

Rösl, Gerhard; Seitz, Franz

## Article

# Central Bank Digital Currency and Cash in the Euro Area: Current Developments and one Specific Proposal

Credit and Capital Markets – Kredit und Kapital

## Provided in Cooperation with:

Duncker & Humblot, Berlin

*Suggested Citation:* Rösl, Gerhard; Seitz, Franz (2022) : Central Bank Digital Currency and Cash in the Euro Area: Current Developments and one Specific Proposal, Credit and Capital Markets – Kredit und Kapital, ISSN 2199-1235, Duncker & Humblot, Berlin, Vol. 55, Iss. 4, pp. 523-551, <https://doi.org/10.3790/ccm.55.4.523>

This Version is available at:

<https://hdl.handle.net/10419/293946>

### Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

### Terms of use:

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*



<https://creativecommons.org/licenses/by/4.0/>

## Central Bank Digital Currency and Cash in the Euro Area: Current Developments and one Specific Proposal\*

Gerhard Rösl\*\* and Franz Seitz\*\*\*

### Abstract

The present paper provides an overview on current developments of cash usage and issue of central bank digital currency (CBDC) in the euro area and proposes a possible design of a digital euro that allows for instant offline payments. Cash usage at the point-of-sale decreased perceptibly in the past years mainly due to the ongoing trend towards digitalization. However, we show that there are also indications that consumers were somewhat pushed into cashless payments by government regulations and supply-side restrictions by commercial banks. Nonetheless, overall demand for euro cash remained strong and even increased relative to GDP since the financial crisis in 2008. In this process, however, we observe a supply-driven shift towards lower banknote denominations. Central banks all over the world are intensively thinking about the potential issue of CBDC as a substitute or complement to cash. Based on some of its preferred characteristics, we propose a double pre-paid scheme combining central elements of TARGET Instant Payment Settlement and electronic money features enabling offline and online instant payments. Since anonymity is categorically discarded by the ECB and as cash has some special advantages from a consumer perspective, the digital euro will rather co-circulate with cash than replace it in transactions.

*Keywords:* Cash, banknotes, money, CBDC

*JEL Classification:* E41, E51, E58

### I. Introduction

This paper provides an overview on the current role of cash (central bank physical currency) and the current discussion about Central Bank Digital Currency (CBDC) in Europe. With respect to the latter, we propose a novel and easy-to-implement double pre-paid design in the euro area which allows for

---

\* We thank an anonymous referee and the editor for helpful comments and suggestions.

\*\* Prof. Dr. Gerhard Rösl, Technical University of Applied Sciences (OTH) Regensburg, Seybothstrasse 2, D-93053 Regensburg, E-Mail: [gerhard.roesl@oth-regensburg.de](mailto:gerhard.roesl@oth-regensburg.de).

\*\*\* Prof. Dr. Franz Seitz, Technical University of Applied Sciences (OTH) Weiden, Hetzenrichter Weg 15, D-92637 Weiden, E-Mail: [f.seitz@oth-aw.de](mailto:f.seitz@oth-aw.de).

offline instant payments. The relationship between these two forms of central bank money is also discussed. Specifically, the paper explores the prospects of both types of money and asks if there is a possible replacement of cash by the digital euro or more likely a co-circulation.

As a starting point, the following chapter II categorizes different types of money which are currently recognized as official means of payment in the euro area including a possible future digital euro. Chapter III starts with surveying current government cash payment restrictions in the EU and analyzes several factors that might have contributed to the declining role of cash at the POS in the past decade. In contrast, total euro cash in circulation increased enormously during this period creating the so-called cash paradox (Zamora-Pérez 2021). It is well-known that this puzzle can be solved by taking non-transactional motives and store-of-value purposes for holding cash as well as foreign demand for euro banknotes into account (see, for instance, Deutsche Bundesbank 2022a). By investigating the denominational structure of cash, we show that the scope of this store-of-value function of euro banknotes has widened over time towards lower denominations. The declining use of cash for transactional purposes might eventually lead to a dominance of private payment solutions with a possible decrease in the level of competition in the payments market and higher transaction fees for money holders (Ahnert et al. 2022; Bindseil et al. 2021). This is one reason why monetary authorities around the globe are currently considering the issuance of CBDC (Kosse/Mattei 2022). The CBDC of the Eurosystem is still in its planning phase, but the principal shape of a future digital euro has become more perceptible recently. In section IV, our paper contributes to the current research on CBDC by showing how a digital euro might be put in circulation based on a suggested two-pillar approach consisting of the TARGET Instant Payment Settlement (TIPS) infrastructure for interbank payments complemented by e(lectronic)-money-type features to allow also for instant offline payments by nonbanks. Such a scheme rests upon a double pre-paid system and enables 24/7/365 instant online and offline payments. In addition, the paper raises the question of potential demand for a digital euro to outcompete cash as a transactional means of payment. Finally, chapter V summarizes and concludes.

## II. Categorization of Different Types of Money in the Euro Area

Table 1 shows different types of money which are currently circulating in the euro area as officially<sup>1</sup> recognized means of payment and how a future CBDC can be incorporated in such a scheme.

---

<sup>1</sup> Not all officially recognized means of payments have legal tender status.

Table 1  
Official Types of Money in the Euro Area

Category of money	Public-issued money			Private-issued money	
	Central bank money			Commercial bank money	E-money
Type of money					
Kind of money	Transferable accounts with the central bank	Central Bank Digital Currency	Banknotes	Transferable accounts with commercial banks	E-money
Issuer	Eurosysteem	Eurosysteem	Eurosysteem	Commercial banks of the euro area	E-money institutions of the euro area
Money holders	Commercial banks	Commercial banks/nonbanks	Nonbanks, commercial banks	Nonbanks	Nonbanks
Control of money supply by Eurosysteem	Yes	Yes	Yes	Only indirectly	Only indirectly
Resemblance to cash	No, but convertible into cash	Central bank issued “digital cash”	Physical cash	No, but convertible into cash	Private-issued “digital cash”
Volume (June 2022)	€ 4,046 bn	-	€ 1,603 bn	€ 10,037 bn	€ 19 bn (End of 2020)

Notes: Data from ECB statistical data warehouse (SDW).  
Source: Own table.

In the euro area, public-issued money in its various forms of central bank money and “government money” (coins) co-circulate with private-issued money comprising transferable accounts held by nonbanks with commercial banks and e-money. Central bank money in the euro area is issued by the Eurosystem, i. e., the European Central Bank (ECB) and the national central banks (NCBs) of all member states of the euro area. It provides demand deposits (reserves) to commercial banks<sup>2</sup> and has the monopoly on the issuance of euro banknotes.<sup>3</sup> The legal basis to issue CBDC by the Eurosystem depends on the design of the digital euro and the purpose for which it is issued, i. e., as wholesale CBDC for commercial banks only or as retail CBDC for the general public (ECB 2020a, 24). By contrast, the issuance of euro coins lies within the competence of the national governments of the euro area countries, but its volume is subject to approval by the ECB.<sup>4</sup> Coin holdings of NCBs are restricted by law to 10 % of total coins issued. Commercial banks are free to generate deposits for non-banks at their will as long as it is in line with general supervisory regulations.<sup>5</sup> The issuance of private e-money in the euro area is regulated in the European e-money directive (2009/110/EC). It requires that e-money is issued only on a pre-paid basis by regulated institutions<sup>6</sup> and can be used for payments only. Those schemes try to somewhat mimic cash as they promise instant payment without using commercial bank accounts (private-issued “digital cash”). E-payment schemes are currently only operational on a country level and cannot be used for cross-border payments in the euro area. The latest available figures on the outstanding volume of e-money in the euro area (€ 19bn) show, however, that the stored amounts are low and even less than total coins in circulation (see table 1).

---

<sup>2</sup> Some NCBs also provide accounts to nonbanks such as private households and enterprises, but only to a very limited extent.

<sup>3</sup> Since the introduction of euro banknotes in January 2002, all euro banknotes are brought into circulation solely by the NCBs. The ECB also has the right to issue banknotes but refrains from doing so. The item “banknotes in circulation” in the ECB’s balance sheet does therefore not reflect the actual net issuance of banknotes by the ECB. For details see (ECB 2022a, 28ff.) and the Decision of the European Central Bank on 13 December 2010 on the issue of euro banknotes (ECB/2010/29; 2011/67/EU).

<sup>4</sup> In addition, there are also agreements between the “micro-states” of Andorra, Monaco, Vatican City and San Marino with the ECB to issue euro coins. These countries are legally neither part of the EU nor the euro area.

<sup>5</sup> In practice, the Eurosystem controls the private money supply indirectly through its monetary policy instruments.

<sup>6</sup> Although the overriding majority of e-money in the euro area is issued by institutions owned by commercial banks, also non-financial institutions are allowed to put this type of money in circulation. Common ways of storing e-money for offline-payments are chips integrated in mobile phones or plastic cards and for online-payments also distant servers.

III. Cash Supply and Demand in the Euro Area

1. Anti-Cash-Cartel in the EU?

Since 2005, when MasterCard declared its “war on cash” (Adams 2006), also other major players of the FinTech industry, representatives from “law-and-order” and few economists (“alchemists”) started allegedly what the former board member of the ECB *Yves Mersch* once called an “anti-cash-cartel” (Mersch 2016). Its supposed members made suggestions to restrict the use of cash including upper limits and reporting obligations for cash payments, withdrawal of high banknote denominations from circulation or even the complete abolishment of cash. By such measures, it would be reportedly much easier to fight against corruption, tax evasion, drug trade, and financing terrorism (e.g., Rogoff 2016; Sands 2016). In addition, it should also be possible to break through the “effective lower bound” of the risk-free interest rate (Buiter/Rahbari 2015). Although these measures would come with disproportionate high economic and social costs (Rösl et al. 2019; Krüger/Seitz 2017), the EU Commission changed its former attitude and put forward proposals to limit the use of cash to € 10,000 per transaction (EU-Commission 2017). After the commissioning of a study on the effects of a harmonization of EU cash payments limits on illicit activities and the internal market, and a public consultation, the EU Commission stopped the beforementioned initiative (EU Commission 2018). However, in 2021, it again tried to back a possible harmonization of these limits under cover of the 6<sup>th</sup> Anti-Money-Laundering Directive. Although this harmonization is not yet in effect, national cash payment restrictions are already in place in 16 EU member states and the latest available data show a quite heterogenous picture (see table 2): Cash payment limits range from countries with no limitations (e.g., Austria) to quite low upper limits for cash usage of just € 500 per transaction (Greece).

Table 2  
National Cash Payment Limits in the EU

Euro area countries			
No cash payment restrictions		Cash payment restrictions (upper limits)	
Austria	No limits	Belgium	€ 3,000, for precious metals € 500
Cyprus	No limits	Greece	€ 500, no limits for buying cars
Estonia	No limits	Italy	€ 1,000
Finland	No limits	Latvia	€ 7,200

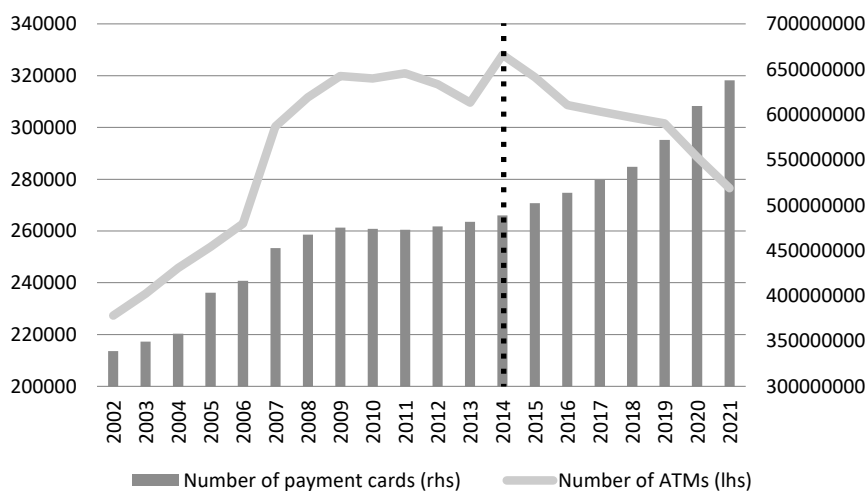
(continue next page)

(Table 2 continued)

Euro area countries			
No cash payment restrictions		Cash payment restrictions (upper limits)	
<b>France</b>	€ 1,000 for domestic taxpayers, € 3,000 for real estate purchases; € 10,000 for non-resident taxpayers acting as consumers; Taxes can be paid in cash up to a maximum of 300 euros	<b>Lithuania</b>	€ 3,000
<b>Germany</b>	No limits (except for anonymous gold purchases € 2,000). Report of origin mandatory for cash payment > € 10,000	<b>Portugal</b>	€ 3,000
<b>Ireland</b>	No limits	<b>Slovakia</b>	For private persons € 15,000, for enterprises € 5,000
<b>Luxemburg</b>	No limits	<b>Slovenia</b>	No limits for private persons, for enterprises € 5,000
<b>Malta</b>	No limits, except for precious metals and others metals, antiques, real estate etc. (limit of € 10,000)	<b>Spain</b>	For private persons € 10,000, for enterprises € 1,000
<b>Netherlands</b>	No limits		
Non euro area EU countries			
No cash payment restrictions		Cash payment restrictions	
<b>Sweden</b>	No limits	<b>Bulgaria</b>	LEW 10,000 (≈ € 5,100)
		<b>Croatia</b>	HRK 75,000 (≈ € 10,000)
		<b>Czech Republic</b>	CZK 270,000 (≈ € 10,500)
		<b>Denmark</b>	No limits for private persons, for enterprises DEK 20,000 (≈ € 2,700)
		<b>Hungary</b>	No limits for private persons, for enterprises HUF 1,500,000 (≈ € 5,000)
		<b>Poland</b>	No limits for private persons, for enterprises PLN 15,000 (≈ € 3,300)
		<b>Romania</b>	LEI 5,000 (≈ € 1,000)

Notes: As of mid-2022.

Source: European Consumer Centres Network (ECC-Net), various national websites.



Notes: Data for 2017 estimated by linear interpolation due to lack of data. Cards issued by resident PSPs, all cards except e-money function.

Source: ECB SDW.

Figure 1: Numbers of Payment Cards and ATMs in the Euro Area

Cash usage can also be limited by supply-side restrictions imposed by commercial banks which put banknotes in circulation on behalf of the central bank, nowadays mainly via Automated Teller Machines (ATMs). As shown in figure 1, the number of ATMs in the euro area decreased over the past 7 years by around 15% from its peak of 328,000 in 2014 to 277,000 in 2021 making the access to cash for the public increasingly more difficult.<sup>7</sup> Exactly at the same time, however, the issuance of payment cards by Payment Service Providers (PSPs) in the euro area went up immensely by 30% from 489 million in 2014 to 638 million units in 2021, equipping euro area residents with 1.9 cards per person in 2021.

This development might be supply- and/or demand-driven. As indicated by the dotted line in figure 1, the sudden break in both time series after an astounding phase of parallel movements from 2002 until 2014, however, seems to show that consumers were at least to some extent pushed into cashless payments by banks, as these not only made cards and mobile payments more attractive but also actively limited the access to cash by removing ATMs and closing branches. At any rate, the card payment infrastructure in the euro area has significantly improved over the past years as the number of POS terminals increased from 8.1 million in 2015 to 13.5 million in 2021. Moreover, the number of card pay-

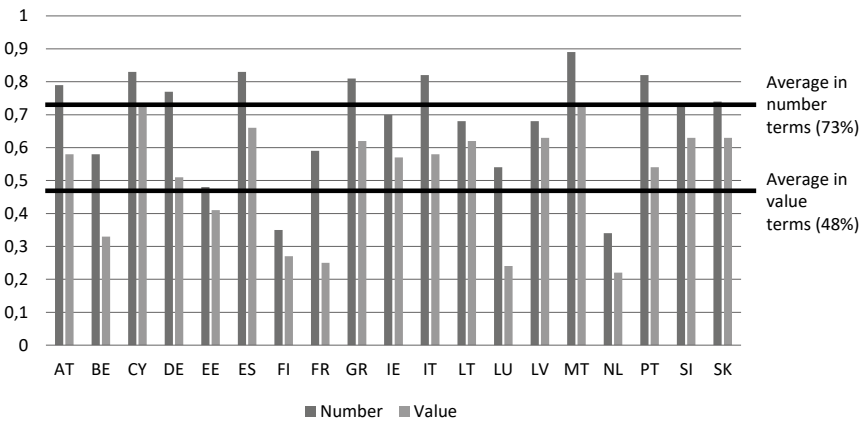
<sup>7</sup> Initiatives like Cash Back or Cash-in-Shop could only partly compensate the decrease in ATMs.



ments at the point of sale in the euro area increased during that period from 29.7 billion to 56.3 billion transactions showing a clear trend towards more intensive use of cashless payments in the euro area.<sup>8</sup>

2. Cash Usage at the Point of Sale

Despite government limitations on cash usage, possible supply-side restrictions for cash by commercial banks, and the provision of a better digital payment infrastructure, cash remains the most popular means of payment at the POS and for P2P transactions in the euro area. The results of the latest comprehensive household survey (SPACE) on the use of cash in the euro area (ECB 2020b) in 2019 show that consumers still prefer to pay in cash over card payments: 73 % of the volume of POS and P2P transactions was carried out using cash as a payment instrument. In value terms, cash transactions in 2019 accounted for 48 % of all transactions. On average, euro area residents made 1.6 transactions (at the POS and P2P) per day, with a corresponding transaction value of € 25.6. However, figure 2 demonstrates a considerable heterogeneity in the payment habits among the different euro area countries.

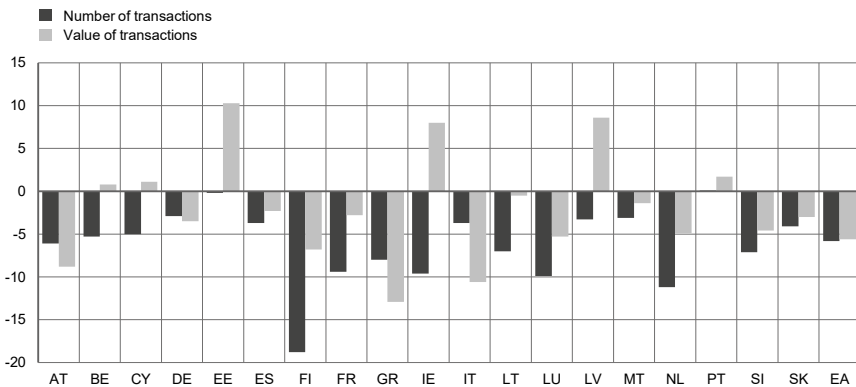


Notes: Data refer to 2019, except for Germany (2017). Recent German data for 2021 show a number share of 58 % and a value share of 30 % (Bundesbank, 2022b).

Source: Own figure, based on data from ECB, 2020b, 20.

Figure 2: Cash Payments – Share in Number and Value of Transactions

<sup>8</sup> See ECB SDW, payment statistics.



Notes: Differences between SUCH (2016) and SPACE (2019) results in percentage points.

Source: European Central Bank, 2020b, 21.

Figure 3: The Evolution of Cash Transactions in Euro Area Countries

In tendency, southern European countries (see, for instance, Malta, Spain, and Italy) are using cash more often for payments than northern countries (see, for instance, Netherlands, Finland and Belgium). Germany – often cited for its alleged special preference for cash – is just in between.<sup>9</sup> In July 2020, the ECB initiated a further survey (IMPACT) in all euro area countries to analyze (inter alia) how the Covid pandemic affected cash demand: 40 % of the respondents replied that they have used less cash since the start of the pandemic, and almost 90 % of them stated that they would continue to pay less with cash (46 % certainly and 41 % probably) after the pandemic (ECB 2020b, 7). Indeed, studies on individual euro area member states clearly confirm the accelerated use of cashless payments since the start of the Covid pandemic (see, for instance, *Ardizzi et al. 2020*; *Deutsche Bundesbank 2022b*; *Jonker et al. 2022*; *Seitz et al. 2022*).

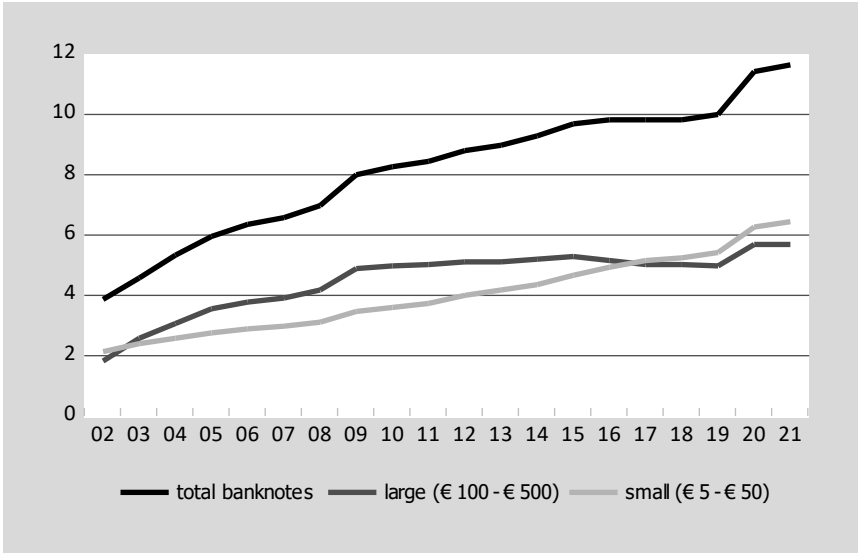
However, there was already a tendency towards cashless payments in most European countries long before the pandemic (*Boar/Wehrli 2021*, *ECB 2020b*). Due to lack of consistent survey data, however, a complete time series on cash usage for payments at the POS (and P2P) in the euro area is not available. Nonetheless, a comparison of the SUCH study in 2016 (*Esselink/Hernandez 2017*) with the SPACE survey in 2019 reveals that the declining use of cash as a transaction medium can be broadly confirmed. On average, cash usage for payments

<sup>9</sup> In effect, Germany ranked 7 in value terms and 12 in number terms of all 19 euro area countries in 2019.

in the euro area (EA) decreased between 2016 and 2019 in value and in number terms by just over 5 percentage points (see figure 3).<sup>10</sup>

3. Total Cash in Circulation

Nevertheless, euro cash remains still heavily in demand since its introduction in 2002. Of the total value of euro cash in circulation in June 2022 (€ 1,634.5 bn), 98 % are banknotes (€ 1,602.6 bn) and only 2 % coins (€ 31.9 bn). Figure 4 shows how total banknotes in circulation as well as its “small” (€ 5 – € 50) and “large” (€ 100 – € 500) denominational sub-groups evolve over time. Note that the time series are presented in percent of nominal GDP to implicitly account for inflation.



Notes: Small: € 5–€ 50, large: € 100–€ 500.

Source: Own figure. Data: ECB.

Figure 4: Total Banknotes in Circulation, Small and Large Denominations in % of Nominal GDP

<sup>10</sup> In volume terms there is a decrease in cash usage in every country (except for a very slight increase in Portugal) whereas in value terms this is generally not the case indicating that cash is substituted more and more by cashless payment media for low value payments.

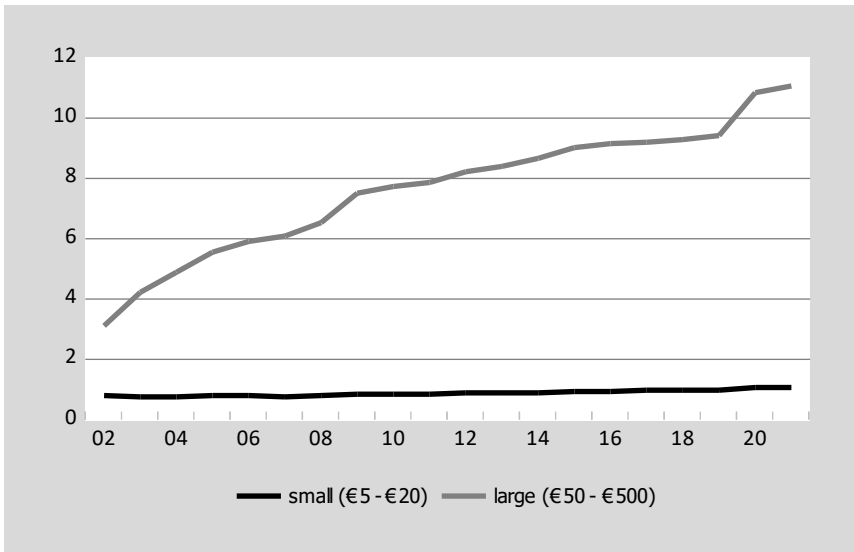
Total cash issued by the Eurosystem not only continued to increase strongly even after the effective end of the cash changeover phase around 2004,<sup>11</sup> it was also in high demand in times of crisis (Rösl/Seitz 2022a). Since central banks provide banknotes and coins in a perfectly elastic way, cash developments are predominantly demand driven. The underlying motives of holding cash can be principally separated into two categories: demand for transaction balances and non-transactional demand such as precautionary and savings motives emphasizing the store-of-value function of cash. Unfortunately, the relative importance of the different motives cannot be measured directly in practice. One indication, however, is the denominational structure of issued banknotes since “small” denominations (for instance € 5 – € 50) are usually used for payments and “large” ones (€ 100 – € 500) for other purposes (Amromin/Chakravorti 2009; Deutsche Bundesbank 2022a). At least on a global scale, there seems to be a clear tendency towards non-transactional use of cash over the past 30 years indicated by a comparatively higher growth of large banknote denominations than small ones even if accounted for a possible inflationary bias towards higher face values (see Rösl/Seitz 2022a). The denominational structure of the banknotes issued by the Eurosystem, however, might – at first glance – suggest that the supposed relationship may not hold for the euro area (see figure 4). In Figure 4 the definition of small euro banknote denominations follows the usual convention of those a bank customer typically gets from ATMs. Consequently, they comprise for most euro area countries the range from € 5 to € 50 and the remaining large denominations consist of € 100, € 200 and € 500 notes. The small denominations grew at a slightly higher pace than the large ones. In 2021, both are around 6 % of GDP (see figure 4). However, the € 50 banknote has a special role as it is usually the smallest denomination that is used as a store-of-value in addition to its transactional purpose (Deutsche Bundesbank 2022a). Since 2002, it increased more than tenfold. If we change our classification scheme and restrict small denominations from € 5 to € 20 notes only, the picture changes drastically (see figure 5).

In this case, the ratio of small denominations to nominal GDP in the euro area is extraordinarily stable around an average of around 0.9 % indicating its steady transactional use (Lalouette/Esselink 2018). By contrast, the larger denominations grew stronger than GDP and also reacted to macroeconomic crises like the outbreak of the financial crisis (2008) and the Corona pandemic (2020) perceptibly. Both facts seem to emphasize the store-of-value function of the so-defined larger denominations (€ 50 – € 500). It is also safe to assume that the higher the denomination within this spectrum,<sup>12</sup> the more dominant the store-

---

<sup>11</sup> The issuance of euro banknotes by the Deutsche Bundesbank reached its projected level of hypothetical DEM issuance end of 2003 (see Bartzsch et al. 2011, 2).

<sup>12</sup> Lalouette/Esselink (2018) even find some evidence of a non-transactional demand for € 20 banknote, but only to a minor extent.



Notes: Own calculations.

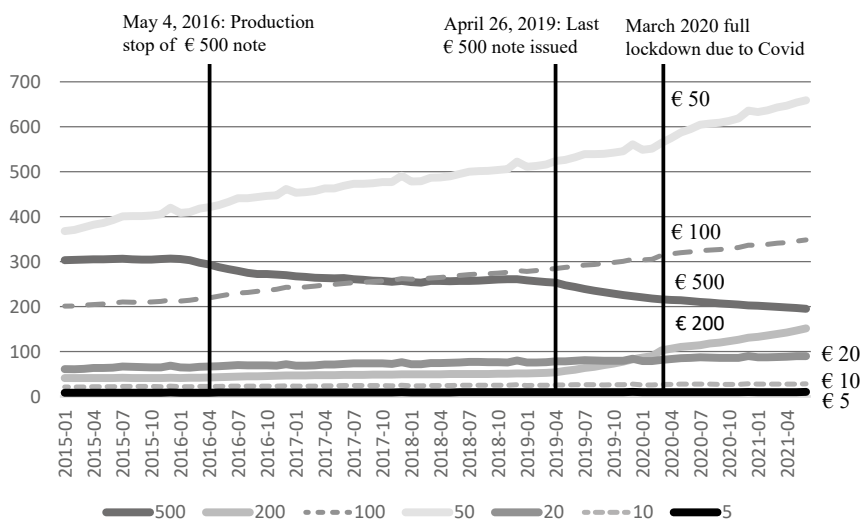
Source: ECB.

*Figure 5: Small (€ 5–€ 20) and Large (€ 50–€ 500) Euro Banknote Denominations in Circulation as % of Nominal GDP (2002–2021)*

of-value component in the demand for these banknotes becomes. Indeed, the payment survey (SPACE) on cash holdings in the euro area indicates that high-value payments (above € 100) accounted for only 3 % of all cash-based transactions (ECB 2020b, 30). Hence, it comes with no surprise that in an econometric analysis the demand for the two highest euro denominations reacts significantly during crisis periods (Rösl/Seitz 2022a). However, the same study also finds such evidence for small denominations if defined as the sum of € 5 – € 100. But the variance in this time series is driven by the € 50 and the € 100 notes (compare figures 4 and 5). As mentioned, the € 50 denomination can be interpreted as “hybrid” banknote which is used both for transaction purposes and as a store of value (Lalouette/Esselink 2018).

#### *4. Demand Shift towards Lower Denominations*

Indeed, an analysis of the denominational structure of euro banknotes indicates that the scope of the store-of-value function has shifted over time towards lower denominations. However, this development seems to be supply-driven: On May 4, 2016, the Governing Council of the ECB decided (ECB 2016) to dis-



Note: Own figure.

Source: ECB.

Figure 6: Development of Single Euro Banknote Denominations from 1/2015 – 1/2022 in € bn.

continue the production of the € 500 banknote, although it keeps its legal tender status and the remaining € 500 bills in the vaults of the NCBs were still to be issued (see figure 6).

Figure 6 exhibits that the denominational demand shifted away from the € 500 note to the € 50 and € 100 “hybrid” notes even slightly before the official announcement of the € 500 production stop when first rumours of this measure reached the public. Since the demand for the next lower large denomination, the € 200 bill, did not react at all in 2016, it seems that market participants viewed the ECB announcement only as a first step to withdraw also the € 200 note from circulation in the foreseeable future. This changed, however, after the last € 500 banknote was issued on April 26, 2019. The demand for the € 200 bill increased strongly afterwards as did both “hybrid” denominations (€ 50, € 100) before, especially when the economies of the euro area went into full lockdown in March 2020. Due to the lockdowns and shutdowns, the increased demand for the hybrid denominations cannot be attributed to transactional demand. As criminal activities also declined at that time (Nivette et al. 2021), there is also no reason to assume that there was an increase in transactional demand for those hybrid notes by the shadow economy.

### 5. Foreign Demand for Euro Banknotes

The enormous increase in the demand for the € 200 note since the last € 500 note was issued in spring 2019 was mainly from residents outside the euro area (Lalouette et al. 2021, 9). Consequently, an analysis of cash issued by the Eurosystem must take also foreign demand into account. Estimates show that the share of euro banknotes outside the euro area is between 30 % and 50 % of the total value of euro banknote circulation (Zamora-Pérez 2021). This implies that at the end of 2021 roughly between € 460 bn and € 730 bn of € 1,554 bn total banknotes issued were held by foreigners. Regarding the demand for single euro denominations, foreign demand concentrates mainly on the high denominations € 100 – € 500 (Rua 2021) although euro cash is also used partly as a medium of exchange in south-eastern European countries (Scheiber/Stern 2016; Scheiber/Stix 2009). In the euro area itself, only around 20 % of total cash in circulation is used for payments. Another 30 % – 50 % is used as a store-of-value by euro area residents (Zamora-Pérez 2021).

## IV. The Digital Euro: Supply and Demand Side Considerations

### 1. Characteristics of the Digital Euro

CBDC is a new type of digital money issued by central banks, denominated in the national unit of account and which represents a genuine liability of the central bank (Boar/Wehrli 2021).<sup>13</sup> It can be classified into two categories (Barontini/Holden 2019): “General purpose” or “retail CBDC” for the public (private households, firms, and even the government) and “wholesale CBDC” for commercial banks or other financial institutions only. In principle, both variants can be “token-based” using a Distributed Ledger Technology (DLT) to store information on a blockchain or “account-based” giving money holders access to ordinary central bank accounts. According to the latest survey by the Bank for International Settlements, 90 % of 80 surveyed central banks are currently engaged in CBDC work, mainly focusing on retail CBDC as a cash-like claim on the central bank, but where the private sector handles all customer-facing activities (Kosse/Mattei 2022).<sup>14</sup> In July 2021, the Governing Council of the ECB decided to formally launch a project for the possible issuance of a digital euro (ECB 2021b). After initially exploring possibilities for an anonymous CBDC (ECB 2019), an official report on a digital euro was published (ECB 2020a) and

<sup>13</sup> The motives for the introduction of CBDC are discussed in Ahnert et al. (2022).

<sup>14</sup> The first CBDC was issued as the “digital Sand Dollar” from the Bahamas in October 2020, and Nigeria followed with its eNaira in September 2021. For update information see <https://www.atlanticcouncil.org/cbdctracker/>.

later supplemented by a summary on key learnings from the discussion so far (ECB 2021a). Together with a variety of up-to-date speeches from ECB Board Members and additional information from the ECB website<sup>15</sup> the principal shape of a future digital euro has become more perceptible.

Although the ECB explicitly keeps all options open (including the termination of the whole project), the digital euro is obviously to be issued only as retail CBDC and its use is therefore restricted to nonbanks such as households and firms. Its purpose is to provide the public with some sort of “digital cash” with an instant payment function. It should not be used as a saving instrument (*Panetta* 2022b). For that reason and to avoid systemic risks that might occur from a possible flight into CBDC in times of (financial) crisis (*Brunnermeier/Niepert* 2019), individual holdings of digital euros will be either limited or indirectly restricted by tiered remuneration (*Bindseil et al.* 2021). From a legal perspective, the Eurosystem will probably issue the digital euro as a genuine central bank liability against nonbanks.<sup>16</sup> So-called indirect CBDC solutions (*Auer/Böhme* 2020, 89), in which financial intermediaries are the owners of CBDC accounts and handle retail payments for the central bank on their own accounts are obviously not being pursued any further.

Nonetheless, financial intermediaries will be given a crucial role in distributing the digital euro on behalf of the Eurosystem just like commercial banks currently provide the public with cash (*Panetta* 2022a). In addition, the digital euro shall get legal tender status and it will be convertible on a one-to-one basis to cash and other official means of payments in the euro area. The final decision to introduce the digital euro will not be taken before autumn 2023 (*Panetta* 2022c). Regarding the payment infrastructure of the digital euro, it is still unclear what solution (token- or account-based or even hybrid) the ECB might prefer. In a recent survey of stakeholders on what they might expect from a digital euro, the respondents emphasize the ability to “pay anywhere” and payments should also be instant, easy, and contactless (*Kantar Public* 2022), and the ECB is willing to meet these demands (*Panetta* 2022c). About the desired protection of personal data, however, the ECB unambiguously stated (see, for instance, *Panetta* 2022c) that complete anonymity regarding the digital euro will not be feasible due to legal requirements regarding anti-money laundering (AML) and combating the financing of terrorism (CFT). Hence, money holders will have to identify themselves when they start using the digital euro (“onboarding”) preferably at a supervised intermediary such as a commercial bank. With respect to the recording of transaction data, the Eurosystem seems to be satisfied with the minimum of

---

<sup>15</sup> See, for instance, the FAQ section on the digital euro on the ECB website, [https://www.ecb.europa.eu/paym/digital\\_euro/faqs/html/ecb.faq\\_digital\\_euro.en.html](https://www.ecb.europa.eu/paym/digital_euro/faqs/html/ecb.faq_digital_euro.en.html).

<sup>16</sup> See [https://www.ecb.europa.eu/paym/digital\\_euro/html/index.en.html](https://www.ecb.europa.eu/paym/digital_euro/html/index.en.html).



data that is needed to perform the payment, but financial intermediaries would have full access to ensure compliance with AML/CFT requirements (*Panetta 2022c*).

## 2. A Novel Double Pre-Paid Design for the Digital Euro

The decision by the ECB not to guarantee full anonymity in the use of the digital euro has severe strategic consequences. It effectively disbands the idea of creating a true digital equivalent to cash since anonymity is one of its fundamental characteristics (*Rösl/Seitz 2022b*). To guarantee broad acceptance (*Kantar Public 2022*), there is also a need for the whole system to work offline which implies that the digital euro will not be built on a DLT technology. Therefore, the ECB will probably choose an account-based payment scheme which has already shown its robustness in practice. *Bechtel/Otto-Schleicher (2021)* plead for using the TARGET Instant Payment Settlement (TIPS) infrastructure of the Eurosystem. However, due to its design characteristics, TIPS per se cannot process instant offline payments. Consequently, TIPS should be combined with a second payment scheme that enables the transfer of monetary value without being connected to a remote server in real-time.<sup>17</sup> Indeed, such a system already exists in the euro area in the form of e-money. In what follows, we show that such a two-pillar structure of a digital euro relying on TIPS and e-money features would also allow to integrate private financial institutions in a way envisaged by the ECB: Commercial banks and eligible PSPs should only act as intermediaries regarding the issuance of the digital euro but would play a crucial role in “know your customer” (KYC) and customer due diligence (CDD) checks as well as AML/CFT (*Panetta 2022a*).

### a) E-Money in the Euro Area

To demonstrate the basic functionality of such a payment scheme for the digital euro, we first recall – by example of e-money stored directly on chips embedded in decentral devices designed for offline-payments<sup>18</sup> – how this type of digital money is currently created in the euro area. As shown in figure 7a, four

<sup>17</sup> The ECB already stated in its press release on the launch of the digital euro project on July 14, 2021, that architectures (including TIPS) “combining centralized and decentralized elements are (...) possible.” (ECB 2021b).

<sup>18</sup> The ECB speaks of a “hardware-based” e-money scheme since both devices communicate offline with each other. By contrast, “software-based” e-money schemes need by definition a connection to a remote server that controls the use of the purchasing power (ECB 2000, 50).

a) **Creation of e-money:** Nonbank 1 gets e-money in exchange for deposits with its commercial bank 1

E-money institution		Central bank		Commercial bank 1		Nonbank 1	
A	L	A	L	A	L	A	L
+ Deposit with central bank	+ E-money held by nonbank 1		- Deposit of commercial bank 1 + Deposit of e-money institution	- Deposit with central bank	- Deposit of nonbank 1	- Deposit with commercial bank 1 + E-money	

b) **Use of e-money for payments:** Nonbank 1 buys a product from nonbank 2 and pays with e-money

Nonbank 1		Nonbank 2		E-money institution	
A	L	A	L	A	L
- E-money held by nonbank 1 + Product		+ E-money held by nonbank 2 - Product			- E-money held by nonbank 1 + E-money held by nonbank 2
				If transaction data reported	

c) **Destruction of e-money:** Nonbank 2 gives back e-money in exchange for deposits with its commercial bank 2

E-money institution		Central bank		Commercial bank 2		Nonbank 2	
A	L	A	L	A	L	A	L
- Deposit with central bank	- E-money held by nonbank 2		+ Deposit of commercial bank 2 - Deposit of e-money institution	+ Deposit with central bank	+ Deposit of nonbank 2	+ Deposit with commercial bank 2 - E-money held by nonbank 2	

Source: Own figure.

Figure 7: Creation, Use, and Destruction of E-Money

separate entities are involved hereby: e-money users (nonbanks), commercial banks, the central bank (system) and e-money issuing institutions.<sup>19</sup>

Assume, that nonbank 1 wants to store e-money on (a chip integrated in) a mobile phone, a plastic card, or any other data storage device for offline payments. In practice, the desired e-money is created at a designated terminal in form of a data set (representing a specific monetary value) which is directly stored on the corresponding chip (for instance, by magnetizing or other types of data transmission). Commercial bank 1 debits the deposit account of its customer accordingly<sup>20</sup> and makes a corresponding credit transfer in favor of the e-money institution using its funds with the central bank. As is obvious from figure 7a, commercial banks are actively involved in the process of e-money creation but act only as financial intermediaries. E-money itself, however, is created by a separate e-money institution which in turn receives central bank deposits from those commercial banks to which the e-money terminal is connected. The central bank settles the respective funds on its own accounts provided to both types of financial institutions (commercial banks and e-money institutions). Note, that e-money in the euro area is only allowed to be issued on a pre-paid basis (as required by the directive, 2009/110/EC). This implies that although more e-money is in circulation, the total money stock in the hands of the public (nonbank liquidity) does not change, only its composition is altered (less deposits with commercial banks and more e-money). From a monetary policy perspective, this is highly desirable.

Figure 7b shows in accounting terms what happens to the participants of the e-money scheme if e-money is spent offline by nonbanks assuming that nonbank 1 purchases a good from nonbank 2. E-money is transferred electronically by means of a device reader or via Bluetooth from the chip stored in the payment device of nonbank 1 to the chip in the payment device of nonbank 2. From the viewpoint of both nonbanks the payment is instantly and finally settled. However, as there is no real-time network connectivity to the server of the e-money institution, it cannot keep track of the e-money spending directly. In this regard, “hardware-based” e-money resembles very much cash. But since every data transaction leaves a trace, it would be at least technically possible to create a system where the e-money institution could identify every single payment once its server is connected to the storage devices (for instance at loading terminals or via a mandatory data transmission once a day). Hence, e-money – even if stored decentral – does not necessarily ensure anonymity. If tracked, the

<sup>19</sup> Note, that e-money systems can in principle also be created without the involvement of central banks. In the euro area, however, monetary authorities have to be included in the analysis since settlements between commercial banks and e-money institutions must be conducted in central bank money (Kovacs et al. 2014).

<sup>20</sup> E-money could, of course, also be created in exchange for cash at special terminals.

payment would lead to an accounting exchange on the liability side of the balance sheet of the e-money institution. Of course, e-money schemes can also be “software-based”. In that case, e-money is still stored in a decentral way, for instance on personal computers or smartphones, but transferring requires a special software (“client”) and – by definition of the ECB – connectivity to a remote server (ECB 2000, 50). Note that this remote server does not necessarily have to be the one of the e-money institution. If so, however, e-money payments in this case are very similar to credit transfers of commercial bank deposits.

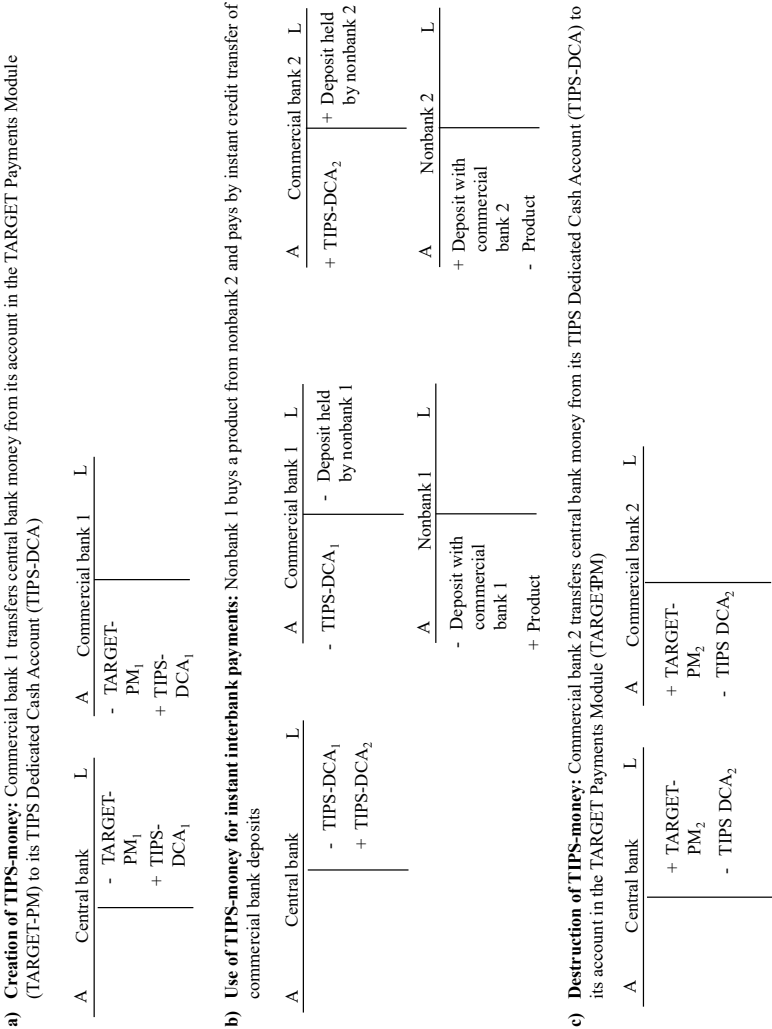
If an e-money holder, for instance nonbank 2 in figure 7c, prefers to give back its e-money in exchange for commercial bank deposits, e-money will be taken out of circulation and all the steps of e-money creation will be simply reversed. Again, this transaction leaves the total money stock in the economy constant.

### b) TARGET Instant Payment Settlement

The next step of our analysis demonstrates the basic features of the TARGET Instant Payment Settlement (TIPS) infrastructure of the Eurosystem. TIPS itself is part of the wider TARGET2 family comprising TARGET2, TARGET2-Securities, TARGET2/T2S consolidation and TIPS – building blocks of a euro area-wide payment and settlement system operated by the Eurosystem.<sup>21</sup> From a pure payment perspective, TARGET2 and TIPS are especially relevant. TARGET2 is the second generation of the Trans-European Automated Real-time Gross settlement Express Transfer system and is, roughly speaking, the “work horse” for standard payments based on central bank money in the euro area. The settlement in the TARGET scheme usually takes one day and the money used is stored at the corresponding Payments Module (PM). Consequently, we refer to this category of central bank book money as TARGET-PM deposits. By contrast, TIPS is reserved for instant payments only and is run on a separate platform. The associated accounts are officially called “Dedicated Cash Accounts” (DCA) although this term is somewhat misleading since there is no cash involved. The funds stored here are just another category of central bank book money (TIPS-money) and we denote the corresponding accounts as TIPS-DCA. Note, that TIPS currently works – just like e-money in the euro area – only on a pre-paid basis.

This means that commercial banks first have to transfer money from their TARGET-PM accounts to their TIPS-DCA before they can use it for instant payments (see figure 8a). The time to transfer funds from TARGET-PM accounts to TIPS-DCA is restricted to the opening hours of TARGET2, i.e., from 7 am to 9 pm CET, but instant payments using TIPS-money are then possible

<sup>21</sup> For more information see <https://www.bundesbank.de/en/tasks/payment-systems>.



Source: Own figure.

Figure 8: Creation, Use and Destruction of TIPS-Money

24/7/365. Assume again that nonbank 1 purchases a good from nonbank 2, this time, however, the payment shall be conducted by instant credit transfer of regular accounts at commercial banks – a possibility which is quite new to European consumers but gains momentum recently. Figure 8b shows how funds are now transferred in an almost instant fashion.<sup>22</sup> Interbank payments are conducted in TIPS-money, whereby the receiving bank credits and the sending bank debits its customer's account accordingly.

If the TIPS-money receiving bank 2 wants to reduce its TIPS balance afterwards (for instance, because of intended cash withdrawals which need to be settled with PM-accounts), it transfers money from its TIPS-DCA to its TARGET-PM account and “TIPS-money” is destroyed although total bank liquidity does, of course, not change (see figure 8c).

### c) The Digital Euro: Combining TIPS with E-Money

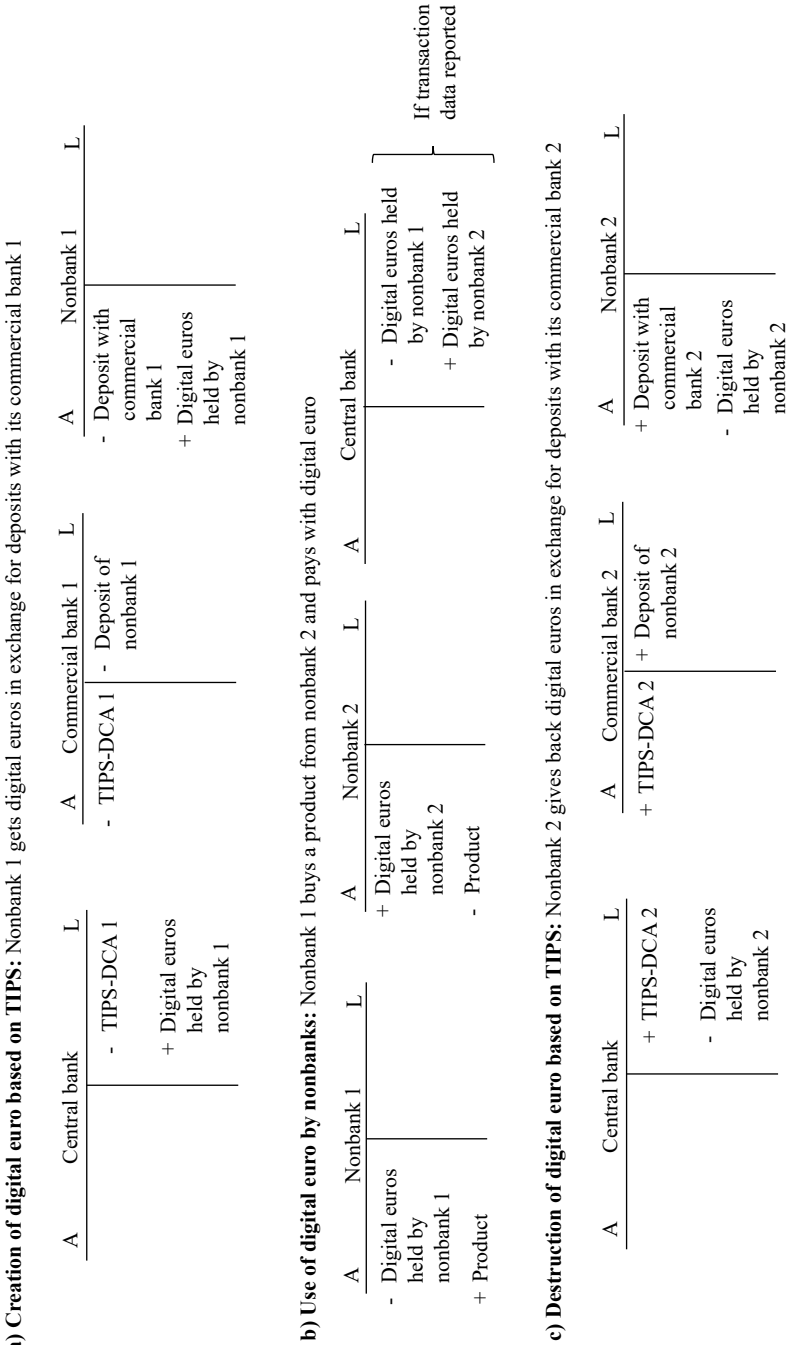
Since its introduction in late 2018, TIPS operates smoothly and reliably. It is therefore a natural candidate for the implementation of an account-based payment scheme for the digital euro. Figure 9a illustrates how a digital euro could be created within the TIPS infrastructure constituting a genuine CBDC.<sup>23</sup>

Analogous to the e-money scheme (compare figures 7a and 9a), two necessary preconditions for the creation of digital euro must be met: Firstly, nonbanks need deposits with their commercial banks in advance, and secondly, commercial banks need beforehand sufficient deposits (reserves) with the central bank (stored on TIPS-DCA) to fully cover the digital euro issued. In this double pre-paid system, commercial banks act indeed only as intermediaries in the process of digital euro issuance. As in the case of e-money, the issuance of a digital euro leaves the total money stock in the hands of nonbanks unchanged but increases afterwards in tendency the demand of commercial banks for additional central bank reserves. On top, payments in digital euro by nonbanks also take place outside the commercial banking system, as it was true for e-money. This comes with no surprise, however, since both types of money are in their nature digital currencies, only the issuer is different – either private or public (see table 1). Figure 9b also shows that payments in digital euro will be principally reflected in an accounting exchange on the liability side of the central bank if tracked accordingly. What would happen if a) the digital euro is only stored on mutually

---

<sup>22</sup> In practice, such a TIPS-based transaction takes only 10 seconds at most. In comparison, “normal” SEPA credit transfers working on the TARGET2 platform and therefore using TARGET-PM accounts need one working day until final settlement.

<sup>23</sup> It is an open question, how central banks' balance sheets in general have to and will adjust (on the liability and asset side) once CBDC is issued. See on this issue, for instance, *Hauser* (2022).



Source: Own figure.

Figure 9: Creation, Use and Destruction of Digital Euro based on TIPS Infrastructure

communicating storage devices used for offline payments (for instance, mobile phones connected via Bluetooth in the moment of payment at the POS or P2P), (b) no history of transaction data are created at the time of spending, and (c) no data transmission from these decentral devices to the TIPS server takes place except when the digital euro is either taken from or given back to the Eurosystem? Such a hypothetical scenario for a digital euro is comparable to banknotes (see chapter III): the Eurosystem knows exactly the volume issued, but it is not able to track single spending and does not know who holds which amounts and in which country. But since full anonymity for the digital euro is rejected by the ECB, we can safely assume that there will be some form of data tracking implemented in its payment scheme.

As in the case of e-money, the destruction of digital euro will be handled by commercial banks which take digital euro back on behalf of the Eurosystem at any time and pay by crediting its customers' accounts leaving nonbank liquidity again unchanged (see figure 9c). But with it comes an inflow of central bank money on TIPS-DCA increasing the liquidity of the commercial bank instantly.

The strengths of our proposed design for the digital euro are twofold. Firstly, it can be implemented on already existing and established payment infrastructures. Secondly, it allows – although still being completely electronic – offline instant payments which seems to be crucial from a user perspective. The disadvantage, though, is the lack of anonymity which is inherent to account-based payment schemes.

### *3. Cash and the Digital Euro: Coexistence or Replacement?*

Due to its intended lack of full anonymity, a digital euro will never be a perfect substitute to cash even if the underlying technology would change from an account-based system to a DLT/Blockchain technology. This raises the general question whether there will be sufficient demand for the digital euro. Obviously, this will depend strongly on its future design and is therefore hard to predict. But given the information currently available, there seems to be little interest in the new digital money by consumers who want to pay in an anonymous way. These people are very likely to continue using cash at least as long as supply-side restrictions by commercial banks and government limitations on cash usage (see chapter II) will not intensify. The Eurosystem as the central provider of cash in the euro area repeatedly emphasized that the digital euro shall not replace but complement cash.<sup>24</sup> And indeed, the expected design of a trackable digital euro seems to be the best way of protecting cash as long as the Eurosystem is willing

---

<sup>24</sup> See, for instance, the ECB's hub page on the digital euro, [https://www.ecb.europa.eu/paym/digital\\_euro/html/index.en.html](https://www.ecb.europa.eu/paym/digital_euro/html/index.en.html).



to provide it in sufficient quantities. For those consumers, however, who prefer to pay cashless, the digital euro might be a principal alternative to private digital payment solutions. Recent surveys, however, indicate that there is currently little need for a European CBDC, as respondents are generally satisfied with the existing (cash and cashless) payment options (see, for instance *Abramova et al. 2022*; *Deutsche Bundesbank 2021*; *Zamora-Pérez et al. 2022*).<sup>25</sup>

This might explain why the ECB recently changed its communication strategy from emphasizing the need for a digital euro because cash will allegedly lose importance at the POS anyhow to a more systemic approach. The digital euro is now officially supported as it safeguards the European payment infrastructure from influences of foreign card and private BigTech payment solutions (ECB 2022b; *Panetta 2022a*; b). Such an approach makes sense if it aims at increasing the level of competition in the European payments market. But finally, it will always be the cost-benefit-ratio for users that decides if a certain means of payment will be successful or not. Although the ECB could outcompete private payment solutions very easily, for instance by making access to TARGET2 and TIPS more expensive for interbank settlements or increasing regulatory requirements, the European monetary authority remains somewhat opaque in this respect: On the one hand, the digital euro should be attractive enough to be widely used but on the other hand it should not drive out private payment solutions and endanger financial market stability (*Panetta 2022a*). The reasoning behind this position is to provide with the digital euro a new form of central bank money that functions as a fallback solution in case confidence in private payment providers deteriorates and cash is not sufficiently in circulation anymore due to the overall trend towards digitalization.<sup>26</sup>

## V. Summary and Conclusions

To sum up, the declining role of cash as a medium of exchange will probably continue in the foreseeable future due to cash payment limitations, further possible supply-side restrictions by the banking system and the lasting trend towards digitalization. But it will presumably take decades (if ever) that cash will be nearly obsolete at the POS in the euro area given the fact that (in volume

---

<sup>25</sup> In countries with well-functioning private payment apps (like Swish in Sweden or Twint in Switzerland), this reasoning is even more convincing.

<sup>26</sup> Possible scenarios for bank intermediation are discussed in *Adalid et al. (2022)*. In this respect, *Keister/Monnet (2022)* offer two interesting arguments in favour of CBDC. Firstly, as banks do less maturity transformation when depositors have access to CBDC, they are less exposed to depositor runs. Secondly, monitoring the flow of funds into CBDC allows regulators to more quickly identify weak banks and take appropriate action.

terms) most retail purchases are currently still paid in cash. In addition, cash is far from being outdated as domestic and foreign residents continuously seek for euro banknotes as a highly liquid store of value. In fact, around 80 % of total euro cash in circulation is not used for domestic transactional purposes. In this regard, however, the observed demand shift towards lower banknote denominations over the past years will not likely be reversed as the ECB has decided not to include a € 500 note into its new banknote series. Anyway, the special characteristics of cash will guarantee sufficient demand in the foreseeable future.

The declining use of cash at the POS was initially one justification by the ECB for the possible issuance of a retail CBDC – the digital euro. Since the official launch of the digital euro project in July 2021, its future shape has become more and more perceptible although no final decision has been taken yet: The digital euro is intended to be a genuine retail CBDC, it should be accepted and used widely at POS in the euro area but not as a saving instrument. Its use will not be fully anonymous. And financial institutions such as commercial banks will act as intermediaries in the issuance and withdrawal of the digital euro from circulation.

But little is known about the technical functionality of the digital euro. Will it be account-based or based on the distributed ledger technology? We follow a suggestion to use a payment scheme based on the well-established TIPS infrastructure of the Eurosystem. But since this account-based system cannot process offline payments, it should be complemented by elements from e-money schemes. Our suggested and novel approach results in a double pre-paid payment scheme, where nonbanks pay in advance for digital euro as do commercial banks for funds used in TIPS to conduct payments to finally settle transactions in real-time within the financial sector initiated by the spending of digital euro.

It is very hard to predict what role a digital euro will play in the future payment markets. Our guess, however, is that there will be a co-circulation with cash in the coming decades. And if the trend towards cashless payments at the POS continues in the euro area, banknotes and coins will probably be substituted by already existing private payment solutions, such as mobile payments as well as debit and credit cards with increased limits for contactless payments, and not by the digital euro. Recall that the digital euro is very likely to be issued on a pre-paid basis in order to be neutral to total money supply in the euro area. But this makes the digital euro cumbersome and costly. The argument that the digital euro could have an advantage of credibility versus private money (ECB 2020a) seems, at least at the moment, not very relevant for ordinary citizens. From their point of view, there are obviously only two types of payments: cash and cashless – without reflection on the issuer (Deutsche Bundesbank 2021). Why change to another new type of cashless payment (i.e., the digital euro), if there are already convenient and well-proven alternatives such as payment cards

or mobile payment schemes? In the e-commerce markets, however, there might be a case for the digital euro, at least as long as the currently evolving instant payment schemes stay well behind their huge potential.

## References

- Abramova, S./Böhme, R./Elsinger, H./Stix, H./Summer, M. (2022): What can CBDC Designers Learn from Asking Potential Users? Results from a survey of Austrian residents, OeNB Working Paper, 241.
- Adalid, R./Álvarez-Blázquez, A./Assenmacher, K./Burlon, L./Dimou, M./López-Quiles, C./Fuentes, N. M./Meller, B./Muñoz, M. A./Radulova, P./Rodriguez d'Acra, C./Shakir, T./Šílová, G./Soons, O./Ventula Veghazy, A. (2022): Central Bank Digital Currency and Bank Intermediation: Exploring different approaches for assessing the effects of a digital euro on euro area banks, ECB Occasional Paper No 293, May.
- Adams, J. (2006): The War on Cash, European Card Review, March/April, 12 – 18.
- Ahnert, T./Assenmacher, K./Hoffmann, P./Leonello, A./Monnet, C./Porcellacchia, D. (2022): The Economics of Central Bank Digital Currency, ECB Working Paper Series, No 2713, August.
- Ahnert, T./Hoffmann, P./Monnet, C. (2022): The Digital Economy, Privacy, and CBDC, ECB Working Paper Series, No 2662, May.
- Amromin G./Chakravorti, S. (2009): Whither Loose Change? The Diminishing Demand for Small-Denomination Currency, Journal of Money, Credit and Banking, Vol. 41 (2–3), 315 – 335.
- Ardizzi, G./Nobili, A./Rocco, G. (2020): A Game Changer in Payment Habits: Evidence from daily data during a pandemic, Banca d'Italia, Occasional Paper, No 591, December.
- Auer, R./Böhme R. (2020): The Technology of Retail Central Bank Digital Currency, BIS Quarterly Review, March, 85 – 100.
- Barontini, C./Holden, H. (2019): Proceeding with Caution: A Survey on Central Bank Digital Currency, BIS Papers, No 101, February.
- Bartzsch, N./Rösl, G./Seitz, F. (2011): Foreign Demand for Euro Banknotes Issued in Germany: Estimation using direct approaches, Deutsche Bundesbank Discussion Paper, Series 1: Economic Studies (20/2011).
- Bechtel, A./Otto-Schleicher, D. (2021): Possible Characteristics of a TIPS-Based Digital Euro, EU Blockchain: Observatory and Form.
- Bindseil, U./Panetta, F./Terol, I. (2021): Central Bank Digital Currency: Functional scope, pricing and controls, ECB Occasional Paper No 286, December.
- Boar, C./Wehrli, A. (2021): Ready, Steady, Go? Results of the third BIS survey on central bank digital currency, BIS Papers, No 114, January.
- Brunnermeier, M. K./Niepelt, D. (2019): On the Equivalence of Private and Public Money, Journal of Monetary Economics, Vol. 106(C), 27 – 41.

- Buiter, W./Rahbari, E. (2015):* High Time to Get Low: Getting Rid of the Lower-bound on Nominal Interest Rates, Global Economics View, Citi Research, 9 April.
- Deutsche Bundesbank (2021):* What do Households in Germany Think about the Digital Euro? First results from surveys and interviews, Monthly report, October, 65–84.
- Deutsche Bundesbank (2022a):* Demand for Euro Banknotes issued by the Bundesbank: Current developments, Monthly Report, April, 67–83.
- Deutsche Bundesbank (2022b):* Payment Behaviour in Germany in 2021.
- Esselink, H./Hernandez, L. (2017):* The Use of Cash by Households in the Euro Area, ECB Occasional Paper No. 201, November.
- EU-Commission (2017):* Proposal for an EU Initiative on Restrictions on Payments in Cash, 23.1.2017, European Commission, Brussels.
- EU-Commission (2018):* Report from the Commission to the European Parliament and the Council on Restrictions on Payments in Cash, 12.6.2018.
- European Central Bank (2000):* Issues Arising from the Emergence of Electronic Money, Monthly Report, November, 49–60.
- European Central Bank (2016):* ECB Ends Production and Issuance of € 500 Banknote, press release, 4 May.
- European Central Bank (2019):* In Focus: Exploring anonymity in central bank digital currencies, No 4, December.
- European Central Bank (2020a):* Report on a Digital Euro, October.
- European Central Bank (2020b):* Study on the Payment Attitudes of Consumers in the Euro Area (SPACE), December.
- European Central Bank (2021a):* Digital Euro Experimentation Scope and Key Learnings.
- European Central Bank (2021b):* Eurosystem Launches Digital Euro Project, press release, 14 July 2021.
- European Central Bank (2022a):* Annual Accounts of the ECB for 2021.
- European Central Bank (2022b):* The Case for a Digital Euro: Key objectives and design considerations, July.
- Hauser, A. (2022):* Old Dogs, New Tricks: Adapting central bank balance sheets to a world of digital currencies, remarks given at Federal Reserve Bank of New York and Columbia SIPA workshop on ‘Monetary Policy Implementation and Digital Innovation’, 1 June 2022.
- Jonker, N./van der Cruijssen, C./Bijlsma, M./Bolt, W. (2022):* Pandemic Payment Patterns, Journal of Banking and Finance, Vol. 143, 106593.
- Kantar Public (2022):* Study on New Digital Payment Methods, Study commissioned by the European Central Bank, March.
- Keister, T./Monnet, C. (2022):* Central Bank Digital Currency: Stability and information, Study Center Gerzensee, Working Paper 22.03, May.
- Kosse, A./Mattei, I. (2022):* Gaining Momentum: Results of the 2021 BIS survey on central bank digital currencies, BIS Papers No. 125, May.

- Kovacs, S./Rieg, J./Welz, M. (2014): Internet Payment Methods: Regulatory requirements for payment services and the e-money business, Bundesanstalt für Finanzdienstleistungsaufsicht (BaFin).
- Krüger, M./Seitz, F. (2017): *The Benefits of Cash (Module 2)*, Fritz Knapp Publisher, Frankfurt/Main.
- Lalouette, L./Esselink, H. (2018): Trends and Developments in the Use of Euro Cash over the Past ten Years, European Central Bank, Economic Bulletin, Vol. 6, 87 – 109.
- Lalouette, L./Zamora-Pérez, A./Rusu, C./Bartzsch, N./Politronacci, E./Delmas, M./Rua, A./Brandi, M./Naksi, M. (2021): Foreign demand for euro banknotes, Occasional Paper Series, No. 253, European Central Bank, Frankfurt am Main, January.
- Mersch, Y. (2016): Bares bleibt Wahres, Gastbeitrag, Spiegel Online, 5 May 2016,
- Nivette, A./Zahnow, R./Aguilar R./Ahven, A./Amram, S./Ariel, B./Arosemena-Burbano, M. J./Baier, D./Bark, H.-M./Beijers, J. E. H./Ber, M. (2021): A Global Analysis of the Impact of COVID-19 stay-at-home Restrictions on Crime, Nature Human Behaviour, Vol. 5, 868 – 877.
- Panetta, F. (2022a): Bringing European Payments to the Next Stage: A public-private endeavour, Keynote speech at the European Payments Council's 20th anniversary conference, Frankfurt am Main, 16 June 2022.
- Panetta, F. (2022b): The Digital Euro and the Evolution of the Financial System. Introductory statement at the Committee on Economic and Monetary Affairs of the European Parliament, Brussels, 15 June.
- Panetta, F. (2022c): A Digital Euro that Serves the Needs of the Public: Striking the right balance, Introductory statement at the Committee on Economic and Monetary Affairs of the European Parliament, Brussels, 30 March.
- Rogoff, K. S. (2016): *The Curse of Cash*, Princeton University Press, Princeton and Oxford.
- Rösl, G./Seitz, F. (2022a): Cash Demand in Times of Crisis, *Journal of Payment Systems & Strategies*, Vol. 16(2).
- Rösl, G./Seitz, F. (2022b): On the Stabilizing Role of Cash for Societies, *IMFS Working Papers*, No. 167.
- Rösl, G./Seitz, F./Tödter, K.-H. (2019): The Cost of Overcoming the Zero Lower-Bound: A Welfare Analysis, *Economies* Vol. 7(67), 1 – 18.
- Rua, A. (2021): Modelling Currency Demand: The case of the euro, *Empirical Economics*, Vol. 61, 1865 – 1881.
- Sands, P. (2016): Making it Harder for the Bad Guys: The case for eliminating high denomination notes, m-rcbg Associate Working Paper Series No 52, Cambridge: Harvard Kennedy School.
- Scheiber, T./Stern, C. (2016): Currency Substitution in CESEE: Why do households prefer euro payments? Oesterreichische Nationalbank (ed.), Focus on European Economic Integration, No. 4, 73 – 98.

- Scheiber, T./Stix, H. (2009): Euroization in Central, Eastern and Southeastern Europe: New evidence on its extent and some evidence on its causes, Working Paper, No. 159, Oesterreichische Nationalbank.*
- Seitz, F./Devigne, L./de Pastor, R. (2022): Different Motives for Holding Cash in France: An Analysis of the Net Cash Issues of the Banque de France, Banque de France Working paper 888, October.*
- Zamora-Pérez, A. (2021): The Paradox of Banknotes: Understanding the demand for cash beyond transactional use, European Central Bank, Economic Bulletin 2/2021, 121 – 137.*
- Zamora-Pérez, A./Coschignano, E./Barreiro, L. (2022): Ensuring Adoption of Central Bank Digital Currencies – An easy task or a Gordian knot?, ECB Occasional Paper Series No 307, October.*