference is due to the increased use of card payments at the point of sale. This means that, during the pandemic, payment behaviour has changed away from cash.[7] In this context, consumers' hygiene concerns regarding the spread of the coronavirus also played a role.[8] By contrast, expenditure in online trade remained almost unchanged. This can be explained by opposite, counterbalancing developments in the trade of goods and services.[9]

According to the quantity equation described above, the ratio between cash consumption and domestic transaction balances corresponds to the circulation velocity of domestic transaction balances, which is depicted in the chart on p. 77. It has been experiencing a downward trend for a number of years, which has been reinforced further by the pandemic. In 2020, transaction balances saw a return frequency of only just over six. This phenomenon can also be described using the average rest or cash holding periods.[10] These are defined as the inverse of the circulation velocity and represent the average amount of time that the cash spends in holding. The average

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6 The data required to estimate cash expenditure in 2021 are not yet available.
7 This is also confirmed by survey data on payments in stationary retail trade from the EHI Retail Institute. According to these data, the share of cash turnover fell from 46.5% in 2019 to 40.9% in 2020; see EHI (2020) and EHI (2021).
8 The risk of spreading the coronavirus via banknotes and coins is very low, however. This has been confirmed by corresponding analyses conducted by the ECB; see Tamele et al. (2021).
9 See Bundesverband E-Commerce und Versandhandel e. V. (bevh) (2021). While sales of goods rose sharply from €72.6 billion to €83.3 billion (+14.6%), sales of services fell by roughly the same amount from €19.6 billion to €9.2 billion (-52.8%).
10 This is based on the Cambridge equation, which is derived directly from the quantity equation: $M = k * P * T$, or money supply = average cash rest period * price level * transactions, where $k = 1/v$.

duration of cash holding periods rose from 1.3 months in 2009 to 1.6 months in 2019. In 2020, it jumped to 1.9 months. One reason that households held cash for longer is that, due to the pandemic, consumers withdrew cash over the counter and from ATMs less frequently but in larger amounts.[11] However, at €510 billion, the total value of over-the-counter and ATM withdrawals in 2020 was €73 billion lower than its value from 2019 as a result of the decline in cash consumption.[12]

Circulation velocity of domestic transaction balances

Annual return frequency
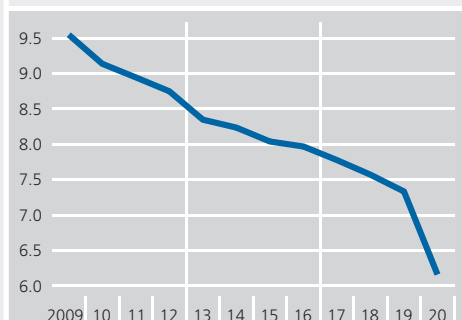
Sources: Bartzsch, Rösl and Seitz (2011b), Bundesverband E-Commerce und Versandhandel Deutschland e. V. (bevh), EHI Retail Institute, PaySys Consultancy GmbH, Federal Statistical Office, and Bundesbank calculations.

Deutsche Bundesbank

11 See Deutsche Bundesbank (2021c), tables 6b and 7b.
12 This decline is largely explained by the sharp drop in cash consumption of around €90 billion described above. In addition, net exports of banknotes in the context of travel in 2020 were €10 billion below their value from the preceding year. This €100 billion decline in demand for banknotes was only partially compensated by the higher domestic demand for banknotes for use as a store of value (around €70 billion in 2020 compared with around €35 billion in 2019).

in these months. In 2002, 2013 and 2018, parts of the long Easter weekend fell in both March and April, which is reflected in flatter peaks. According to the table, the size of the regression effect stands at around 13, meaning that, in the Easter months, the volume of €50 banknotes in circulation is 13 million notes higher than usual. This calendar effect is thus considerably smaller than the seasonal effect at Christmas. The largest component of the time series under consideration is its rising trend, the (local) level of which is shown in the second subchart from the top. This amounted to 4,600 million notes at the end of the estimation period in September 2020, with the total volume of €50 banknotes in circulation standing at 4,750 million notes. The (local) slope of the trend, i.e. the trend growth, is shown in the third subchart from the top and represents the direction of the trend. It exhibits exclusively positive values, which is reflected in the increase in the trend. Since September 2010, the

slope has tended to grow, which is reflected in the non-linear, ever steeper trend path.

While the underlying development in €50 banknotes in circulation is described using trend and season as unobservable components, the intervention variables capture special factors. The total (cumulated) effects of the intervention variables on the circulation of the €50 banknote are indicated in the second-to-last subchart from the top. The peaks shown reflect the estimated effects of outliers. These have an impact on banknote circulation only in the month in which they occur. In contrast to these temporary influences, the structural breaks, modelled via the intervention variables, exert a lasting influence on banknote circulation. For instance, the volume of €50 banknotes in circulation rose permanently in March 2002, shortly after the introduction of euro cash, by an estimated 29 million notes. This level shift was due to the replenishment of holdings used as a store of value following the

Various trend breaks in German-issued €50 banknotes in circulation, especially owing to crises

Structural time series model for €50 banknotes in circulation

We identify, as the structural time series model for €50 banknotes in circulation, a model augmented by a deterministic seasonal component with a local linear trend:

$$y_t = \mu_t + \gamma_t + \varepsilon_t, \qquad \varepsilon_t \sim NID(0, \sigma_\varepsilon^2), \quad t = 1, ..., n, \tag{1a}$$

$$\mu_t = \mu_{t-1} + \nu_{t-1} + \eta_t, \quad \eta_t \sim NID(0, \sigma_\eta^2), \quad t = 1, ..., n, \tag{2a}$$

$$\nu_t = \nu_{t-1} + \zeta_t, \qquad \zeta_t \sim NID(0, \sigma_\zeta^2), \quad t = 1, ..., n, \tag{2b}$$

where y_t denotes the observable time series of €50 banknotes in circulation, μ_t the trend, γ_t the seasonal component and ε_t the irregular component. μ_{t-1} is the local stochastic level and ν_{t-1} the local stochastic slope of the trend μ_t. ν_t follows a random walk and ε_t, η_t and ζ_t are mutually uncorrelated, independent and normally distributed disturbances with variances σ_ε^2, σ_η^2 and σ_ζ^2. The deterministic seasonal component γ_t follows the trigonometric seasonal form. Equation [1a] is the observation equation. Equations [2a] and [2b] are referred to as state equations and the whole model as a state-space model.

Additional "intervention variables" are added to the model in order to explain the time series. These variables represent special events which lead to outliers[1] and trend breaks.[2] Additionally, the calendar effect of the Easter holidays is modelled by means of a regression variable.[3] To do this, observation equation [1a] is augmented as follows:

$$y_t = \mu_t + \gamma_t + \beta x_t + \sum_{j=1}^{h} \lambda_j \omega_{j,t} + \varepsilon_t, \quad \varepsilon_t \sim NID(0, \sigma_\varepsilon^2), \quad t = 1, ..., n, \tag{1b}$$

where x_t denotes the dummy variable for the Easter holidays and $\omega_{j,t}$ represents the jth intervention variable. The intervention variables in equation [1b] comprise outliers and trend breaks in the local level. In the former case, these are impulse dummies

and, in the latter, step dummies. In order to also incorporate a trend break in the local slope, state equation [2b] is augmented accordingly:

$$\nu_t = \nu_{t-1} + \tilde{\lambda}\tilde{\omega}_t + \zeta_t, \quad \zeta_t \sim NID(0, \sigma_\zeta^2), \quad t = 1, ..., n, \tag{2c}$$

where $\tilde{\omega}_t$ is an impulse dummy variable. It takes on the value of one in the period in which the underlying event occurs and zero otherwise. The final structural time series model for (the number of) €50 banknotes in circulation thus consists of the observation equation [1b], the two state equations [2a] and [2c] and the state equations for the deterministic seasonal component, not shown here.

In order to estimate the model, the log-likelihood function is maximised regarding the unknown parameters, especially the variances σ_ε^2, σ_η^2 and σ_ζ^2. To do this, we apply the Kalman filter to calculate and minimise the forecast errors of the one-step forecasts of the observable time series and its variances.[4]

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1 An outlier is an unusually high value of the irregular component at a given point in time.
2 In a first step, the times at which potential intervention variables occur (e.g. October 2008) are identified using exceptionally high values of the residuals. In a second step, the identified potential intervention variables are interpreted as exceptional events (e.g. financial crisis).
3 The structural time series model presented here is a tool to create projections. We have therefore opted not to incorporate regression variables which model demand motives. For example, the transaction motive could be modelled by cash consumption and non-euro area foreign demand by the exchange rate. In section 4.3 of Deutsche Bundesbank (2019), such econometric models are estimated as ARDL models for the demand for small, medium-sized and large denominations as well as for the domestic demand for euro banknotes issued by the Bundesbank.
4 These forecast errors and their variances are also used to calculate the standardised forecast errors, based on which we examine whether the residuals of the state-space model are independent, homoscedastic and normally distributed.

cash changeover, which lasted until the end of 2003.[19] A further structural break occurred in October 2008 as a result of the escalation of the financial crisis, when demand for €50 banknotes saw a sustained rise of 45 million notes. In this period, liquid, secure assets for use as a store of value were sought after, which caused demand especially for large-denomination banknotes to grow steeply.[20] The next structural break, which took place in July 2015, caused a permanent increase in the number of €50 banknotes in circulation of 22 million notes. This was due to restrictions on withdrawals from ATMs in Greece, when the debt crisis there came to a head. At that time, the Greek government was deadlocked in heated negotiations with the European Commission, the rest of the euro area, the ECB and the International Monetary Fund about a further bailout programme in return for reform measures. As a result, German tourists took more €50 banknotes with them on their travels to Greece.[21] This additional demand was transaction-related. The next structural break is in connection with the ECB Governing Council's decision on 4 May 2016 to discontinue the production and issuance of the €500 banknote. This resulted in declines in these banknotes and shifts to the next smaller denominations all the way to the €50 banknote,[22] the circulation of which showed a sustained increase in June 2016 of 33 million notes. As can be identified in the chart on p. 80, the cumulated effects of the structural breaks on the level of the trend amounted to an estimated 130 million notes until June 2016.

In March 2020, at the beginning of the coronavirus pandemic, there was a further trend break in the local level, which, at 71 million notes, was considerably stronger than the other struc-

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19 See Deutsche Bundesbank (2011a). By contrast, the transaction balances of banknotes were already replenished shortly after the introduction of euro cash; see Bartzsch et al. (2011b), Section 2.2.6.
20 See Deutsche Bundesbank (2009b).
21 Such an effect was also observed for the €10 and €20 banknotes.
22 See Deutsche Bundesbank (2018b).

Estimation of a structural time series model for the circulation of the German-issued €50 banknote

In million notes

Item	Estimate
Trend:	
Local level	4,600.16***
Local slope	31.88***
Seasonal effects:	
February (seasonal low)	− 32.09***
December (seasonal high)	62.22***
Regression variable:	
Dummy variable for the Easter holidays	12.54***
Intervention variables in the form of trend breaks:	
Trend break in the local level in March 2002 due to the introduction of euro cash	29.10***
Trend break in the local level in October 2008 due to the financial crisis	45.23***
Trend break in the local level in July 2015 due to restrictions on withdrawals from ATMs in Greece (debt crisis)	22.43**
Trend break in the local level in June 2016 due to the end of production of the €500 banknote	32.96***
Trend break in the local level in March 2020 due to the coronavirus crisis	71.25***
Trend break in the local slope in May 2020 due to the coronavirus crisis	− 12.66***
Intervention variables in the form of outliers:	
December 2004	− 23.58***
December 2005	− 28.84**
December 2007	32.39***
December 2008	30.38***
December 2012	33.15***
March 2013	21.56***
May 2017	− 24.13***
March 2018	19.99***
Number of observations (January 2002-September 2020)	225
Log likelihood (in the case of convergence)	− 473.6
Variance of errors in the one-step forecasts	75.88
Goodness of fit for seasonal trending data, R_s^2	0.74
Test of the null hypothesis of normally distributed residuals using the Doornik-Hansen statistic	0.85
Test of the null hypothesis of homoscedastic residuals using the H(h)-statistic	1.37
Test of the null hypothesis of serially uncorrelated residuals for lag k using the Box-Ljung Q-statistic	Q(14)=24.11** Q(15)=24.15** Q(16)=24.15** Q(17)=24.45**

Notes: *** Significant at the 1% level. ** Significant at the 5% level. In terms of seasonal effects, only the seasonal high and the seasonal low are listed. The test for uncorrelated residuals was carried out for lags 1 to 24. Only those results for lags for which the null hypothesis is rejected are listed.

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Components of the circulation of the German-issued €50 banknote

In million notes, monthly data
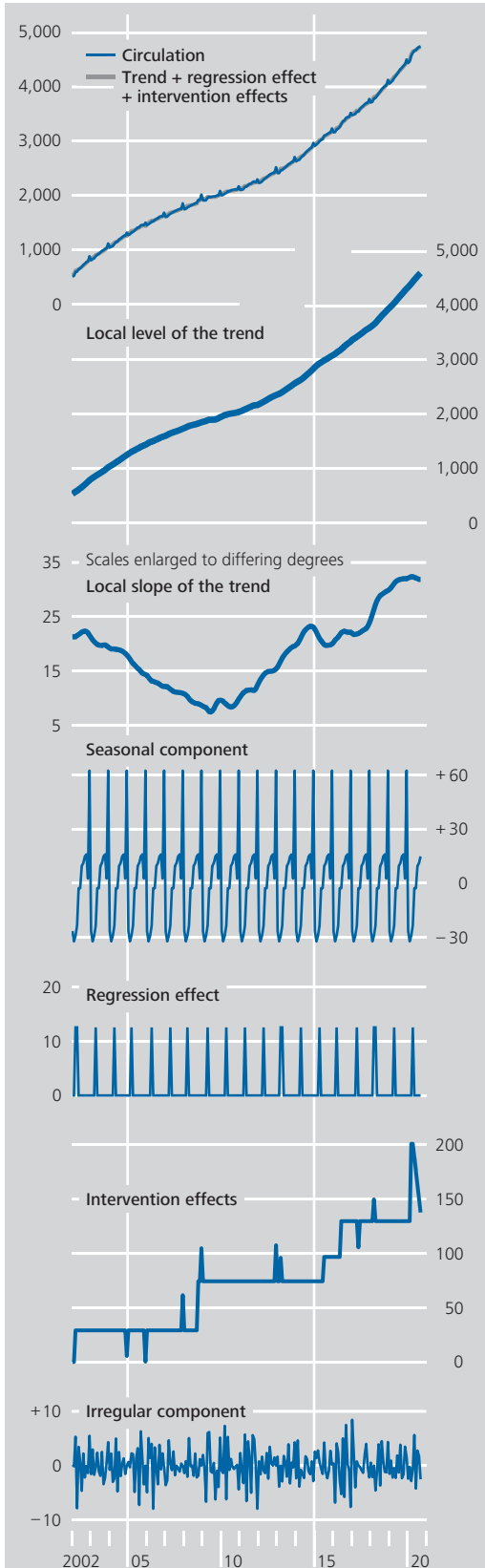
Deutsche Bundesbank

tural breaks. This was probably due to precautionary motives or concerns regarding potential logistical restrictions on the supply of cash. The precautionary holdings of €50 banknotes built up in March 2020 were reduced again in the subsequent months. This development is reflected in the model by the negative trend break in the local slope in May 2020, which has caused the trend to decline by around 13 million notes each month since. As the chart shows, the precautionary holdings of €50 banknotes built up in March 2020 had almost completely receded by the end of the estimation period in September 2020. A similar development was observed for the other banknote denominations during the pandemic.[23]

Demand for German-issued banknotes for precautionary purposes at beginning of pandemic reflected in two trend breaks

The structural time series model was estimated using data up to and including September 2020, and the circulation of €50 banknotes thereby projected over the period from October 2020 to September 2021. The outcome is shown together with the projection of the ARIMA model, which is traditionally used in banknote requirement planning, in the chart on p. 81.[24] We see that the projection using the structural time series model replicates the actual circulation of €50 banknotes well, and performs better than the ARIMA model. This is also reflected in measures of projection performance.[25] At the end of the projection period in September 2021, there were 4,937 million

Projected circulation of German-issued €50 banknotes during coronavirus crisis

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23 According to the structural time series models for the other denominations, there was a positive structural break in the level of the trend in March 2020. In April and May, a negative structural break in trend growth occurred, which resulted in the precautionary holdings of all denominations built up in March 2020 receding again by September 2020 at the latest. This process took longer for the large denominations than for the small banknotes, as it was obscured by the simultaneous build-up of cash reserves.
24 The ARIMA model used is an ARIMAX(1,1,0)(1,1,0)$_{12}$. The exogenous regressors X comprise step dummies for the financial crisis in October 2008 and the discontinuation of the issuance of €500 banknotes in Germany in April 2019. The effect of the coronavirus pandemic is modelled using impulse dummies for the months spanning the March 2020 to September 2020 period.
25 For instance, the root mean squared prediction error of the structural time series model, at 24.4, is significantly below that of the ARIMA model, at 67.8. The statistical informative value of this comparison is, however, limited by the short projection period of just 12 months.

€50 banknotes in circulation. This circulation is overestimated by both projection models, but significantly more so by the ARIMA model, with a projected 5,085 million notes, than by the structural time series model, with a projected 4,983 million notes.

Concluding remarks

Above-average increase in German-issued euro banknotes in circulation during pandemic almost exclusively due to domestic build-up of holdings as store of value

The volume of Bundesbank-issued euro banknotes in circulation continued to grow strongly in the wake of the coronavirus crisis and amounted to €884 billion at the end of 2021. Since 2015, domestic demand as a store of value has been the most important driver of demand for German-issued banknotes, while the dynamics previously stemmed from foreign demand. This development was lent further impetus by the coronavirus pandemic. The stronger-than-average rise in banknotes in circulation during this period was almost exclusively due the build-up of holdings for use as a store of value in the form of large-denomination banknotes. Increased demand for banknotes is a typical phenomenon in times of crisis, where people prefer to rely on tried and tested concepts and place their confidence in cash as default-free central bank money.[26] At the beginning of the coronavirus crisis in March 2020, this was likely to have been due to precautionary motives with regard to potential logistical restrictions on the supply of cash in lockdown. However, it quickly became apparent that the cash cycle worked and that the supply of cash was guaranteed at all times. The precautionary motive of banknote demand was therefore eclipsed by the store-of-value motive as a result of a lack of spending opportunities.

Developments during pandemic described here are global phenomenon

The developments described here are a global phenomenon.[27] In most other countries, the volume of banknotes in circulation grew strongly during the pandemic, although online

Projected circulation of the German-issued €50 banknote

In million notes

Deutsche Bundesbank
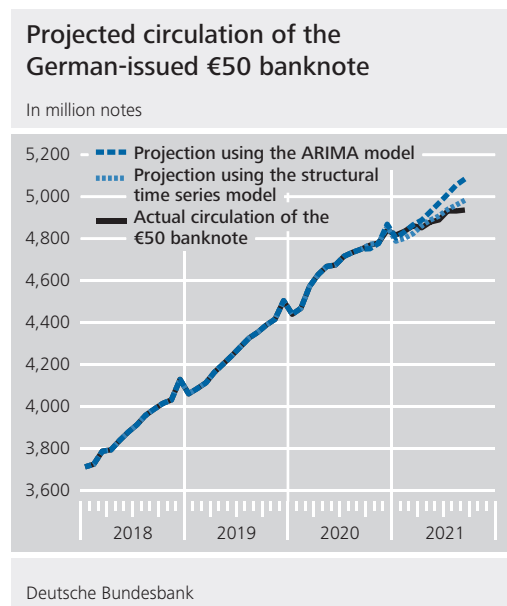
trade gained market share and consumers increasingly paid using cashless instruments in shops due to an – unfounded[28] – fear that the virus could be transmitted via banknotes. The holdings built up in the first few months of the pandemic can be explained by precautionary considerations. The increases declined in the ensuing period, though banknote demand remained at an elevated level internationally. The sharp rise in the volume of large-denomination banknotes in circulation indicates that this is a general increase in holdings used as a store of value, typical for crises. International developments thus also underscore the significance of cash as an indispensable anchor of confidence in times of crisis.

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26 Rösl and Seitz (2021) examine the demand for small and large-denomination banknotes since the 1990s from an international perspective. They show that the demand for cash grows in major crises, be they technological crises, financial market crises or natural disasters.
27 For more information, see Ashworth and Goodhart (2021). Their analysis is based on a dataset comprising almost 70 countries, accounting for 90% of global gross domestic product, including all 37 OECD countries. For the euro area, see also European Central Bank (2021) and Tamele et al. (2021).
28 Analyses conducted by the ECB show that the risk of the coronavirus spreading via banknotes and coins is very low; see Tamele et al. (2021).

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