EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Claudia Lambert, Chloe Larkou, Cosimo Pancaro, Antonella Pellicani, Meri Sintonen

Digital euro demand: design, individuals' payment preferences and socioeconomic factors

No 2980

Abstract

By applying a structural demand model to unique consumer-level survey data from the euro area, we assess how different CBDC design options, combined with individual (revealed) preferences, influence the potential demand for a digital euro. Estimating the demand for a digital euro, we find that if it were unconstrained, it could range, in steady state, between 3-28% of household liquid assets or €0.12 - €1.11 trillion, depending on whether consumers would perceive the digital euro to be more cash-like or deposit-like. With an illustrative €3,000 holding limit per person, it could instead range between 2-9% or €0.10 - €0.38 trillion. Privacy, automatic funding, and instant settlement raise its potential demand.

Keywords: Central bank digital currency, demand estimation, structural model, design attributes

JEL Codes: E41, E50, E58

Non-technical summary

The digital transformation of payments has led to a general decline in physical cash payments, a trend which has been further accelerated by the COVID-19 pandemic. This shift in people's payment habits has, in turn, prompted central banks around the globe to explore the concept of issuing central bank digital currencies (CBDCs) as a new form of public money designed for retail payments. Like cash, a CBDC would be a central bank liability, but offered in a digital form. In the euro area, the Eurosystem is examining the possibility of issuing a CBDC, i.e., a digital euro. Importantly, the issuance of a digital euro is unlikely to increase the amount of central bank money in circulation in steady state. In fact, it is expected to be lower than today due to the progressive decline in the usage and demand for banknotes, coupled with the current digital euro design, which is intended to serve as a digital form of cash.

The potential demand for a digital euro is a key variable that will determine the economic implications of its introduction. Given that a digital euro would be a novel means of payment, demand is uncertain and challenging to predict. It will hinge, among other things, on its design features and how it compares to existing means of payment – in particular sight deposits and cash. To this end, our study aims to quantify answers to the following questions: How individual payment preferences can be used to estimate demand for digital euro? And more specifically, what range of holdings could be reasonably expected for a digital euro? How would different CBDC design choices affect the demand? How does the estimated demand vary with individual characteristics? By doing so, this study contributes to assessing the potential financial stability implications of a digital euro. Insights from this analysis can also be used to identify the features that are important for its attractiveness and the effectiveness of those that are designed to limit its use as a store of value.

In this study, we apply a structural demand model to consumer survey data for the euro area. The key idea of the used empirical strategy is to consider digital euro, cash, and sight deposits as sets of different product attributes. Based on how individuals allocate their liquid assets between cash and bank deposit, we can identify preferences towards the product attributes. Then, assuming that individuals' estimated preferences remain unchanged following the introduction of a digital euro, we can predict its demand. More specifically, by identifying individuals' revealed preferences for a wide range of design features and controlling for socio-demographic factors, we estimate the potential demand for a digital euro conditional on a set of design features as close as possible to those outlined by the ECB.

In order to empirically estimate the demand parameters, we use a dataset compiled from the following consumer surveys: i) The Study on the payment attitudes of consumer in the euro area (SPACE), ii) the Household Finance and Consumption Survey (HFCS), and iii) Payment behaviour in Germany in 2021. In the analysis, we consider 12 attributes, based on available data, including ease of use, security, transaction speed, anonymity/privacy, settlement speed, remuneration rate, acceptance rate, budgeting usefulness, online store capability, person-to-person (P2P), automatic funding, and contactless functionality.

The results indicate that if the demand were unconstrained, the estimated digital euro take-up could lie between 3% and 28% of total household liquid assets, which is equivalent to €0.12 trillion - €1.11 trillion, depending on whether consumers perceive digital euro to be closer to cash or deposits, respectively. We also show that with an illustrative €3,000 holding limit per person, the aggregate digital euro take-up could range between 2% and 9% of total household liquid assets in steady state. This can be translated into a total amount of digital euro in circulation ranging from €0.10 trillion to €0.38 trillion. To put this into perspective, the amount of euro banknotes in circulation was €1.57 trillion at the end of 2022. We also find that 80% of individuals would not be affected by the €3,000 limit, as their estimated digital euro holdings are less than this amount. Our findings suggest that important design attributes for the attractiveness of a digital euro include anonymity/privacy, automatic funding and instant settlement.

In an extension of the main analysis, we apply our framework to estimate the potential value of digital euro transactions relative to cash and existing digital payments, taking into account all use cases, including physical and online stores as well as transfers between individuals. In a steady state, the estimated digital euro payments could range from 25% to 44% of total retail transaction values, depending on whether individuals would perceive it to be a closer substitute for existing digital alternatives or cash, respectively. Overall, the more the digital euro is perceived to resemble cash by the public, the lower the estimated holdings and the higher the estimated transactions, and vice versa if the digital euro is perceived to more closely resemble deposits.

1 Introduction

The digital transformation of payments has led to a general decline in physical cash payments, a trend which has been further accelerated by the COVID-19 pandemic. This shift in payment habits has, in turn, prompted central banks around the globe to explore the concept of issuing central bank digital currencies (CBDCs) as a new form of public money designed for retail payments. Like cash, a CBDC would be a central bank liability, but offered in a digital form. In 2022, around 93% of central banks were investigating the possibility of introducing a CBDC (Kosse and Mattei, 2023).

In the euro area, the Eurosystem has examined the possibility of issuing a CBDC, henceforth a digital euro, and its potential design. On 18 October 2023, following the investigation phase of the digital euro project, the ECB decided to move to the preparation phase (ECB, 2023). While the actual decision on whether to issue a digital euro will be taken at a later stage, many of the likely design features have already been identified. Based on ECB (2023) and European Commission (2023), a digital euro would enable citizens to use central bank money for all kinds of digital payments throughout the euro area, free of charge for basic use and with a high level of privacy. As a complement to cash, it would ensure that public money can continue to serve as an anchor of the monetary system. Moreover, it would protect the strategic autonomy of European payments and strengthen the resilience of the currency union by filling the gap left by the lack of a pan-European electronic payment solution that is available and accepted across Europe (Panetta, 2022a).

While a digital euro would offer a wide range of benefits, it could also potentially have implications on monetary policy and financial stability, as individuals might choose to transfer funds from their commercial bank accounts to digital euro wallets.[1] Lower demand for commercial bank deposits could entail consequences for the banking sector credit provision, risk-taking, profitability and resilience (ECB, 2020). However, in order to prevent undesirable consequences, the ECB has emphasised that a digital euro would be designed as a means of payment and not as a form of investment (Panetta, 2023b). Specifically, to discourage its excessive use as a store of value, digital euro holdings would be limited, and they would not be remunerated. In addition, the so-called 'reverse waterfall' mechanism would allow users to link their digital euro account to a bank account, enabling them to make payments without necessarily holding any digital euros (ECB, 2023). However, the introduction of a digital euro is not anticipated to raise the total amount of central bank money in circulation in steady state. On the contrary, it is expected to decrease from current levels due to the ongoing reduction in the use and demand for physical banknotes. This trend is further supported by the current design of the digital euro, which aims to replicate the functions of cash in a digital format.

In this paper, we first assess how CBDC design, individuals' revealed payment preferences, and socioeconomic factors could affect digital euro demand, and then we estimate the potential demand for a digital euro. We

[1] In contrast to deposit substitution, cash substitution into digital euro would be neutral as it would simply constitute a change in the type of central bank money held by the public. The ECB's preliminary analyses have shown that imposing, for example, a €3,000 holding limit per person would avoid negative consequences on the financial system (Panetta, 2023b).

focus on consumers as the ECB has communicated that merchants would be able to receive and process digital euros, but not hold them. The potential demand for a digital euro is a key variable that will determine the economic implications of its introduction in conjunction with the envisaged safeguards. Given that a digital euro would be a novel means of payment, demand is uncertain and challenging to predict. It will hinge, among other things, on the design features and how it compares to existing means of payment – in particular cash and sight deposits.[2] To this end, our study aims to quantify answers to the following questions: What range of holdings could be reasonably expected for a digital euro conditional on its design, individuals' payment preferences and socioeconomic factors? How would different design choices affect its demand? How the estimated demand varies with individual characteristics? By doing so, this study contributes to assessing the potential financial stability implications of a digital euro. Insights from this analysis can also be used to identify the features that would drive its demand and the effectiveness of those that are designed to limit it.

In particular, we apply a structural demand model to consumer survey data for the euro area, leveraging on a strategy first introduced by Li (2023). The key idea of this approach is to consider digital euro, cash, and sight deposits as sets of product attributes. Based on how individuals allocate their liquid assets between cash and bank deposits, we can identify preferences towards different product attributes. Presuming that the estimated preferences remain unchanged following the introduction of a digital euro, they can be used to predict the demand for a digital euro conditional on its design features. More specifically, in this model, individuals obtain utility from holding cash and deposits. Therefore, independent of the introduction of a digital euro, individuals decide how to allocate endowment of liquid assets between cash and sight deposits based on the relative utilities from holding these forms of money. Such utilities depend on the differences in the product attributes, individuals' characteristics and the product fixed effect that captures the average impact of individuals' unobserved idiosyncratic preferences. However, forecasting the demand for a new payment method, such as a digital euro, based on users' current preferences for cash and deposits presents significant challenges. Since this digital currency has not yet been introduced, predicting its adoption involves considerable uncertainties and assumptions about future user behaviour and market dynamics.

In order to empirically estimate the demand parameters, we use a dataset compiled from the following consumer surveys: i) The Study on the payment attitudes of consumer in the euro area (SPACE), ii) the Household Finance and Consumption Survey (HFCS), and iii) Payment behaviour in Germany in 2021 (Bundesbank, 2022). The dataset is constructed by employing statistical matching techniques and contains detailed information on individuals' cash and deposit holdings, their payment patterns, and perceived advantages of existing payment methods. In our analysis, we consider 12 features based on available data, including ease of use, security, transaction speed, anonymity/privacy, settlement speed, remuneration rate, acceptance rate, budgeting usefulness, automatic funding, online store capability, person-to-person (P2P), and contactless functionality. In

[2] Sight deposits are deposits that can be withdrawn immediately without restrictions and are comparable to demand deposits in other jurisdictions. We use this terminology to be consistent with that used in our data source, the Household Finance and Consumption Survey.

the counterfactual analysis, we introduce a digital euro as a set of product attributes based on the ECB's envisaged design features to the extent possible. We also analyse the sensitivity of the demand to different design parameters by varying the similarity of the attributes to those of cash or bank deposits.

The results indicate that if the demand is unconstrained, the estimated digital euro take-up could lie between 3% and 28% of total household liquid assets, which is equivalent to €0.12 trillion - €1.11 trillion. To put this into perspective, the amount of euro banknotes in circulation was €1.57 trillion at the end of 2022. We also show that with an illustrative €3,000 holding limit per person (i.e., an amount beyond which no additional individual holdings are allowed), the aggregate digital euro take-up could range between 2% and 9% of total household liquid assets in a steady state.[3] This can be translated into a total amount of digital euro in circulation ranging from €0.10 trillion to €0.38 trillion, depending on whether consumers perceive digital euro to be closer to cash or deposits, respectively. According to our findings, 80% of individuals would not be affected by the €3,000 limit, as their preferred digital euro holdings are estimated to be less than this amount. However, the actual level of the limit would be set based on further in-depth analysis before the possible issuance of a digital euro (ECB, 2023). Our findings suggest that anonymity/privacy, automatic funding and instant settlement are among the key drivers of the demand. Moreover, because the foreseen reverse waterfall mechanism would allow users to make online payments even without any digital euro holdings, the actual take-up could be expected to be lower than what is estimated in this analysis.[4]

In an extension of the main analysis, we apply our framework to also estimate the potential value of digital euro transactions relative to cash and existing digital payments, taking into account all use cases, including physical stores, e-commerce and transfers between individuals. The results from this analysis suggest that the estimated digital euro payments could range from 25% to 44% of total retail transaction values in a steady state, depending on whether individuals would perceive a digital euro to be a closer substitute for existing digital alternatives or cash, respectively. We find that widespread merchant acceptance is the most significant feature of a digital euro as a means of payment. Overall, our results from these two parts of the paper indicate that the more the digital euro is perceived to resemble cash, the lower the estimated demand for holdings and the higher the estimated demand for transactions, and vice versa if the digital euro is perceived to more closely resemble deposits.

Our study contributes to a growing literature on CBDCs. Most academic discussions so far have revolved around the reasons for issuing a CBDC and its potential economic implications.[5] The current literature has also mainly focused on the use of a CBDC as a store of value rather than as a means of payment (Ahnert et al.,

[3] Preliminary analyses have shown that imposing, for example, a €3,000 holding limit per person would avoid negative consequences on the financial system (Panetta, 2023b).

[4] The reverse waterfall mechanism eliminates the need to prefund the digital euro account for performing payments, as any shortfall would be covered instantly from the linked commercial bank account, provided it has sufficient funds available. Nevertheless, the envisaged offline function of the digital euro would still require sufficient prefunding. We are not able to identify the effects of the reverse waterfall due to the lack of data on users' preferences for this feature.

[5] See, e.g., Ahnert et al. (2022), Brunnermeier and Landau (2022), Whited et al. (2023), Adalid et al. (2022), Bindseil (2023), Li et al. (2024), Hemingway (2022).

2022). To our knowledge, this is the first paper to gauge the potential demand for both digital euro holdings and transactions by using payment survey data. While prior studies have also tried to ask citizens directly about their willingness to adopt and use a hypothetical CBDC, such approach has turned out to be challenging since there is often divergence between what individuals express in their responses and their subsequent actions. Instead, our paper uses individuals' revealed preferences towards different product features, which does not rely on survey respondents' understanding of the digital euro. By predicting the potential demand for a digital euro, our study can provide policymakers with valuable insights and support informed decisions regarding its design. Moreover, it contributes to the academic debate, showing that the uptake will be limited if a CBDC is designed as a means of payment. Lastly, our study sheds further light on how CBDC demand could potentially vary across socio-economic characteristics and different types of consumers based on their technology-savviness.

The remainder of the paper is organized as follows: Section 2 provides an overview of the relevant literature, while Section 3 outlines the structural demand model and our methodology for estimating it. Section 4 describes the data sources used and explains how we define various product attributes based on the survey data. In Section 5, we present the results for the estimated demand parameters, while Section 6 describes the ECB's outlined design features for a digital euro. Section 7 presents the results for the potential digital euro demand, while Section 8 introduces an extension which estimates the potential demand for digital euro transactional usage in terms of value. Finally, Section 9 concludes.

2 Literature

Only a small, albeit rapidly growing, number of papers have analysed CBDC demand by using different estimation approaches.

A first strategy exploits a social welfare maximising approach using Dynamic Stochastic General Equilibrium (DSGE) models. For instance, Burlon et al. (2024) employ a quantitative DSGE model calibrated to euro area data, drawing on the existing evidence on bank stock price reactions to digital euro news, in order to determine the demand for a digital euro under different design options. According to their proposed baseline calibration for the euro area, the optimal amount of a digital euro in circulation that would maximise welfare would lie between 15% and 65% of quarterly real GDP in equilibrium, equivalent to a range of €0.45 trillion to €1.95 trillion.[6] However, measuring welfare effects is very challenging and requires making considerable assumptions.

Another strand of the literature uses empirical models and survey data to infer potential take-up and usage patterns of CBDCs. The approach taken in these studies is derived from the industrial organisation literature, in which a product is described as a bundle of characteristics. This setup allows for estimating substitution

[6] After having rounded up the size of the population in the euro area to 340 million citizens and the average quarterly GDP to €3 trillion in 2021, the range of 15-65% is equivalent to €0.45 - €1.95 trillion.

patterns implied by the introduction of a new product. For Canada, Li (2023) applies a characteristics-based structural demand model to Canadian survey data to quantify households' potential CBDC holdings relative to its close alternatives, i.e., cash and demand deposits. The findings suggest that CBDC holdings to be in range between 4% and 55% of households' liquids assets, depending on whether households perceive CBDC to be closer to cash or deposits. Li (2023) finds that budgeting usefulness, anonymity, bundling of bank services and the rate of return are the most significant design attributes for the attractiveness of a CBDC. Also using Canadian survey data, Huynh et al. (2020) study consumers' payment choices among cash and cards and predict the usage of CBDC as a means of payment. They specify and estimate a structural demand model as a two-stage process and vary the levels of consumer adoption and merchant acceptance rates. Using a similar approach for the euro area, Nocciola and Zamora-Pérez (2024) focus on consumers' choices of using CBDC to pay at the point of sale (POS). They find that under full adoption and acceptance, CBDC could potentially capture a usage share ranging between 28% and 37% of the total number of POS transactions depending on the design. The authors also find that modelling the adoption stage affects the results significantly; after taking into account potential adoption costs the CBDC share at POS drops to 2.6%. In contrast, our framework allows estimating the ratio of CBDC transaction values instead of solely focusing on discrete choices among different payment options. In addition to POS payments, our study also takes into account payments in online stores and between individuals.

Several consumer surveys have asked respondents directly about their willingness to adopt a CBDC and desired design features. Bijlsma et al. (2023) surveyed respondents in the Netherlands and directly asked about their intentions to adopt and use a hypothetical CBDC. They found that roughly 50% of the Dutch consumers would be willing to open a CBDC account, with the majority indicating they would transfer up to €500 in the case of a non-interest-bearing CBDC. Those who value privacy and security showed greater willingness to adopt a CBDC. Likewise, Bidder et al. (2024), using a 2023 survey of German consumers, reveal that almost half of the respondents were interested in a digital euro if it is unremunerated. However, this interest increased to nearly 60% if the digital euro provided the same interest rate as their existing bank accounts. These figures show a slight increase compared to an earlier wave of the survey conducted in 2021, which indicated that 40% of respondents expressed willingness for using a digital euro (Bundesbank, 2021). Cash payers tended to have a more negative attitude towards a digital euro, while those who were familiar with digital payments and have heard of the digital euro before, had a more favourable view of CBDC. However, it is important to note that survey results based on broad descriptions of CBDCs may have limited predictive value in terms of consumer behaviour, as they rely on people's understanding of CBDC, which may not be accurate. There is evidence that even for means of payment that consumers know well, such as cash and cards, self-reported preferences may diverge from actual usage patterns (ECB, 2022). Instead, our paper uses individuals' revealed preferences based on their allocation decisions between cash and deposits (as well as cash and digital payments), which does not rely on survey respondents' understanding of CBDC.

Our paper is also related to the growing literature on how CBDC potentially affects bank deposits and thus bank intermediation. For example, Adalid et al. (2022) consider three different digital euro take-up scenarios for illustrative purposes: a low demand scenario, a high demand scenario, and a scenario with a capped take-up. These scenarios yield a deposit outflow from banks representing 1%, 34% and 3% of total customer deposits, respectively. While the illustrative take-up scenarios can give an idea of the magnitude of deposit substitution associated with different demand intensities, uncertainty around the assumptions on which these scenarios are based remains high. Gross and Letizia (2023) simulate integrated balance sheets of banks, non-bank agents, and the central bank, leading to a CBDC-in-total-money share of 1% to 20% for the euro area, with the lower bound characterising a CBDC that is perceived as cash-like whereas the upper bound applies to a deposit-like CBDC. This range of values can be translated into a total demand ranging from €0.2 - €3 trillion.[7] They show that incorporating supply-side factors into the model and allowing banks to respond to the CBDC introduction can greatly reduce the upper bound of the predicted CBDC take-up. However, such studies often assume CBDC to be a perfect substitute for deposits with the focus being primarily on the differences in the rate of return. Meanwhile, our approach models CBDC as an imperfect substitute for deposits, where CBDC can differ from deposits in a variety of product attributes.

3 Model and methodology

This section describes our methodological strategy to estimate CBDC demand that closely follows Li (2023). More specifically, in Section 3.1, we explain the structural demand model we use to study how individuals allocate their liquid assets between cash and deposits.[8] In this model, cash, deposits and CBDC are viewed as product bundles of different attributes. Individuals obtain utility from holding cash and deposits, which depends on each product's attributes, individual and household level characteristics as well as product fixed effects. We estimate individuals' preferences for different product attributes by applying the model to survey data. In Section 3.2 we proceed by introducing CBDC to the model as an additional choice for individuals to allocate their liquid assets to. Assuming that preferences towards the product attributes do not change after the introduction of CBDC, the demand for CBDC can be predicted on the basis of its design attributes and individuals' relative preferences for each attribute. While our main analysis described in this section focuses on estimating the demand for CBDC holdings, we also estimate the demand for CBDC transactions using the same approach in Section 8.

[7] Based on euro area M2 at the end of 2022.

[8] In this paper, we refer to individuals given that the data (described in detail in Section 4) used to estimate the model is available on the individual (consumer) level.

3.1 Random utility model

In our model each individual is endowed with w_i units of liquid assets in a given period. For each unit, individuals make a choice to hold it in cash or deposits. Individual's i indirect utility of holding product j, $u_{i,j}$, consists of an observable part and an unobservable, i.i.d. utility shock ($\epsilon_{i,j}$). The observable part of the indirect utility, $V_{i,j}$, includes product-specific attributes ($x_{i,j}$), a set of individual and household-level characteristics (z_i), and a product-specific constant (η_j).

$$u_{i,j} = \alpha' x_{i,j} + \gamma_j' z_i + \eta_j + \epsilon_{i,j} = V_{i,j} + \epsilon_{i,j} \tag{1}$$

Vector α represents the preference parameters for different product attributes, whilst γ_j captures the impact of individual and household-level characteristics on the utility of holding product j, where $j \in \{cash, deposits\}$. The utility shock, ϵ_j, is randomly drawn from a given distribution and captures the unobserved idiosyncratic preferences, while the constant $\eta_{i,j}$ represents the average impact of these unobserved preferences on the utility of product j. Therefore, even if the observed utility for holding one euro in cash is higher than for deposits (i.e., $V_{i,c} > V_{i,d}$), the final choice is random.

We make a general assumption that the i.i.d. utility shock follows a Type I extreme value distribution. Given this assumption, the choice probability depends only on the observable parts of the indirect utility. Individual i holds w_i euros and therefore makes w_i number of choices. By the law of large numbers, the probability of holding one euro in asset j is equivalent to the asset j's share $s_{i,j}$ in the individual's total liquid asset balance. The share of product j in total liquid assets is given by $s_{i,j} = \frac{q_{i,j}}{w_{i,j}}$, where $q_{i,j}$ is the balance of asset j and $w_{i,j} = q_{i,c} + q_{i,d}$ is the liquid asset balance which consists of the sum of cash and demand deposit balances held by individual i.

We take the difference between the logs of deposit and cash shares to obtain the log of the deposit-to-cash ratio. This ratio depends on the difference between the observed utilities for deposits and cash, which in turn reflects the differences in product attributes $x_{i,d} - x_{i,c}$, individual and household-level characteristics, z_i, and the difference in the product-specific constants $\eta_d - \eta_c$.

$$ln(\frac{q_{i,d}}{q_{i,c}}) = V_{i,d} - V_{i,c} = \alpha'(x_{i,d} - x_{i,c}) + (\gamma_d - \gamma_c)' z_i + \eta_d - \eta_c \tag{2}$$

Equation (2) is estimated by applying OLS to individual-level data. The results are reported in Section 5 of this paper.

This equation shows that only the utility difference matters for individuals' choices, therefore the effects of individual and household-level characteristics can only be identified if they are product specific (i.e., $\gamma_i \neq \gamma_c$). Since different values of γ_d and γ_c that result in the same differences ($\gamma_d - \gamma_c$) will lead to the same choices, the overall level of $(\gamma_d - \gamma_c)$ needs to be set and the same applies to $(\eta_d - \eta_c)$. Following Li (2023), we normalize the parameters for cash, γ_c and η_c to equal zero. After this normalization, the estimated η_d reflects the average impact of the unobserved idiosyncratic preferences on the utility for deposits relative to cash, and the estimated γ_d reflects the effects of individual and household-level characteristics z_i on the utility for deposits relative to cash.

3.2 Introducing CBDC

We now introduce CBDC in the model as a new product that individuals can allocate their endowed euros to, depending on the CBDC design features and individuals' relative preferences for each feature. More specifically, the demand for CBDC depends on the observed utility for CBDC, $V_{i,CBDC}$, as well as on the assumptions on the unobserved utility shock, $\epsilon_{i,j}$. We first focus on calculating each individual's observed utility for CBDC, $V_{i,CBDC}$. By assuming that the previously estimated preference parameters for the product attributes $\hat{\alpha}$ remain the same after CBDC issuance, the observed utility for CBDC can be calculated using the CBDC attributes, $x_{i,CBDC}$, under different scenarios as below:

$$V_{i,CBDC} = \hat{\alpha}' x_{i,CBDC} + \gamma'_{CBDC} z_i + \eta_{CBDC} \tag{3}$$

Because the effects of the individual characteristics and the effects of the constant (i.e., γ_{CBDC} and η_{CBDC}, henceforth referred to as 'CBDC-specific effects', are unknown for CBDC, we need to make assumptions on these depending on whether people would perceive CBDC as a closer substitute for cash or deposits. Intuitively, we do not know how individuals would value a product that does not exist yet. Therefore, we perform several counterfactual analyses, where we assume that these CBDC-specific effects range from being cash-like (i.e., taking the normalised parameter values for cash $\gamma_c = 0$ and $\eta_c = 0$) to being deposit-like (i.e., taking the estimated values of these parameters, $\gamma_d = \hat{\gamma}$ and $\eta_d = \hat{\eta}$).[9]

For example, if individuals perceive CBDC to be a perfect substitute for cash, in which case assuming $\gamma_{CBDC} = \gamma_c$, then the individual and household-level characteristics affect the utilities for cash and CBDC identically. In other words, individuals from a given demographic group would equally value CBDC and cash. Similarly, assuming $\eta_{CBDC} = \eta_c$ means that the average impact of the unobserved idiosyncratic preferences on the utility of CBDC is identical to that of cash.

Next, we explain how the potential demand for a CBDC can be predicted based on a logit model. The utility of CBDC also depends on the distribution of the random utility shock, $\epsilon_{i,j}$, which is assumed to follow an i.i.d. Type I extreme value distribution, as mentioned above. Given the distributional assumption on $\epsilon_{i,j}$, and by the law of large numbers, the probability of allocating one euro of the total endowment, w_i, into CBDC is

[9] In reality, the parameters γ_{CBDC} and η_{CBDC} could also lie outside this range, but this paper does not consider these cases that would require extrapolation.

equivalent to the share of digital euro holdings out of the individual's total liquid assets. This is given by the following equation:

$$s_{i,CBDC} = \frac{exp(V_{i,CBDC})}{exp(V_{i,c}) + exp(V_{i,d}) + exp(V_{i,CBDC})} \in (0,1) \tag{4}$$

Assuming that the endowment, w_i, is unaffected by the CBDC issuance, the demand for CBDC comes from the substitution away from cash and deposits.[10] In the logit model, the demand for CBDC draws proportionally from cash and deposits, so the percentage changes in deposit and cash demand are identical by assumption. Before the introduction of CBDC, the initial share of cash and deposits is given by:

$$s_{i,k} = \frac{exp(V_{i,k})}{exp(V_{i,c}) + exp(V_{i,d})}$$

where $k = \{c, d\}$. Following the introduction of a CBDC, the new share of cash and deposits is given by:

$$s'_{i,k} = \frac{exp(V_{i,k})}{exp(V_{i,c}) + exp(V_{i,d}) + exp(V_{i,CBDC})}$$

The predictions for CBDC demand can be used to evaluate how much bank deposits (and cash holdings) could decline following CBDC introduction. After the introduction of a CBDC, under the logit model, the share of deposits or cash in total liquid assets is given by the following equation:

$$s'_{i,j} = \frac{exp(V_{i,j})}{exp(V_{i,c}) + exp(V_{i,d}) + exp(V_{i,CBDC})} \in (0,1)$$

In this paper, we also predict the potential demand for a digital euro using a nested logit model, which allows for CBDC to be a closer substitute for cash or deposits. Appendix A explains how the nested logit model can be used to predict demand for CBDC and Appendix C.2 describes the results, which are similar to the results from the basic logit model.

4 Data and variables

To empirically estimate individuals' preferences for a range of product attributes of cash and deposits, we construct a unique dataset for the euro area by combining information from the following consumer surveys: i) the Study on the Payment Attitudes of Consumers in the Euro area (SPACE, 2022), ii) the Household Finance and Consumption Survey (HFCS, 2023), and iii) Payment behaviour in Germany in 2021 (Bundesbank, 2022).

[10] This is a plausible assumption given that households have specific liquidity preferences based on factors such as transaction needs, safety, and convenience. The introduction of CBDC would simply add another option that fits within these preferences, rather than changing the overall demand for liquidity.

Most of the product attributes and preferences towards the attributes are measured using the SPACE 2022, which provides consumer level information on the use of different payment methods and the reasons behind payment choices. More specifically, it consists of a payment diary recording detailed transaction level data on payment behaviour, and a supplementary questionnaire where respondents are asked about their payment preferences and advantages of different payment instruments. The survey provides information on individual and household level characteristics and covers data from 2021 to 2022 for all euro area countries, except for Germany and the Netherlands since the corresponding central banks carry out their own payment surveys separately from the one conducted by the ECB.[11] For Germany, we use the Deutsche Bundesbank's data, based on a questionnaire largely harmonised with the one used in the other countries.[12]

While the SPACE 2022 contains information about individuals' cash holdings, it lacks data on deposits. To address this gap, we use the HFCS 2023 that contains data on households' bank deposits for all euro area countries.[13] The survey covers the sample period 2021-2022 and provides harmonised data for all euro area countries. Given that the two surveys are not conducted on the same sample of individuals, we employ statistical matching techniques to impute the deposits from the HFCS into the SPACE data. Statistical matching is a method used to combine information from two non-overlapping surveys with common background variables. The imputation of the deposits is described in more detail in Appendix B. Before imputing the deposits and calculating the variables of interest, we pre-process the data to ensure consistency.[14] After this, our sample comprises around 34,000 individuals, and a total of almost 100,000 reported payment transactions. Table D1 in Appendix D shows the distribution of individual respondents across countries.

We measure individuals' total cash holdings as the sum of cash in wallet (at the beginning of the day of the payment diary) and cash kept outside wallet (either for precautionary reasons or as an alternative way of saving).[15] As regards the deposits, we use the imputed sight account balances for each individual. We focus on sight deposits since they can be readily used for transactions and thus can be considered a close alternative to a digital euro. The average cash holding was around €370, with a median cash holding of €90, during the period under study. The average sight deposit holding amounted to about €13,100, with a median holding of €2,000, indicating a skewed distribution with a long right tail. We add one to each respondent's

[11] The SPACE sample is designed to ensure representativeness of the population for gender, age, education and region. To take into account seasonality in payments (payment behaviour may be different in terms of the days of the week), quotas were also defined on the day of the transactions to achieve representativeness for each day of the week.

[12] Due to methodological differences the data for the Netherlands cannot be used for our study.

[13] The HFCS is a household-level survey providing detailed information on various aspects of the household balance sheets, income, consumption, and related economic and demographic variables. The survey also provides individual level information on the reference person, including demographic characteristics.

[14] This includes, for example, cleaning the data, handling missing values, and treating variables consistently across the different datasets.

[15] Cash in wallet is reported in euros, while the amount of cash kept outside wallet is reported in the following categories: 100 or less, 100-250, 251-500, 501-1000, 1001-5000, more than 5000. The categorical variable is converted into numeric by taking the middle point of each category. If an individual is in the top category (i.e., more than 5000), we assume that the amount kept outside wallet for that individual is €5,000. For missing values, we assume that the amount of cash kept outside wallet is zero. We also calculate cash in wallet at the end of the day by taking into account cash spent and withdrawn during the day of the payment diary. Our results are robust to using this alternative measure.

cash holdings and sight deposits to account for all individuals in the sample, including those who do not have any reported deposits or cash holdings.[16] Otherwise, these important groups of individuals would be omitted from the analysis. This also allows us to calculate the dependent variable in our empirical estimations, that is the log of the deposit-to-cash ratio. Figure 6 in Appendix E shows the share of cash and sight deposits in individuals' liquid assets across the countries. While most of the liquid assets are held in deposits, there are some heterogeneities in asset allocation across countries.

Understanding consumer preferences for the different product attributes is key for estimating the demand for a digital euro, the remainder of this section explains how each attribute and preferences towards them are measured using information on existing products. In addition to the product attributes, individual and household level characteristics can affect the utilities obtained from holding cash and deposits. Therefore, we also take into account various socio-economic factors including country of residence, household size, age, gender, income, education level, occupation, internet usage, income received in cash, and ease of access to cash. Our analysis goes even beyond this, and at the end of this section, we categorise individuals into consumer types based on their current preferences for payment methods (cash or cashless), their level of familiarity with technology and access to banking services. This allows us to provide a deeper understanding on the preferences of different user groups. The product attributes and the individual and household characteristics serve as explanatory variables when estimating the Equation (2) in Section 3.

4.1 Product attributes

We consider 12 product attributes associated with the store of value and means of payment functions: 'Ease of use', 'Transaction speed', 'Security', 'Budgeting usefulness', 'Anonymity/privacy', 'Instant settlement', 'Automatic funding', 'Merchant acceptance rate', 'Online store capability', 'Contactless function, 'Person-to-person (P2P)', and 'Remuneration rate'. Our selection of the attributes is based on the available data and knowledge on features that are deemed important for consumer payment choice and digital euro design. We also take into account additional product attributes that are not considered in related previous studies (Li, 2023; Nocciola and Zamora-Pérez, 2024). Next, we explain how we construct each product attribute and identify preferences towards them, based on the advantages of cash and cards and the use of different payment features reported in the SPACE 2022 and the corresponding German data.

Because cards are directly linked to deposit accounts, we use the perceived advantages of cards to measure advantages of deposits to make payments compared to cash. The surveys ask respondents to select up to three advantages for cash and cards across eight attributes: perceived acceptance, transaction speed, ease of use, safety, budgeting usefulness, anonymity/privacy, instant settlement and carrying cash.[17] The reported

[16] There are 1,138 respondents with no cash holdings in our dataset. We exclude respondents with over €15,000 cash holdings (seven respondents). For robustness, we repeat the analysis by also excluding individuals with zero cash holdings from the sample.

[17] The surveys consider five possible advantages for both cash and cards (perceived advantage, transaction speed, ease of use, safety, and budgeting usefulness). However, three advantages are unique to a single payment instrument: the convenience

advantages reveal that the features that make each payment method attractive are different (Table 1). During the period under study, budgeting usefulness, anonymity/privacy and instant settlement were perceived as the main advantages of cash. When it comes to card payments, the majority of the respondents deemed not having to worry about carrying enough cash as the key advantage of cards. Most people seem to consider cards to be easier, faster, and safer to use than cash. Cash, on the other hand, is primarily seen to be more useful for expenditure control.

Table 1: Proportion of cash/card users by advantages of each payment method

Attribute	Of cash users, %	Of respondents, %	Of card users, %	Of respondents, %
Ease of use	27.86	18.39	50.03	40.96
Transaction speed	23.69	17.05	50.26	42.82
Safety	24.9	16.89	33.76	28.17
Budgeting usefulness	49.2	38.13	21.79	19.37
Anonymity	41.22	40.08	-	-
Instant settlement	33.59	31.28	-	-
Automatic funding	-	-	63.44	61.22

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Moreover, we use the payment diaries to extract and identify preferences for merchant acceptance rate, online capability, contactless feature, and P2P capability. The respondents are asked to report all their POS (point-of-sale), P2P (person-to-person) and online transactions during the payment diary. The diaries include information on various characteristics of all transactions, including the transaction value, the place or the purpose of the payment (e.g., supermarket, restaurant, payment to another person), the chosen payment instrument and whether the merchant accepted alternative payment methods. The SPACE 2022 contains up to 16 transactions during a one-day payment diary for each respondent, including up to eight POS transactions and eight online payments.[18] The corresponding German survey, in turn, has a three-day payment diary, containing also up to eight POS transactions and eight online payments during each day of the diary. As a result, the possible maximum number of payments is 16 in the SPACE 2022 and 48 in the corresponding German survey per respondent.[19] Summary statistics of the online, P2P and contactless payments as well as the merchant acceptance rates are presented in Table D4 in Appendix D.

associated with not having to worry about carrying enough cash is applicable only to cards, while anonymity/privacy and instant settlement are features exclusive to cash.

[18] It's important to note, that there are some advantages and limitations associated with recording payment behaviour through one-day diaries. One-day diaries offer a more comprehensive record of transactions compared to diaries spanning over several days (Jonker and Kosse, 2013). At the same time, the level of uncertainty in survey data is more prominent in one-day diaries, particularly when drawing conclusions for countries and other population subgroups with small sample sizes. Conversely, longer diary periods, encompassing several days, capture a greater number of transactions per sample unit, thereby enhancing the precision of estimated indicators (Schmidt, 2014).

[19] After excluding respondents who did not make any payments (about 7,300 respondents), the average number of transactions per diary was 3 and the average value of transactions was €38 during the period under study.

Ease of use, transaction speed, security and budgeting usefulness

To measure ease of use, transaction speed, security, and budgeting usefulness of cash and deposits, we use the individual-specific responses on whether these features are perceived to be advantages of cash or cards. When the survey respondents are asked to select the main advantages of cash over cards, and vice versa, ease of use, speed, safety, and budgeting usefulness are offered as potential advantages for both payments instruments. We assign a value of 1 for the chosen features and a value of 0 for the not chosen features. For the estimations, we calculate the relative perceived ease of use, speed, safety and budgeting usefulness of cash and cards by calculating the difference between the assigned values so that the variable of interest can get a value of -1, 0, or 1.

Ease of use typically refers to people's perceptions of how easy or convenient it is for them to use cash or cards, while transaction speed is determined by how fast it is for them to use each payment instrument (e.g., the time it takes to complete a payment transaction or withdraw cash). Security refers to how safe people feel it is for them to use each payment method, such as risk of theft or fear of losing money. Budgeting usefulness, in turn, relates to people's perceptions of how easy it is to keep track of their expenses when using cash or cards. For example, people may perceive cash to be more useful for budgeting because it gives a signal of the remaining budget via a glance into one's wallet, or serves as commitment device to avoid overspending (Hernandez et al., 2017; Von Kalckreuth et al., 2014). However, in contrast to Li (2023), our data allows budgeting usefulness to be a potential advantage associated with both cash and cards.

Anonymity/privacy and instant settlement

Anonymity/privacy and instant settlement are considered as features unique to cash since card payments are by default not anonymous and not necessarily settled instantly like cash payments. As a consequence, anonymity/privacy and instant settlement are considered exclusively potential advantages of cash in the SPACE 2022. Therefore, anonymity/privacy and instant settlement can only contribute to an individual's utility from cash, and not utility from deposits (cards). We assign a value of 1 if the respondent has chosen the feature to be an advantage of cash.

Anonymity means that the user's identity does not need to be revealed when using a payment instrument and that transactions are untraceable. Privacy, on the other hand, refers to an individual's right to decide when, how, and to what extent information about them is shared with others. Cash tends to be anonymous (and therefore by default safeguards privacy) as opposed to cards. Furthermore, cash payments are instantly settled, meaning that the funds are made available immediately for use by the recipient, whereas settlement of card payments may take more time.

Automatic funding

The digital euro is designed to contribute to a seamless and user-friendly experience by embedding various functionalities such as the 'automatic funding'. Such function refers to the option for users to set up rules or conditions under which their wallet would be automatically funded instead of manually transferring funds. Automatic funding requires linking the digital euro wallet to a funding source, such as a bank account, enabling the digital euro wallet to be regularly funded based on the users' preferences. The design features of a potential digital euro are discussed in more detail in Section 6.

In this paper, the attribute automatic funding refers to the convenience offered by the usage of cards for payments of not needing to check physical cash availability in the wallet before making a transaction. Indeed, the convenience associated with not having to worry about carrying enough cash is considered as a potential advantage of card payments in the SPACE 2022. This means that individuals do not have to check whether they have enough cash to make payments and transfer funds to a physical wallet by withdrawing cash. Therefore, automatic funding can only contribute to the utility from holding deposits if the respondent has chosen this feature to be an advantage of cards over cash.

Merchant acceptance rate

For each cashless payment (card or mobile payment) recorded in the payment diaries, respondents are asked whether cash was accepted by the merchant. Similarly, for each transaction paid in cash, the respondents are asked to report whether other payment methods (cards or mobile payments) were accepted by the merchant. We use this information to measure the card (cash) acceptance rate for each individual, which is based on how often an individual encounters a store where he cannot pay with cards (cash). What matters for consumers is not the aggregate-level merchant acceptance of cards or cash, but rather their personal experience of the acceptance rate after optimising which stores to visit. Unlike Nocciola and Zamora-Pérez (2024), we calculate the actual acceptance rates instead of using the perceived acceptance of cash and cards reported in the possible advantages of cash and cards.

We calculate the relative individual-specific unacceptance rate as the difference between the card and cash unacceptance rates. The card unacceptance rate is defined as the number of transactions where cards are not accepted (i.e., the store is cash-only) divided by the total number of transactions recorded for each respondent. Similarly, the cash unacceptance rate is given by the number of transactions where cash is not accepted divided by the total number of transactions recorded for each respondent. In our analysis, we first calculate the unacceptance rate, instead of the acceptance rate, given that individuals are more likely to observe if the store does not accept their preferred payment method. After this, we calculate the acceptance rate by taking the inverse of the unacceptance rate. This is an important feature for payment methods given that individuals are likely to obtain higher utility from holding cash (cards) the more often they encounter stores that do not accept cards (cash).

Online purchase, contactless and P2P functionality

Since cash cannot be used for online purchases but deposits (cards) can, we set online capability to take a value of one for deposits (cards) and zero for cash. To analyse individuals' preferences towards this attribute, we use the respondents' online transaction frequency since those who shop online more frequently should obtain more utility from digital payments and therefore from holding deposits. A transaction is defined as online whenever the order of the goods or services and the payment are made online.[20] We calculate the online transaction frequency by dividing the number of transactions made online by the total number of transactions recorded for each respondent.

For each recorded POS transaction, the surveys also contain information on whether the respondent used contactless technology for the payment. The contactless function refers to the ability to make contactless payments (i.e., "touch-free" payments) with a given payment instrument. Since deposits (cards) can be used to make contactless payments while cash cannot, this feature is set to take a value of one for deposits (cards) and zero for cash. We combine this attribute with the respondents' contactless payment frequency; individuals who use contactless technology more often should obtain higher utility from holding deposits (using cards).[21]

On the other hand, cash can be used to pay another person while (physical) cards cannot.[22] Therefore, the P2P capability is set to take the value of one for cash and zero for deposits (cards). Similar to the online purchase capability, we use respondents' P2P transaction frequency to identify the impact of this feature to the individuals' utility. P2P transactions refer here to payments carried out between individuals, such as family members and friends, charity donations or for home services (e.g., cleaning, babysitting and home repairs). For each respondent, the P2P transaction frequency is calculated as the number of P2P payments over the total number of transactions recorded by the individual.

Remuneration

The rate of return reflects the usability of a given asset as a store of value or as a form of investment. Because neither the SPACE 2022 nor the HFCS 2023 contain information on individual-level deposit rates, we use information on country-level deposit rates reported by euro area credit institutions, retrieved from the ECB's Interest Rate Statistics (MIR). We use interest rates on both household overnight deposits and deposits with agreed maturity. While the interest rate more closely associated with sight deposits would be the overnight deposit rate, during the period under study the interest rates of overnight deposits were close to zero (Figure E1 in Appendix E). This means that there is not enough variation over time or across countries to allow

[20] There are different types of payment methods that can be used when purchasing goods or services online. Some common payment methods include debit/credit cards, bank transfers, mobile payments and digital wallets.

[21] A transaction is counted as contactless if a card's contactless technology or a mobile app was used to conduct the payment. When counting the share, only POS payments are taken into account.

[22] Even though cards can be used to make P2P payments via mobile payment solutions, consumers tend to perceive cards and mobile payments as two distinct payment methods (due to their different user experiences), since the card would only charge the consumer's account in this case. Therefore we treat these as separate payment methods and assume that (physical) cards cannot be used to make P2P payments.

this variable to be identified in a regression framework. Consequently, the average deposit rate is calculated instead, which varies more across countries and time. We merge these deposit rates by the respondent's country of residence and the month and year of the respondent's payment diary.[23] The remuneration rate of cash is assumed to be zero.

4.2 Consumer types

To better understand individuals' preferences and potential demand for a digital euro among different user groups, we categorise individuals into three different consumer types: cash-affine, tech-savvy, and underbanked individuals. The three consumer types are measured with dummy variables, respectively. These categories are derived based on respondents' self-stated preferences, familiarity with new technology, and access to banking services. Cash-affine consumers are determined by their self-stated payment preferences. Individual fall into this category if they have declared a preference for using cash as their primary payment method. Tech-savvy individuals are identified based on their self-reported preferences and their actual usage of mobile payments. If respondents have expressed a preference for cashless payments or have used mobile payment methods during the payment diary, they are considered tech-savvy. Underbanked individuals are derived through survey questions regarding their engagement with different banking services. We classify individuals as underbanked if they have indicated that they do not have a bank account (neither a savings account nor a payment account) or a payment card.

In our sample, 19% were cash-affine, 64% tech-savvy, 16% underbanked, while 16% did not fall into any of these consumer types under the period under study (Figure E2 in Appendix E). While these groups are intentionally non-mutually exclusive, the correlation between these three groups is relatively low such that we can include all three dummies in the estimations simultaneously without running into issues of multi-collinearity (Table D5 in Appendix D). Appendix D includes descriptive statistics for the three consumer types.

5 Estimated preferences

This section presents the results for the estimated demand-side parameters and their relative importance in explaining individuals' allocation of liquid assets between cash and deposits. More specifically, we estimate Equation (2) in Section 3 to obtain the demand-side parameters, including preference parameters, α, the effect of individual characteristics, γ_d, and the constant, η_d. Equation (2) is estimated using OLS regression and standard errors are clustered on the individual level.

The dependent variable in our model is the individual log of the deposit-to-cash ratio (i.e., individual holdings of sight deposits over cash holdings). We focus on sight deposits, which can be readily used for transactions

[23] We address the issue of potential endogeneity of country-level deposit rates by using an instrumental variables (IV) approach in the spirit of Villas-Boas (2007), and similar to Egan et al. (2017) and Albertazzi et al. (2020). The approach and results are described in Appendix C.3.

and are thus a closer substitute for a digital euro, compared to deposits in savings accounts. The explanatory variables in our model include 12 different product attributes as well as various household and individual-level characteristics described in Section 4. The estimations are performed on the euro area sample, but country fixed effects are included in the regressions.

Table 2 shows the estimated preference parameters for different product attributes and the constant (i.e., the intercept of the regression model). We find that most of the coefficients are statistically significant and have a sign that is in line with our original expectations. The sample consists of around 34,000 individuals. The effects of the individual and household characteristics on the utilities of holding deposits relative to cash are reported in Table D8 and D9 in Appendix D.

Table 2: Estimated preferences for product attributes

Variable	Log(deposit/cash)
Deposit rate	2.807
Online payment	0.027***
Acceptance rate	0.013
Anonymity/privacy	-0.201***
Budgeting usefulness	0.095***
Instant settlement	-0.11***
Speed	0.147***
Security	0.151***
Automatic funding	0.148***
Ease of use	0.065***
P2P payment	0
Contactless	0.006***
Constant	0.310
Adjusted R-squared	0.206
Observations	34019

Note: Standard errors are clustered on the individual level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In line with intuition, the estimation results suggest that there is a positive relationship between the deposit rate and the holdings of deposits relative to cash. Specifically, individuals that face a 0.1 percentage point higher deposit rate tend to have a 28% higher deposit-to-cash ratio. However, similarly to the findings of Li (2023), we find that the coefficient for the deposit rate is statistically insignificant. This might stem from the fact that there was little variation in the average deposit rate across time and countries during the period under study.

Anonymity/privacy and instant settlement, as explained in Section 4.1, refer to the perceived advantages associated with cash and have a negative effect on the deposit-to-cash ratio. Given that cash is anonymous while deposits are not, this implies that when people consider anonymity to be important, they obtain more utility from holding cash and hence hold more cash relative to deposits. Likewise, if individuals value the capability to settle transactions instantly, they tend to allocate more liquid assets to cash as opposed to deposits.

Budgeting usefulness, speed, security and ease of use, on the other hand, can be considered as advantages of either cash or cards (deposits). These variables reflect the relative importance of these features for each individual (the difference between the dummy variables). We find that the coefficients for these variables are positive and statistically significant. This means that when the attribute is considered as an advantage of cards over cash, the deposit-to-cash ratio is higher. For example, if individuals perceive cards as easier to use than cash, they are inclined to hold a larger amount of deposits in relation to cash.

In contrast, automatic funding is an advantage of cards since it is linked to bank accounts and therefore one does not have to check whether the physical wallet has enough funds and potentially manually transfer more funds into it by withdrawing cash. According to expectations, the estimates suggest that automatic funding has a positive effect on the deposit-to-cash ratio, meaning that when people value automatic funding, they hold more deposits relative to cash.

Acceptance rate refers to the relative merchant acceptance rate of cash and cards, in other words, the difference between the perceived acceptance rate of cards and the perceived acceptance rate of cash at the individual level. Predictably, we find that the coefficient associated with the acceptance rate attribute is positive, indicating that the more often individuals encounter stores that accept cards, the higher the deposit-to-cash ratio is. However, the coefficient is not statistically significant.

The preferences towards online purchase, P2P payment and contactless functionality are identified using the fraction of transactions conducted online, between individuals, and using contactless payments, respectively. Table 2 shows that the online payment capability and contactless functionality have the expected effect on the deposit-to-cash ratio, while the P2P functionality does not have a statistically significant coefficient. Specifically, since cash cannot be used to make online purchases or contactless payments, the more frequently people shop online or use the contactless functionality, the more deposits they tend to hold relative to cash. However, these features have a smaller effect on the deposit-to-cash ratio compared to the other variables.

Finally, the regression constant reflects the average impact of the unobservable individual preferences on the utility of deposits relative to cash. We find that the constant is positive, and thus increases the utility from holding deposits relative to cash. However, in contrast to Li (2023), the constant in our analysis is relatively small and not statistically significant. A possible explanation is that the independent variables in our model explain most of the variation in the dependent variable. Furthermore, the adjusted R-squared of our model is 0.22, indicating that approximately 22% of the variation in the dependent variable is explained by the product attributes and the individual characteristics in our model. This value is significantly higher than in previous related studies. Alternatively, the smaller constant in our study in relation to Li (2023) could possibly reflect the taste differences for cash between Canadian and euro area citizens.

6 Key design features of a digital euro

To predict the potential demand for a digital euro, we introduce a hypothetical digital euro into the model as a new means of payment by making assumptions on the different product features described in Section 4.1. In this section, we construct a baseline design based on the key features of a digital euro as outlined by the ECB as of October 2023 (see ECB (2023), which aggregates and summarises the findings from the investigation phase of the digital euro project), and the European Commission's legislative proposal on a digital euro (European Commission, 2023). During the investigation phase of the digital euro project, the ECB regularly shared information regarding how a digital euro could be designed. To shed light on the impact of different design choices on the demand of a digital euro, we also explore two alternative hypothetical design scenarios: a cash-like design and a deposit-like design. Table 3 displays how we set the digital euro product features under the three hypothetical design scenarios. In particular, the attributes that we deem relevant to the respective design scenario are assigned a value of one (indicating full presence), while attributes that we see as not relevant are assigned a value of zero (denoting absence).[24]

Table 3: CBDC attributes under hypothetical design scenarios

Attribute	Cash-like design	Deposit-like design	Baseline design
Ease of use	Cash	Card	Card
Transaction speed	Cash	Card	Card
Security	Cash	Card	Card
Budgeting usefulness	Cash	Card	Card
Acceptance rate	Cash	Card	Card
Online store	0	1	1
P2P	1	0	1
Anonymity/privacy	1	0	0.5
Instant settlement	1	1	1
Remuneration rate	0	Deposit rate	0
Contactless	1	1	1
Automatic funding	0	1	1

Note: The table shows the product attributes of CBDC under the three design scenarios; cash-like design, deposit-like design, and baseline design.

Our deposit-like design represents an account-based CBDC and is assumed to have characteristics similar to bank deposits (or digital payments).[25] Meanwhile, our cash-like design serves as a proxy for a so-called 'token-based CBDC'. Unlike the deposit-like design, it would not be linked to a payment account, meaning that the

[24] One attribute that is not being considered in our study is the fact that CBDC is public money, as opposed to deposits being private money. However, the survey used to identify and define the attributes does not include any questions that allow us to identify and isolate the effect of this possible additional attribute.

[25] The design features under the deposit-like scenario are assumed to be identical to the characteristics of bank deposits, except for the instant settlement feature, which we set to take a value of one instead of zero, in order to differentiate between bank deposits and the deposit-like CBDC design.

balances or tokens would be stored locally on a physical device (e.g., mobile wallet or physical card). In this case, we assume that the digital euro design features are identical to cash in almost every dimension.[26] The baseline design, on the other hand, combines elements from both the cash-like (token-based) and deposit-like (account-based) designs, recognising that these are not necessarily mutually exclusive categories.[27] The rest of this section is focused on explaining the attribute assignment under the baseline design, based on the ECB's official communication.

The ECB would design a digital euro so that it would respond to the needs of individuals (ECB, 2023). Consumer surveys have identified that the features Europeans value the most are wide acceptance, ease of use, low costs, high speed, security, and consumer protection (eKantar Public (2022)). Indeed, the ECB has communicated that the digital euro would be designed in a way that makes it is easy to use (even for unskilled consumers), secure (providing the highest levels of fraud prevention and consumer protection), and efficient by permitting fast payments (ECB, 2020). Given that the digital euro would inherently be a digital payment method, we assume that its user experience would resemble other digital payments in terms of ease of use, transaction speed, security, and budgeting usefulness. Therefore, we use the individual-specific responses for advantages of cards from the SPACE 2022 to measure the ease of use, speed, security, and budgeting usefulness of a digital euro under our baseline design.[28]

The ability to pay anywhere is considered by the public to be the most important feature of a potential digital euro (Kantar Public, 2022). Currently, there is no single European digital payment method that is universally accepted across the entire euro area. For the digital euro to meet such expectations, people should be able to use it in all their everyday payments; in physical and online stores as well as from person to person (Panetta, 2023a). Assigning legal tender status to the digital euro along with mandatory acceptance would ensure wide merchant acceptance throughout the euro area and help establish the necessary network effects that are key for the success of payment solutions. According to the legislative proposal, merchants accepting existing digital means of payment would be required to also accept the digital euro (European Commission, 2023).[29] Based on this, we set the acceptance rate of a baseline design to be equal to the acceptance rate of cards.

In addition to paying at physical stores, the ability to make person-to-person and online transactions has been recognised as essential features of a digital euro (ECB, 2023). Accordingly, we assign a value of one to both

[26] The design features under the cash-like scenario are assumed to be identical to the characteristics of physical cash, except for the contactless feature, which we set to take a value of one instead of zero, in order to differentiate between physical cash and the cash-like CBDC design.

[27] Additionally, it is important to notice that these two concepts are technology-agnostic, meaning that they could be implemented using either traditional centralised or decentralised distributed-ledger technology (DLT).

[28] There exists no data for other digital payment instruments, such as mobile payments, on these features in the SPACE 2022 survey. Therefore, we use the responses for cards to measure the ease of use, speed, safety, and budgeting usefulness of a digital euro under the baseline design. Moreover, based on the SPACE 2022 data, most people perceive cards to be easier, faster and safer payment instruments than cash (see Table 1 in Section 4.1).

[29] Specifically, merchants across the euro area would be required to accept the digital euro, except very small merchants who do not accept comparable digital payments (as the cost to set up the infrastructure needed for accepting digital euro payments would be disproportionate). See Articles 7 and 9 of the Proposal for a Regulation of the European Parliament and of the Council on the establishment of the digital euro.

online and P2P capability. The public has also expressed a strong preference for instant and contactless payments for any new payment technology (Kantar Public, 2022). Correspondingly, since digital euro transactions would be instantly settled and contactless, we set both features to take a value of one.

Privacy protection is among the most crucial objectives of a digital euro (ECB, 2023). The ECB has declared its commitment to ensuring the highest levels of privacy for the digital euro, stating that it would offer a level of privacy equal to or higher than that of private digital solutions (Panetta, 2022b).[30] While full anonymity is not deemed as a viable option because it would raise concerns about the digital euro potentially being used for illicit purposes, the digital euro is intended to offer a cash-like level of privacy for lower-value offline payments (ECB, 2023). Consequently, we set the baseline design's level of anonymity or privacy to 0.5, as it is expected to be higher than that of deposits (cards), but lower than that of cash.

The proposed digital euro legislation foresees that the ECB should develop limits on individual digital euro holdings to restrict its use as a form of investment (European Commission, 2023). Although the level of the holding limit would be determined closer to its potential issuance, preliminary analyses by the ECB indicate that a cap of €3,000 would avoid negative effects for the financial system and monetary policy (Panetta, 2023b). Consequently, we apply this illustrative holding limit (ex-post) to evaluate its effectiveness in preventing the excessive use of a digital euro as a store of value. In other words, we limit each individual to hold a maximum of €3,000 digital euros after estimating the individuals' preferred digital euro holdings in Section 7.4. In addition, since the ECB has explicitly stated its intention not to remunerate the digital euro, as also outlined in the proposed legislative framework, we assume a zero remuneration rate under the baseline design.

Nevertheless, the digital euro is intended to be designed such that tools to limit the store of value function would not unduly restrict its use as a means of payment. To mitigate the risk of impairing the usability of the digital euro to send and receive payments by applying a limit on individual digital euro holdings, the ECB has introduced the so-called "waterfall" mechanisms in the digital euro design (ECB, 2023). These mechanisms would allow users to send and receive payments in digital euros for amounts exceeding the holding limit by redirecting the funds to or from their linked non-digital euro accounts.[31] More importantly, these mechanisms would enable users to perform digital euro payments even without holding any digital euro in their wallet. However, based on the available data, we are not able to identify individuals' preferences towards the envisaged waterfall mechanisms and thus do not model such functionalities in our study.

Finally, the digital euro is designed to encompass an automatic funding function enabling users to define rules or conditions under which their digital wallet would be automatically funded. This can include a predefined

[30] Under this set-up, for online payments personal and transaction data would only be accessible to payment intermediaries due to know-your-customer and anti-money laundering requirements.

[31] Specifically, digital euro users would be able to perform digital euro payments even when their digital euro holdings are not sufficient, by pulling the funds needed from their linked accounts ("reverse waterfall approach"). Conversely, digital euro users would be able to receive digital euro payments beyond the holding limit by automatically transferring funds in excess to their linked non-digital euro account ("waterfall approach").

threshold balance[32] or scheduled intervals[33]. The possibility to opt for automatic funding could increase the demand for digital euro holdings. As a consequence, the attribute 'automatic funding' is assigned a value of one.

7 Counterfactual analysis

This section presents the results for the estimated demand for a potential digital euro under the three hypothetical design scenarios: the baseline design, the cash-like design, and the deposit-like design, as outlined in Section 6. Using the estimated demand-side parameters from Table 2 in Section 5, and Table D8 and D9 in Appendix D, we conduct a counterfactual analysis on the digital euro take-up. This analysis yields the aggregate digital euro share, which represents the ratio of total digital euro holdings over total household liquid assets in the euro area. This analysis relies on the assumptions that individual preferences do not change after the introduction of a digital euro, and that there are no endogenous changes in the attributes of deposits and cash after the potential digital euro issuance.

Firstly, in Section 7.1, we show the predicted take-up of a digital euro assuming that consumer preferences were similar to those in 2022. We also show to what extent it could affect the demand for cash and bank deposits.[34] Subsequently, Section 7.2 discusses the impact of each design feature on the demand for a digital euro. Section 7.3 explores heterogeneities in the estimated demand across euro area countries and across different demographic groups. Section 7.4 imposes an illustrative holding limit ex-post on individual digital euro holdings and investigates its impact on the aggregate digital euro share.

7.1 Predicted demand for digital euro holdings

In this section, we predict the potential demand for a digital euro and to what extent it could substitute for cash and bank deposits based on the basic logit model described in Section 3.2. The demand for a digital euro is measured by the aggregate digital euro share, s_{CBDC}, which is generated by aggregating individuals' estimated digital euro shares.

More specifically, the aggregate digital euro share, s_{CBDC}, is calculated as the ratio of total digital euro holdings across all individuals, i, over total liquid assets, $w = \sum_i w_i$, such that $s_{CBDC} = \sum_i s_{i,CBDC} w_i$. This is equivalent to the weighted sum of each individual's CBDC share:

[32] When the digital euro balance falls below a certain level, an automatic transfer of funds is triggered from the linked funding source to the digital euro wallet.

[33] A predetermined amount of funds, within the individual holding limit, is automatically transferred into the digital euro wallet at regular or specified time intervals based on the users' preferences or financial needs.

[34] However, our previous results using older SUCH (2016) data shows that the consumer preferences seem to be rather stable over time.

$$s_{CBDC} = \sum_i \frac{w_i}{w} s_{i,CBDC} \tag{5}$$

where the weight $\frac{w_i}{w}$ is the ratio of each individual's liquid assets over total liquid assets, and $s_{i,CBDC}$ is derived either from the logit model or nested logit model. While the focus of this paper is the baseline digital euro design scenario, we also report the results under the two alternative design scenarios, the cash-like design and deposit-like design.

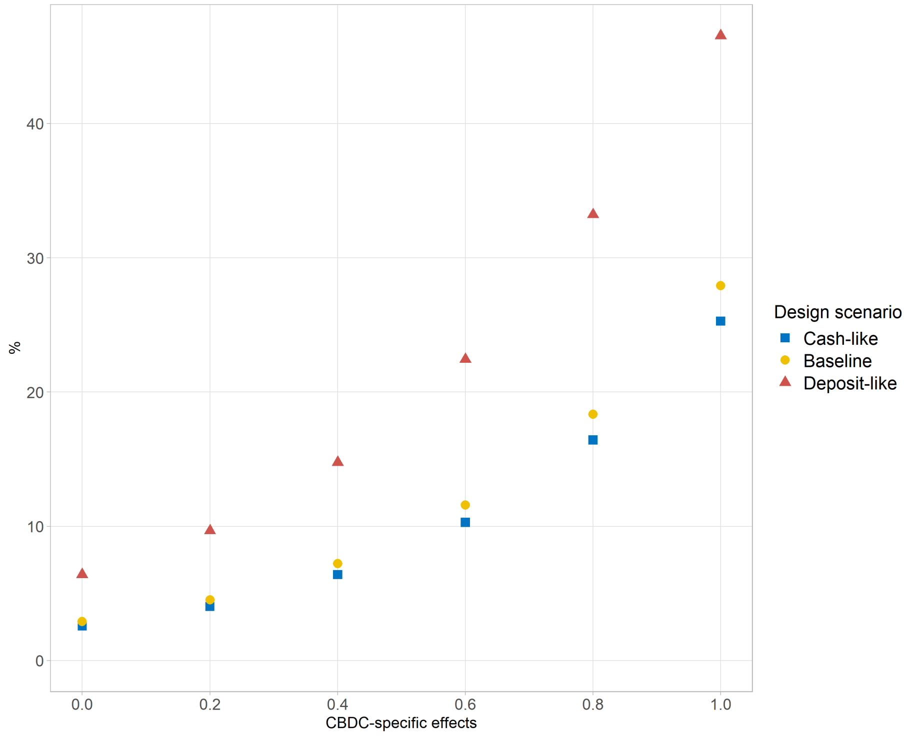
An individual's observed utility for the digital euro, $V_{i,CBDC}$, depends on three components: i) the individuals' preferences towards different product attributes, captured by $\hat{\alpha}' x_{i,CBDC}$, ii) how individuals with different characteristics value the digital euro ($\gamma' z_i$), and iii) the average impact of the unobserved idiosyncratic preferences η_{CBDC}. As explained in Section 3.2, we do not know how consumers would value a product that does not exist yet. Therefore, we need to make assumptions on the CBDC-specific effects (i.e., the effects of the individual characteristics and the effects of the constant) to calculate an individual's observed utility. We assume that they range from being cash-like ($\gamma_{CBDC} = \gamma_c = 0$ and $\eta_{CBDC} = \eta_c = 0$) to being deposit-like ($\gamma_{CBDC} = \gamma_d = \hat{\gamma}$ and $\eta_{CBDC} = \eta_d = \hat{\eta}$). When CBDC-specific effects are identical to cash (deposits), we assume that households perceive a digital euro to be similar to cash (deposits). Figure 1 plots the aggregate shares of the estimated digital euro holdings for different values of CBDC-specific effects on the x-axis.

Figure 1 shows that under the assumed baseline design, the aggregate digital euro share would range between 3% and 28% of total household liquid assets, depending on whether consumers would perceive the digital euro to be similar to cash (the lower bound) or deposits (the upper bound). This implies that between 3-28% of individuals' total liquid assets would be held in digital euro, with the rest being allocated to cash and sight deposits. As plotted, the aggregate digital euro shares increase in the CBDC-specific effects (γ_{CBDC} and η_{CBDC})) across all three design scenarios. When the CBDC-specific effects are closer to being deposit-like ($\gamma_{CBDC} = \hat{\gamma}$ and $\eta_{CBDC} = \hat{\eta}$), individuals would tend to hold more of their liquid assets in digital euros. This is because in our sample, the median euro area citizen holds around 95% of their liquid assets in sight deposits and only 5% of their liquid assets in cash.[35] Therefore, if the digital euro were perceived to be closer to the individuals' preferred liquid asset (deposits), individuals would hold more of it.

Moreover, we find that the aggregate digital euro shares are the highest under the deposit-like design, due to the positive remuneration rate that is unique to this design scenario. In this case, the aggregate digital euro share ranges between 6% and 47%. Instead, the cash-like design yields the lowest aggregate digital euro shares, between 3% and 25%. Therefore, we find that the difference in the aggregate digital euro shares under the baseline and cash-like design scenarios is very small and is mainly driven by the anonymity/privacy and automatic funding features. Under our baseline design, the digital euro offers a lower level of anonymity

[35] The definition of liquid assets here is the sum of sight deposits and cash holdings. These numbers are based on the SPACE survey and on the HFCS for the imputed sight deposits.

Figure 1: Aggregate digital euro shares of total household liquid assets under different design scenarios



Note: The graph plots the aggregate digital euro shares against different assumptions of the CBDC-specific effects. At point zero (one) on the x-axis, CBDC-specific effects are assumed to be cash-like (deposit-like).

compared to the cash-like design. On the other hand, it features the automatic funding, which is not present in the cash-like design. The effects of these two features on the estimated demand of a digital euro partly offset each other, leading to relatively similar shares of digital euro take-up under the two hypothetical designs.[36]

Under the logit model, the demand for a digital euro is assumed to draw proportionately from cash and sight deposit holdings. This means that, based on the aggregate digital euro shares under the baseline design, deposit holdings would decline by 3% if the digital euro was perceived to be similar to cash, and by 28% if the digital euro was perceived to be similar to deposits.[37] Meanwhile, the decline in cash holdings would correspond to 7% to 33%, respectively. Consistent with the results of Li (2023), we find that the crowding-out effects of the digital euro on the demand for deposits and cash depend to a large extent on the two CBDC-specific effects; the effects of the individual and household characteristics, γ_{CBDC}, and the digital euro fixed effect, η_{CBDC}. We find that our results are robust to using a more complex and sophisticated nested logit model, the results of which are reported in Appendix C.2.

[36]Anonymity/privacy is set to one under the cash-like design and to 0.5 under the baseline design, while automatic funding is assumed to be one under the baseline design and zero under the cash-like design.

[37]These estimates represent the maximum reductions in deposit holdings due to a CBDC introduction given that we do not consider banks' endogenous responses to the introduction of a CBDC. Doing so, would reduce the demand for CBDC and therefore the subsequent decline in demand for sight deposits.

7.2 Impact of different design features

This section investigates how different design features affect the estimated take-up of a digital euro. Table 4 presents the results of a sensitivity analysis where we change the design attributes of a digital euro one-by-one, whilst keeping the other attributes fixed, and assess the impact on the aggregate digital euro share under the baseline design and based on the logit model. The second column indicates the change in the design attribute we consider, while the third and fourth columns display the resulting percentage changes in the digital euro share when the digital euro is perceived to be more similar to cash and deposits, respectively. When the CBDC-specific effects are deposit-like, the percentage changes are smaller compared to when CBDC-specific effects are cash-like. This is because aggregate CBDC shares are higher under deposit-like CBDC effects, and therefore a level change of equal magnitude under cash-like and deposit-like CBDC specific effects, would lead to a smaller percentage change under deposit-like CBDC specific effects.

Table 4: Percentage change in demand when a product attribute is changed under the baseline design

Design attribute	Change in attribute	% Change in CBDC share	
		cash-like CBDC effects	deposit-like CBDC effects
Remuneration rate	0% $\rightarrow$ 0.1%	29.84	19.69
Anonymity	0.5 $\rightarrow$ 1	9.85	6.83
Acceptance rate	1 $\rightarrow$ 0.5	-0.61	-0.44
Online store	1 $\rightarrow$ 0	-2.53	-1.81
Automatic funding	1 $\rightarrow$ 0	-13.03	-9.61
Instant payment	1 $\rightarrow$ 0	-9.82	-7.18
P2P	1 $\rightarrow$ 0	-0.04	-0.03
Contactless	1 $\rightarrow$ 0	-0.52	-0.37

Note: The percentage changes in the aggregate digital euro shares in response to a change in the design attributes based on the logit model. The second column describes the change in a design attribute relative to the baseline design, while keeping all the other attributes unchanged. The last two columns show the percentage change in the aggregate digital share in response to the attribute change, for cash-like and deposit-like CBDC specific effects.

Although the ECB's outlined digital euro design does not foresee that holdings of digital euro would be remunerated, our results show that the estimated demand for digital euro holdings is highly sensitive to a remuneration rate. For example, when we change the remuneration rate from 0% to 0.1%, the aggregate share of individuals' liquid assets allocated to the digital euro increases by 20-30%, depending on the CBDC-specific effects. Moreover, it is important to note that the impact of the remuneration rate depends on the initial level from which the interest rate increases.

Beyond the remuneration rate, our results suggest that changing the anonymity, automatic funding and instant payment features from their baseline specifications affect the take-up of a digital euro significantly. For example, when we increase the feature of anonymity from 0.5 under the baseline design (partial anonymity) to one (full anonymity), the share of digital euro holdings increases by 7-10%, depending on whether the digital euro is perceived to be cash-like or deposit-like. Similarly, excluding the option for automatic funding results in a 10% to 13% decrease in the digital euro share, ceteris paribus. Finally, changing the instant settlement feature from one to zero decreases the demand for a digital euro by 7-10%.

These results are consistent with previous studies. For instance, Li (2023) identifies that the rate of return and anonymity are among the most significant design attributes affecting CBDC demand. Furthermore, our findings are supported by several consumer surveys conducted in the euro area related to the demand for a potential digital euro and its desired design features. For example, a high degree of privacy or anonymity is associated with a greater willingness to hold digital euro (Bijlsma et al., 2023; Bundesbank, 2021; Kantar Public, 2022). In addition, Kantar Public (2022) identifies that instant settlement is among the most important features reported by Europeans for any new payment method.

7.3 Digital euro holdings across consumer types

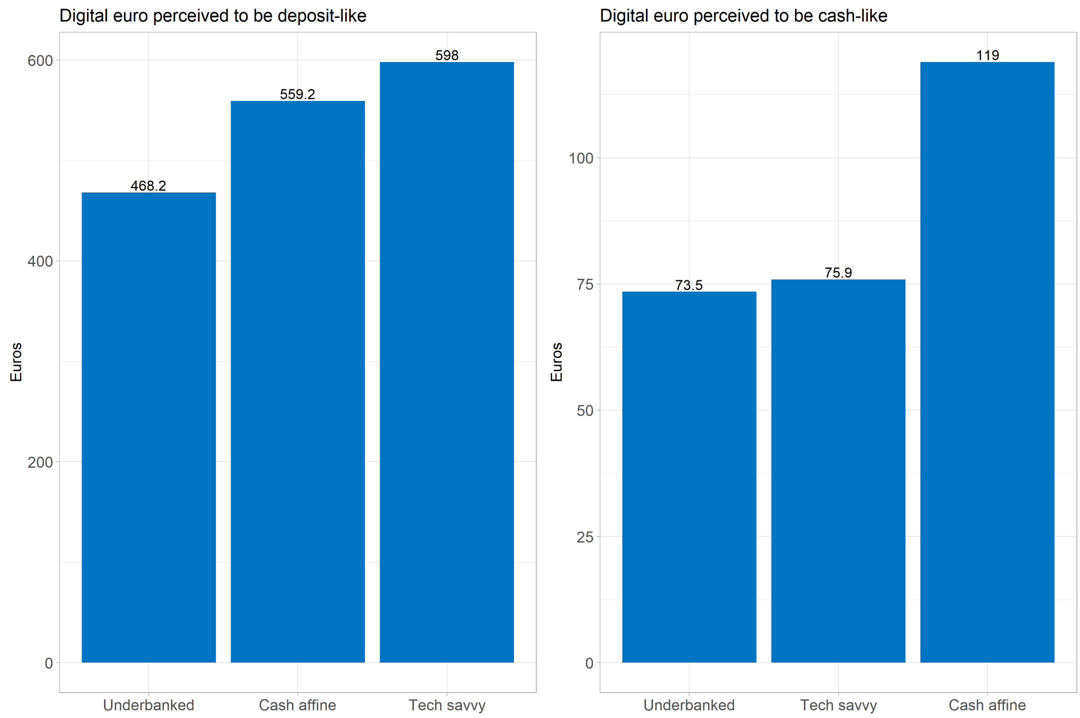
A distinctive feature of our study is that we go beyond considering the role of socio-demographic factors in affecting the demand for a CBDC. As explained in Section 4.2, we classify individuals into cash-affine, tech-savvy, and underbanked consumers based on their current payment preferences, the degree of technology-savviness, and whether they have access to banking services. Our hypothesis is that these consumer types will play distinct roles in the potential uptake of a digital euro. Figure 2 presents the median predicted digital euro holdings across the different consumer types when the effects of the individual characteristics are deposit-like and cash-like, respectively. We concentrate on median holdings instead of averages because the distribution of digital euro holdings is highly skewed.[38]

Figure 2 shows that when individuals perceive the digital euro to be closer to deposits, tech-savvy persons tend to hold more digital euros compared to cash-affine consumers and underbanked individuals. This is in line with our intuition that individuals that are more familiar with technology are more likely to adopt a digital euro when it is perceived as a closer substitute for deposits. This is because when we assume that CBDC-specific effects are deposit-like, individuals in any given consumer group that would prefer to hold more deposits, would also want to hold more digital euros. In addition, given that a digital euro represents a form of digital money, it may be easier for tech-savvy persons to handle a digital euro and related technologies, such as digital wallets.

In contrast, when the CBDC-specific effects are identical to cash, the median cash-affine consumer would hold more digital euros than other consumer types. Table D6 in Appendix D shows that cash-affine users also have larger cash holdings in our sample. In particular, Table 1 in Section 4.1 shows that cash-affine consumers

[38] Here we focus on analysing the predicted holdings of digital euro instead of the shares, mainly because the latter is entangled with the effects of wealth. For example, we find that more tech-savvy individuals tend to hold more digital euro (when perceived to be deposit-like), but they also have more liquid assets. If these two effects cancel out each other, the digital euro shares between the different consumer groups should be similar. If this wealth effect dominates, individuals in more tech-savvy groups could end up having lower digital euro shares in comparison to other consumer types.

Figure 2: Median digital euro holdings by consumer type



favour cash because of attributes such as budgeting usefulness and instant settlement, as well as its ability to preserve anonymity or privacy. A digital euro could therefore appeal to cash-affine users if it offers a high level of privacy, instant settlement, and can be used for budget management.

Moreover, our results suggest that a digital euro could improve financial inclusion because underbanked individuals are also estimated to demand digital euros. In fact, people without access to a bank account or digital devices would also be able to pay with a digital euro by using a token-based version (such as a physical digital euro payment card). Users would also be able to exchange digital euros for cash or vice versa via cash machines (ECB, 2023). However, our results suggest that underbanked people would hold the lowest amount of digital euros in both cases. This could be explained by the fact that underbanked individuals might be less inclined to open a digital euro account with a bank or other service providers as it might be perceived as an obstacle by those who do not currently have a bank account (or a payment card).[39]

The median holdings across other demographic groups, such as age, income, and education level are reported in Figure E4 in Appendix E.

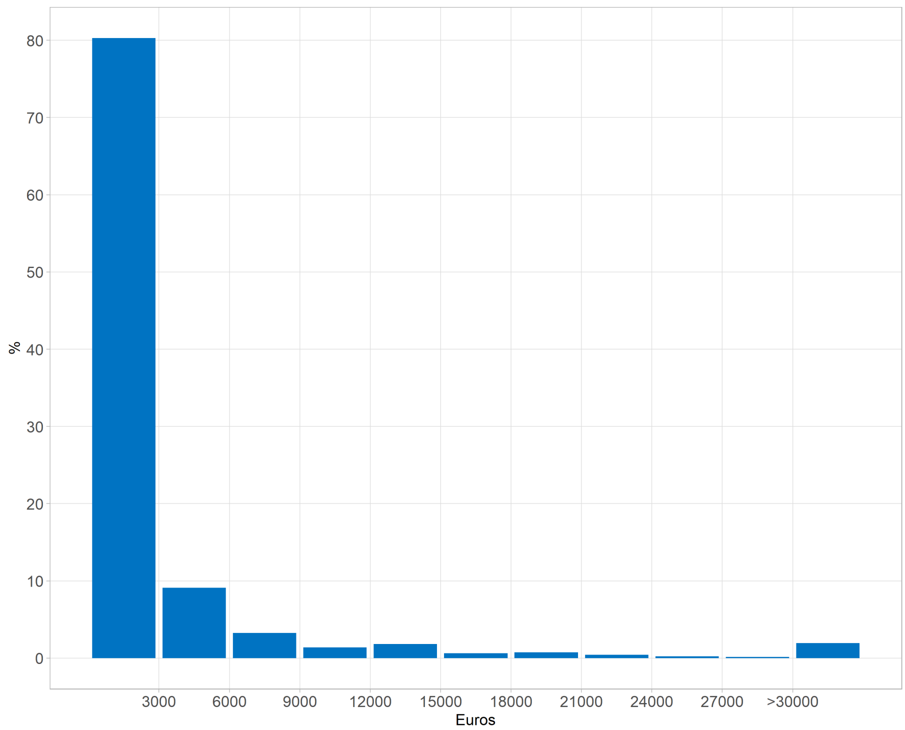
[39]To enhance financial inclusion, the proposed regulation envisages that dedicated authorities will provide basic digital payment services and digital inclusion support face-to-face in physical proximity to persons with disabilities, functional limitations or limited digital skills, and elderly people.

7.4 Impact of imposing a limit on individual digital euro holdings

As explained in Section 6, the implementation of a digital euro would entail safeguards to rule out unwarranted consequences on financial stability and bank intermediation. One effective tool would be to impose a limit on individual holdings to neutralise potential adverse effects by limiting deposit outflows from banks, thereby establishing an upper bound on the total amount of digital euro in circulation. Thus far, initial analyses by the ECB suggest that a €3,000 holding limit per person would avoid negative effects on the financial system (Panetta, 2023b). However, the actual level of the individual holding limits would be calibrated closer to the potential introduction of a digital euro to reflect the economic and financial conditions prevailing at that time.

In this section, we assess the impact of a holding limit on digital euro demand by imposing an illustrative limit of €3,000 ex-post. More specifically, we constrain the estimated digital euro holdings at €3,000 for those exceeding this amount and recompute the aggregate digital euro shares in total household liquid assets. Lastly, we also provide estimates for the overall amount of digital euro in circulation.

Figure 3: Distribution of estimated individual digital euro holdings before imposing a holding limit when the digital euro is perceived to be deposit-like



Note: Estimated digital euro holdings across individuals at the upper range of the estimates (CBDC-specific effects are deposit-like).

Figure 3 shows the distribution of the estimated digital euro holdings across individuals prior to imposing the holding limit at the upper range of the estimates (CBDC-specific effects are deposit-like). We find that

80% of individuals would not be constrained by the €3,000 limit as their estimated digital euro holdings are less than this amount, even at the upper range of the estimates. Table D11 in Appendix D shows that the individuals constrained by the holding limit are generally those that tend to hold a large amount of liquid assets, associated with higher income, education and employment rates (Table D12 Appendix D).[40]

Table D10 in Appendix D shows the estimated average digital euro holding with and without the illustrative holding limit. After capping the holdings at €3,000, the average digital euro holding is €1,100 (in contrast to €3,220 before imposing the limit), in the upper bound scenario where the digital euro is perceived to be similar to deposits. The estimated median holding is €560 both before and after constraining the holdings, meaning that half of the euro area citizens would hold less than this amount. Conversely, in the lower bound scenario where the digital euro is perceived to be similar to cash, the individual's estimated average digital euro holding is €305 (as opposed to €360 under the no holding limit scenario), with a median holding of around €80.[41]

After restricting the individual digital euro holdings to a maximum of €3,000, we also calculate the aggregate digital euro shares under the different hypothetical design scenarios, as explained in Section 7.1. Figure 4 shows a significant decrease in the aggregate digital euro shares in a steady state. Specifically, these findings indicate that after imposing the illustrative holding limit ex-post, the digital euro take-up would fall within a range of 2-9% of household liquid assets under the assumed baseline design compared to 3-28% when the demand is unconstrained.

As a further analysis, we also determine the overall digital euro demand in terms of value, providing an estimate for the total amount of digital euro in circulation.[42] Table 5 displays the estimated amounts of digital euro in circulation with and without the illustrative €3,000 holding limit. Under our baseline design, we find that the amount of digital euro in circulation ranges between €0.12 - €1.11 trillion when the demand is not restricted, depending on whether individuals would perceive digital euro to be closer to cash or deposits. After imposing the holding limit, the findings suggest that the total digital euro demand could range between €0.10 and €0.38 trillion. To put these results into perspective, the amount of euro banknotes in circulation was €1.57 trillion at the end of 2022.[43]

Our results are overall consistent with those of previous studies introduced in Section 2, albeit yielding more moderate upper bound estimates. Thus far, the ECB's preliminary analyses indicate that digital euros amounting to a total of between €1.0 to €1.5 trillion would not have negative effects for the financial system (Panetta, 2023b). Our results suggest that in normal times, assuming an unremunerated digital euro, it is unlikely that the demand would exceed this threshold even if the demand is unconstrained. Meller and Soons (2023)

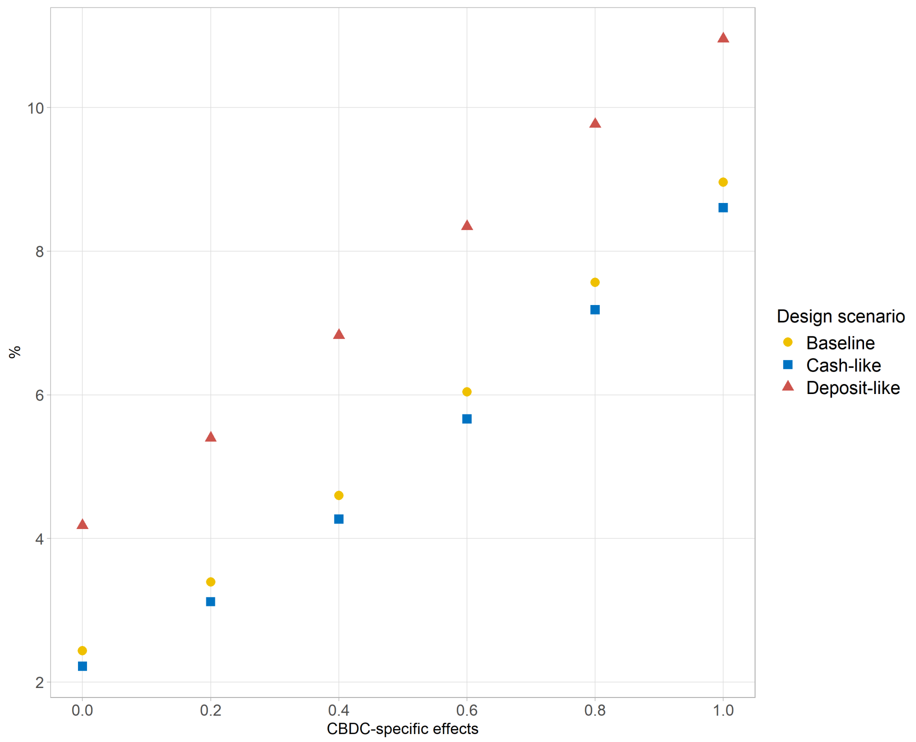
[40] We find that the average digital euro share among those demanding less than and more than €3,000 digital euros is comparable (26% and 30%, respectively).

[41] The individual's median digital euro holding remains the same after imposing the holding limit ex-post.

[42] We extrapolate the total amount of digital euro in circulation by multiplying the estimated average digital euro holding by the size of the population in the euro area, which was about 340 million at the end of 2022.

[43] The data series underlying this estimation can be found under: `https://data.ecb.europa.eu/publications/ecbeurosystem-policy-and-exchange-rates/3030618`.

Figure 4: Aggregate digital euro shares of total household liquid assets under different design scenarios after imposing the illustrative holding limit



Note: The graph plots the aggregate digital euro shares against different assumptions of the CBDC-specific effects. At point zero (one) on the x-axis, CBDC-specific effects are assumed to be cash-like (deposit-like).

Table 5: Overall digital euro take-up (EUR billions)

	Cash-like CBDC-specific effects	Deposit-like CBDC-specific effects
Without a holding limit	123.5	1105.5
With a holding limit	104.5	382.4

Note: The cash-like CBDC-specific effects and deposit-like CBDC-specific effects represent the lower and upper bound of the predicted digital euro demand, respectively.

simulate how banks might respond to different retail deposit outflows and find that the impact of a digital euro introduction on banks' liquidity risks and funding structures would have been contained in the event of a €3,000 holding limit, had it been hypothetically introduced in 2021. Our study also contributes to the literature by estimating the effects of a holding limit, suggesting that a cap of €3,000 digital euros per person would not affect the individual holdings significantly since the majority of individuals are estimated to hold less than this threshold.

8 Extension: Estimating demand for digital euro transactions

Our analysis goes beyond just estimating demand for CBDC holdings and as an extension also estimates the transaction demand for CBDC. In this section, we apply our framework to estimate the potential demand for digital euro transactions in relation to existing means of payments, including cash, cards and mobile payments. Therefore, in contrast to the previous analysis in this paper, we focus on the determinants influencing the use of a digital euro for payment purposes. As an outcome of this analysis we get the share of digital euro transactions out of the total value of retail transactions in a steady state.

By employing the methodology described in Section 3, we first estimate how the preferences for different product attributes, the effects of individual characteristics, and the constant, explain individuals' money spent using existing digital payments and cash, as opposed to assets allocated to cash holdings and sight deposits in the previous analysis. In order to empirically estimate the demand parameters, we use data from the SPACE 2022 and the corresponding German survey as described in Section 4. In our analysis, digital payments include transactions conducted with non-cash payment instruments related to purchases at physical and online stores as well as payments between individuals.[44] Figure 7 in Appendix E displays significant heterogeneities in payment patterns across euro area countries. In particular, Slovenia, Malta and Austria have the highest inclination towards cash payments, accounting for approximately 60% of the total value of transactions. Meanwhile, in Finland cash transactions constituted less than 15% of the total value of transactions in 2022.

First, we re-estimate Equation (2) by using the log of the ratio of digital transaction values to cash transaction values (i.e., the log of value of digital payments over the value of cash payments) as the dependent variable in the model (instead of the log of sight deposits over cash holdings).[45] Then, we use the derived estimated demand-side parameters in a counterfactual analysis where we characterise a digital euro as a set of design parameters as explained in Section 6.[46] Finally, we consider the impact of the different design features on the demand for digital euro transactions.

8.1 Estimated demand-side parameters

The estimated preference parameters for the different product attributes and the constant explaining consumer payment choice are reported in Table D13 in Appendix D. We find that most of the coefficients are statistically significant and have a sign that is in line with economic intuition. The sample consists of around 36,000

[44] The POS transactions include payments made with cards and mobile payment solutions. Meanwhile, online transactions include card payments, mobile payments, and credit transfers related to online stores and P2P payments.

[45] Before calculating the dependent variable, (i.e., the log of digital transaction values over cash transaction values), we add one to each individual's value of card transactions and value of cash transactions. We do this in order to keep those individuals in our sample who made no payments with digital payment instruments or cash during the payment diary. Those individuals who made no payments are excluded from the sample.

[46] We consider the same attributes as in the previous digital euro holding analysis apart from the remuneration rate, which is not expected to influence the choice between cash and digital payments.

individuals.

More specifically, we find a strong negative relationship between the merchant acceptance rate and the money spent on existing digital payments in relation to cash payments. This confirms the presumption that merchant acceptance plays a key role in consumers' payment choice. Similarly, our estimates indicate that anonymity/privacy and instant settlement have a negative effect on the value of transactions made with digital payment instruments relative to the value of transactions made with cash. Also, we find that budgeting usefulness, speed, security and ease of use have positive and statistically significant coefficients, because these attributes are based on the relative payment-specific ratings on the advantages of cards and cash.

Moreover, the option for automatic funding has a positive effect on the use of digital payments over cash payments. This is because when using cards, one does not typically have to manually prefund their wallet (i.e., carry enough cash with them). Therefore, individuals that value this feature obtain more utility from using digital payment methods vis-à-vis cash payments. We also find that the coefficients of the e-commerce, P2P, and contactless functionalities have the expected sign and are significant most cases.

The constant, which reflects the average impact of the unobservable individual preferences on the utility from making payments using cards relative to cash, is negative and statistically significant, as shown in Table D13 in Appendix D, suggesting that it reduces the utility from making payments with cards relative to making payments with cash. The adjusted R-squared is 0.57 indicating that the product attributes and the individual characteristics explain a large part of the variation in the dependent variable. The effects of the individual characteristics and the country fixed effects are reported in Table D14 and D15 in Appendix D, respectively.

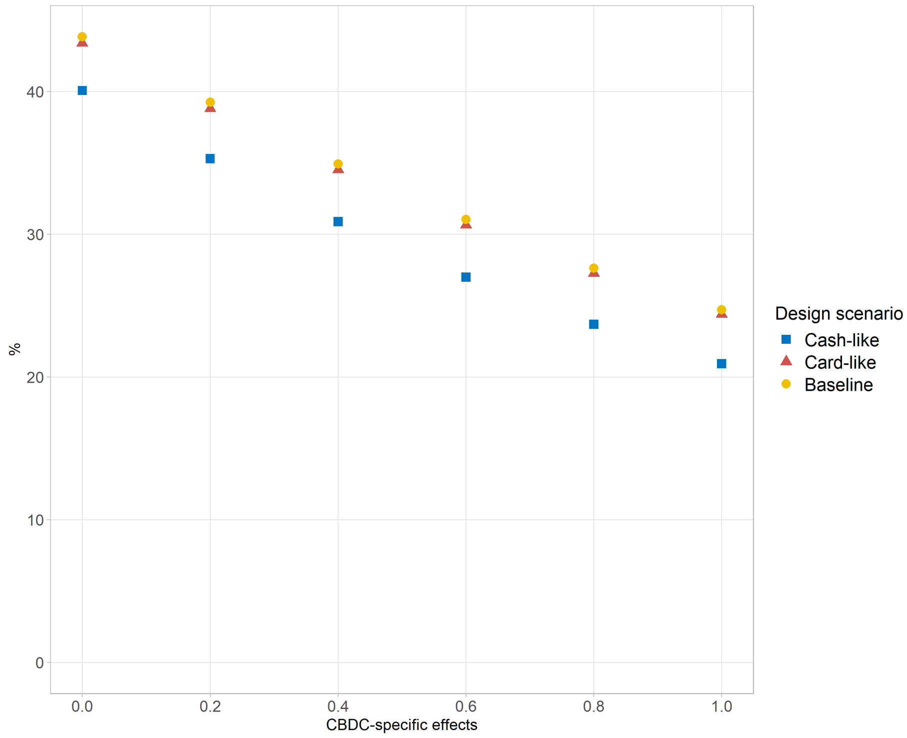
8.2 Predicted digital euro share in the total transaction values

This section presents the counterfactual analysis for the aggregate digital euro share in total transaction values according to the logit model, similarly to Section 7. Figure 5 plots the aggregate digital euro shares against different values of CBDC-specific effects, that is γ_{CBDC} and η_{CBDC}, under the different design scenarios (baseline design, cash-like design and card-like design).

In steady state, our baseline design results suggest that the digital euro payments could range between 25% and 44% of the total retail transaction values, depending on whether individuals would perceive digital euro to be a closer to existing digital payments or cash, respectively. Contrary to the results in Section 7.1, we find the digital euro shares decline with the CBDC-specific effects. In other words, when individuals perceive digital euro to be closer to private digital payment methods (i.e., the larger the effects of the household characteristics and the constant), the lower is the digital euro share in the total transaction values.[47]

[47]This might stem from the fact that during the period under study, cash was still the most frequently used payment method in the euro area, representing 59% of transactions (SPACE 2022). Hence, when digital euro more closely resembles the consumers' currently preferred payment method, they obtain more utility from using it.

Figure 5: Aggregate share of digital euro transaction values under different design scenarios



Note: The graph plots the aggregate digital euro shares against different assumptions of the CBDC-specific effects. At point zero (one) on the x-axis, CBDC-specific effects are assumed to be cash-like (deposit-like).

Under the card-like design, the digital euro share ranges between 24-43%, while under the cash-like design the share ranges between 21-40% of total retail transaction values. These results suggest that the digital euro transactions would be the highest under the baseline design among the three different design scenarios. This is explained by the fact that our baseline design combines the most attractive features from the card-like and cash-like scenarios. For instance, in our baseline design digital euro provides a higher degree of anonymity/privacy than the card-like design, and instant settlement unlike the card-like design. Nevertheless, the difference in the estimated shares under the baseline and card-like designs is negligible. In addition, because the option for automatic funding under the baseline design would eliminate the need to prefund the digital euro wallet, the estimated shares are higher compared to the cash-like scenario.

The distributions of individual digital euro transaction values are reported in Table D16 in Appendix D and Figure E5 in Appendix E.

8.3 Impact of different design features

Table 6 shows the percentage changes in the aggregate digital euro shares in response to a change in the design attributes based on the logit model. The second column describes the change in a design attribute relative to the baseline design, while keeping all the other attributes unchanged. The last two columns show the percentage change in the aggregate digital share in response to the attribute change, for cash-like and deposit-like CBDC specific effects.

Table 6: Percentage change in transactional demand when a product attribute is changed under the baseline design

Design attribute	Change in attribute	% Change in CBDC share	
		cash-like CBDC effects	deposit-like CBDC effects
Anonymity	$0.5 \rightarrow 1$	0.95	1.24
Acceptance rate	$1 \rightarrow 0.5$	-43.74	-50.14
Online store	$1 \rightarrow 0$	-2.37	-3.05
Automatic funding	$1 \rightarrow 0$	-8.71	-11.13
Instant payment	$1 \rightarrow 0$	-4.58	-5.85
P2P	$1 \rightarrow 0$	-0.03	-0.04
Contactless	$1 \rightarrow 0$	-1.93	-2.49

Note: The percentage changes in the aggregate digital euro shares in response to a change in the design attributes based on the logit model. The second column describes the change in a design attribute relative to the baseline design, while keeping all the other attributes unchanged. The last two columns show the percentage change in the aggregate digital share in response to the attribute change, for cash-like and deposit-like CBDC specific effects.

It is immediately apparent from Table 6 that universal merchant acceptance is the most important feature, followed by automatic funding and instant settlement. Specifically, lowering the acceptance rate from a scenario where digital euro is fully accepted to a scenario where it is only partially accepted, reduces the transaction value shares between 44-50%, depending on the realisation of the CBDC-specific effects. Furthermore, eliminating the automatic funding feature, which we find to be one of the key drivers of the demand for both digital euro holdings and transactions, would decrease the share between 9-11%. Finally, if the digital euro was to be issued without the instant settlement feature, the share of digital euro transaction values would be reduced by 5-6% under our baseline design.

Lastly, putting together the results from the two parts of our paper, suggest that the more digital euro resembles cash (i.e., the closer substitute it is perceived to be for cash than for private digital money), the lower the expected digital euro holdings and the higher the expected digital euro transactions, and vice versa. Therefore, if the public perceives the digital euro as a digital version of cash, the expected substitution away from bank deposits, and the overall impact on financial intermediation, would be smaller.

9 Conclusion

The potential demand for a digital euro, which depends on its design and the applied safeguards, is a key variable that will determine the economic implications associated with its introduction. As a digital euro would be a novel means of payments, estimating demand is complex given multiple factors that influence potential demand jointly and possibly in opposite directions.[48] Therefore, analyses that shed light on the consequences of specific design features can provide valuable insights. To this end, this paper estimates the potential demand for a digital euro, by applying a structural demand model to euro area survey data. We identify consumer preferences towards a wide range of product features based on how individuals allocate their liquid assets between cash and bank deposits. Assuming that the estimated preferences remain the same after the hypothetical issuance of a digital euro, we employ them to predict the demand for a digital euro, conditional on a set of design features.

Our results suggest that if the demand is unconstrained, the estimated digital euro take-up could lie between 3% and 28% of total household liquid assets, which is equivalent to €0.12 trillion - €1.11 trillion. We also show that under the assumed baseline design, with an illustrative €3,000 holding limit per person, the aggregate digital euro take-up could range between 2% and 9% of total household liquid assets in a steady state. The lower (upper) range of the estimates corresponds to a scenario where individuals perceive digital euro to be more cash-like (deposit-like). This can be translated into a total amount of digital euro in circulation ranging between €0.10 trillion - €0.38 trillion. We find that the majority of individuals would not be affected by the €3,000 cap since their estimated digital euro holdings are less than this amount. At the end of 2022, the amount of euro banknotes in circulation was €1.57 trillion, which exceeds our upper range estimate for digital euro in circulation, also when the demand is not limited. Importantly, the potential launch of a digital euro is unlikely to raise the overall amount of central bank money in circulation in steady state due to the declining use and demand for banknotes, along with the digital euro design, which is meant to act as a digital equivalent of cash.

We find that important design attributes for the attractiveness of a digital euro include a high degree of privacy or anonymity, automatic funding, and instant settlement. Meanwhile, a holding limit and no remuneration are found to be effective tools to curb the maximum amount of digital euro in circulation, thereby avoiding disruption to the financial system. Moreover, the envisaged waterfall functionality, which would enable users to make payments even without holding any digital euro in their wallet, could lower the expected demand even further.

In an extension of the main analysis, we apply our framework to estimate the potential value of digital euro transactions relative to cash and existing digital payments. Our findings suggest that, in steady state, the estimated digital euro payments could range between 25% and 44% of total retail transaction values, depending on consumer perceptions.

Overall, our results suggest that the more the digital euro is perceived to resemble cash, the lower the estimated holdings and the higher the estimated transactions, and vice versa if the digital euro is perceived to more closely

[48] Moreover, such estimation relies on users' current preferences for cash and deposits, which inevitably involves uncertainties and assumptions regarding future user behaviour and market dynamics.

resemble deposits. We find that widespread merchant acceptance is the most important feature for the usage of digital euro as a means of payment.

While our study sheds light on the potential take-up of a digital euro, it is subject to some caveats that should be considered when interpreting the results. Firstly, given that the digital euro is not an existing product, we rely on assumptions on how it could be perceived by the public. This gives rise to a wide range of estimates for the aggregate digital euro shares. Secondly, there are limitations related to data availability. Not all information is available in the SPACE dataset and therefore part of it needs to be imputed from the HFCS. Whilst we apply statistical matching methods used in previous literature to impute individuals' deposits, these methods introduce an additional degree of uncertainty in our estimation procedure. Furthermore, our paper focuses on a steady state where consumers hold the amount of digital euro that maximises their utility, and therefore it does not take into account the transition period where only part of the consumers have adopted a digital euro. However, the diffusion of new technologies typically follows a gradual pattern and is associated with some frictions.

In our study, we do not model the adoption stage, i.e., the stage in which consumers opt to add new product to their portfolio considering the potential costs associated with adopting a digital euro. We prioritise the relevance of the steady state take-up from a financial stability perspective, leaving the exploration of adoption dynamics for future research. Overall, this study offers valuable insights for policymakers and CBDC designers on the potential uptake and usage of a digital euro, the impact of the different design choices, as well as its potential consequences for the demand of cash and deposits in the euro area.

References

Adalid, R., Álvaro Álvarez Blázquez, Assenmacher, K., Burlon, L., Dimou, M., López-Quiles, C., Fuentes, N. M., Meller, B., Muñoz, M. A., Radulova, P., d'Acri, C. R., Shakir, T., Šílová, G., Soons, O., and Veghazy, A. V. (2022). Central bank digital currency and bank intermediation. Occasional Paper Series 293. European Central Bank.

Ahnert, T., Hoffman, P., Leonello, A., and Porcellacchia, D. (2022). CBDC and financial stability. Working Paper Series 2783. European Central Bank.

Albertazzi, U., Burlon, L., and Pavanini, N. (2020). The shadow value of central bank's refinancing operations. Working Paper Series 2480. European Central Bank.

Bidder, R., Jackson, T., and Rottner, M. (2024). CBDC and banks: Disintermediating fast and slow. Discussion Paper 15/2024. Deutsche Bundesbank.

Bijlsma, M., van der Cruijsen, C., Jonker, N., and Reijerink, J. (2023). What triggers consumer adoption of central bank digital currency? Journal of Financial Services Research. vol. 65(1), pages 1-40.

Bindseil, U. (2023). Tiered CBDC and the financial system. Working Paper Series 2351. European Central Bank.

Brunnermeier, M. and Landau, D. (2022). The digital euro: policy implications and perspectives. Study requested by the ECON committee. European Parliament.

Bundesbank, D. (2021). What do households in Germany think about the digital euro? First results from surveys and interviews. Monthly Report. October 2021, pp. 65-84.

Bundesbank, D. (2022). Payment behaviour in Germany in 2021.

Burlon, L., Muñoz, M. A., and Smets, F. (2024). The optimal quantity of CBDC in a bank-based economy. AEJ: Macroeconomics. forthcoming.

ECB (2020). Report on a digital euro. October 2020.

ECB (2022). Progress on the investigation phase of a digital euro – second report. European Central Bank.

ECB (2023). A stocktake on the digital euro: Summary report on the investigation phase and outlook on the next phase. European Central Bank.

Egan, M., Hortaçsu, A., and Matvos, G. (2017). Deposit competition and financial fragility: Evidence from the US banking sector. American Economic Review. vol. 107(1), pages 169-216.

European Commission (2023). Regulation of the european parliament and of the council on the establishment of the digital euro. https://perma.cc/36VB-QLGE.

Gross, M. and Letizia, E. (2023). To demand or not to demand: on quantifying the future appetite for CBDC. IMF Working Paper 2023/009. International Monetary Fund.

Hemingway, B. (2022). The impact of central bank digital currency on bank deposits and the interbank market. Working Paper Series 110. Bank of Lithuania.

Hernandez, L., Nicole, J., and K., A. (2017). Cash versus debit card: The role of budget control. Journal of Consumer Affairs. vol. 51(1), pages 91–112.

HFCS (2023). The household finance and consumption survey: Results from the 2021 wave. Statistics Paper Series 46. European Central Bank.

Huynh, K., Molnar, J., Shcherbakov, O., and Yu, Q. (2020). Demand for payment services and consumer welfare: The introduction of a central bank digital currency. Staff Working Paper 2020-7. Bank of Canada.

Jonker, N. and Kosse, H. (2013). Estimating cash usage: The impact of survey design on research outcomes. De Economist. vol. 161(1), pages 19-44.

Kantar Public (2022). Study on new digital payment methods. March 2022.

Kosse, A. and Mattei, I. (2023). Making headway – Results of the 2022 BIS survey on central bank digital currencies and crypto. BIS Papers 136. Bank for International Settlement.

Li, J. (2023). Predicting the demand for central bank digital currency: A structural analysis with survey data. Journal of Monetary Economics. vol. 134, pages 73-85.

Li, J., Usher, A., and Zhu, Y. (2024). Central bank digital currency and banking choices. Staff Working Papers 24-4. Bank of Canada.

Meller, B. and Soons, O. (2023). Know your (holding) limits: CBDC, financial stability and central bank reliance. Occasional Paper Series 326. European Central Bank.

Nocciola, L. and Zamora-Pérez, A. (2024). Transactional demand for central bank digital currency. Working Paper Series 2926. European Central Bank.

Panetta, F. (2022a). The digital euro and the evolution of the financial system. Introductory statement at the ECON Committee of the European Parliament. 15 June 2022.

Panetta, F. (2022b). A digital euro that serves the needs of the public: striking the right balance. Introductory statement at the ECON Committee of the European Parliament. 30 March 2022.

Panetta, F. (2023a). A digital euro: widely available and easy to use. Introductory statement by Fabio Panetta, Member of the Executive Board of the ECB, at the Committee on Economic and Monetary Affairs of the European Parliament. 24 April 2023.

Panetta, F. (2023b). Interview with Les Echos. Interview with Fabio Panetta, Member of the Executive Board of the ECB, conducted by Karl de Meyer. 24 May 2023.

Rubin, D. (1986). Statistical matching using file concatenation with adjusted weights and multiple imputations. Journal of Business and Economic Statistics. vol. 4(1), pages 87-94.

Schmidt, T. (2014). Consumers' recording behaviour in payment diaries – Empirical evidence from Germany. Survey Methods: Insights from the Field.

SPACE (2022). Study on the payment attitudes of consumers in the euro area (SPACE). European Central Bank.

Villas-Boas, S. B. (2007). Vertical relationships between manufacturers and retailers: Inference with limited data. Review of Economic Studies. vol 74(2), pages 625–52.

Von Kalckreuth, U., Schmidt, T., and Stix, H. (2014). Using cash to monitor liquidity: Implications for payments, currency demand, and withdrawal behavior. Journal of Money, Credit and Banking. vol. 46(8), pages 1753-1785.

Whited, T., Wu, Y., and Xiao, K. (2023). Will central bank digital currency disintermediate banks? HIS Working Paper 47. Institut für Höhere Studien.

Appendix

A Nested logit model

As the logit model's substitution pattern uniformly draws from deposits and cash, this section introduces a more flexible solution based on the so-called nested logit model, closely following Li (2023). This is relevant to capture the impact of different digital euro design scenarios. For instance, if a digital euro is a closer substitute to deposits, it is reasonable to expect a more significant decline in the demand for deposits, with a relatively smaller impact on the demand for cash. This is not captured by the logit model where the deposit-to-cash ratio remains stable.

Under a nested logit model, the unobserved utility shock, $\epsilon_i = (\epsilon_{i,c}, \epsilon_{i,d}, \epsilon_{i,CBDC})$, that captures individual preferences, is distributed jointly as a generalized extreme value, and can be correlated across products that are more similar substitutes. This means that demand for digital euro would mainly draw from its closer substitute.

Suppose that a digital euro is a closer substitute to deposits in the sense that they are part of the same nest, meaning that the unobserved utilities for digital euro and deposits are correlated. Such a scenario could arise when both digital euro and deposits share a feature, which cannot be identified empirically since there is no data on individuals' perceptions towards this feature, such as a feature of digital payments. This could drive the correlation between their unobserved utilities, and thus modelled indirectly through the nested logit approach.

More specifically, the conditional probability of choosing digital euro from the nest, denoted as $s_{i,CBDC}$, represents the probability of selecting digital euro after taking into account the other products in the nest, multiplied by the probability of choosing the nest as a whole. Therefore, under the nested logit model, the share of digital euro holdings out of an individual's total liquid assets is given by:

$$s_{i,CBDC} = \frac{exp(\frac{V_{i,CBDC}}{\tau_d})}{exp(\frac{V_{i,CBDC}}{\tau_d}) + exp(\frac{V_{i,d}}{\tau_d})} \frac{[exp(\frac{V_{i,CBDC}}{\tau_d}) + exp(\frac{V_{i,d}}{\tau_d})]^{\tau_d}}{[exp(\frac{V_{i,CBDC}}{\tau_d}) + exp(\frac{V_{i,d}}{\tau_d})]^{\tau_d} + exp(V_{i,c})} \tag{6}$$

where $\tau_d = \sqrt{1 - \varrho_{d,CBDC}} \in (0, 1]$ is an inverse measure of the correlation $\varrho_{d,CBDC} \in [0, 1)$ between the unobserved utilities for deposits and digital euro. The observed utilities for digital euro and deposits are scaled by a factor of $\frac{1}{\tau_d}$. This is because a positive correlation between their unobserved utilities would imply a greater role of the observed utilities in explaining the choice between a digital euro and deposits.

In the extreme case that $\varrho_{d,CBDC} = 0$, this reduces to the logit model where the digital euro share (6) would be identical to (5). When $\varrho_{d,CBDC} > 0$, the demand for a digital euro draws more than proportionally from deposits and the impact of $\varrho_{d,CBDC}$ on the digital euro share depends on the sign of the observed utility difference between digital euro and deposits, $(V_{i,CBDC} - V_{i,d})$.

Under the nested logit model, the share of deposits and cash following the potential digital euro issuance depends on the assumption on whether digital euro is a closer substitute for deposits or cash (i.e., part of the same nest). Suppose that digital euro and deposits are in the same nest, B_{d_CBDC}. Then the share of deposits out of total liquid assets is the conditional probability of choosing deposits from the nest B_{d_CBDC}, multiplied by the probability of choosing the nest B_{d_CBDC}. This is given by the following equation:

$$s'_{i,d} = \frac{exp(\frac{V_{i,d}}{\tau_d})}{exp(\frac{V_{i,CBDC}}{\tau_d}) + exp(\frac{V_{i,d}}{\tau_d})} \frac{[exp(\frac{V_{i,CBDC}}{\tau_d}) + exp(\frac{V_{i,d}}{\tau_d})]^{\tau_d}}{[exp(\frac{V_{i,CBDC}}{\tau_d}) + exp(\frac{V_{i,d}}{\tau_d})]^{\tau_d} + exp(V_{i,c})})$$

The cash share, in turn, under this scenario would be given by:

$$s'_{i,c} = \frac{exp(V_{i,c})}{[exp(\frac{V_{i,CBDC}}{\tau_d}) + exp(\frac{V_{i,d}}{\tau_d})]^{\tau_d} + exp(V_{i,c})}$$

where $\tau_d = \sqrt{1 - \varrho_{d,CBDC}} \in (0,1]$ is an inverse measure of the correlation $\tau_d =$ $varrho_{d,CBDC} \in [0,1)$ between the unobserved utilities for deposits and digital euro.

B Imputation of the deposits

Given that the SPACE 2022 and the HFCS 2023 are not conducted on the same sample of individuals, we use statistical matching techniques to impute the deposits from the HFCS 2023 to the SPACE 2022 data.

In this section, we explain the statistical matching techniques used to impute the deposits from the HFCS 2023 into the SPACE 2022. The HFCS 2023 asks respondents to provide information on the current balance on their sight accounts, which we use to measure the deposits. It is important to note that the SPACE 2022 survey questions are addressed to a given individual, while the HFCS 2023 is a household-level survey where the questions are addressed to a given household. Therefore, we first harmonise the two surveys by converting the HFCS 2023 household-level variables into individual-level indicators, a prerequisite for applying the imputation methodology in a consistent manner.[49]

[49]Given that the HFCS is a household-level survey, the individual-level explanatory variables such as age, gender and education refer to those of the reference person (head of household). When household-level variables need to be used, such as income, we convert these into individual-level indicators by dividing them by the number of adults in the household. Furthermore, most variables (e.g., income) in the HFCS are numerical variables, while in the SPACE the corresponding variables are categorical.

Statistical matching is a method used to combine information from two non-overlapping surveys with common background variables. We use a method of statistical matching which combines both parametric and non-parametric techniques standard in the literature (Rubin, 1986). The purpose of this technique is to generate a single dataset from various datasets, where each dataset contains a specific variable of interest, and all contain some variables in common. Our variable of interest in the HFCS 2023 is the sight deposits, whereas the variables of interest in the SPACE 2022 are all the defined product attributes (e.g., acceptance rate, security, anonymity etc.).

This technique consists of two steps. In the first step, we generate the predicted values of sight deposits, as a function of the other variable of interest (a product attribute) and a set of control variables (all individual and household-level characteristics that are common in the SPACE 2022 and the HFCS 2023).[50] Unlike other statistical matching procedures that assume that variables of interest are conditionally independent given the control variables, Rubin's imputation procedure does not make this assumption. Instead, we assume a partial correlation between the two variables of interest (i.e., between deposits and the attribute). For this exercise, we use three values of partial correlation, $\rho = 0.2$, $\rho = 0.5$ and $\rho = 0.8$. We find that the partial correlation assumed does not have a large effect on the imputed deposits and therefore our baseline specification consists of $\rho = 0.5$. Furthermore, given that there is more than one variable of interest in the SPACE 2022 dataset, the procedure is repeated for the different attributes in Section 4.1.

In the second step, we match the predicted values using a minimum distance criterion, conditional on a set of control variables. This generates the imputed observed value of the match for the missing deposit. In particular, the procedure by Rubin (1986) matches each unit of missing deposits (that is, units in SPACE 2022) with the unit that has the closest new predicted deposit value in HFCS 2023, conditional on identical characteristics informed by the set of common variables. While the imputed deposits are fairly similar under different matching techniques, we find that matching on income and age groups results in an optimal balance between achieving a good match and preserving an adequate number of observations. Both steps of the statistical matching procedure are performed on the country level.

C Additional results

C.1 Effects of individual and household characteristics

The estimated coefficients for individual and household characteristics for the log of the deposit to cash ratio are shown in Table D8 and Table D9 in Appendix D. These are estimated simultaneously with the preference parameters according to Equation (2) in Section 3.

[50] The variables include age, gender, income, education, labour status, household size. For all countries except Germany, we also include four dummy variables that indicate whether the household owns a savings account, a pension account, a mortgage, and any financial investments.

Most of the coefficients for the individual and household-level characteristics are statistically significant and have a sign that is in line with expectations. For example, the coefficient for the income is positive and statistically significant, which implies that individuals with higher income levels have a higher deposit-to-cash ratio. This stems from the fact that individuals with higher incomes tend to accumulate larger savings, which are more likely held in bank deposits. Similarly, we find that individuals belonging to the oldest age group (65 and over) tend to hold more deposits relative to cash, consistent with higher accumulated savings by older individuals compared to their younger counterparts.

Moreover, we find that the education level and occupation status have a significant relation with the deposit-to-cash ratio. For example, the estimation results suggest that higher educated individuals tend to hold a higher fraction of their liquid assets in deposits. Likewise, employed individuals and students are associated with a higher deposit-to-cash ratio compared to unemployed individuals. We also find a negative relationship between being retired and the deposit-to-cash-ratio.

Our estimates also suggest that the perceived access to cash affects the deposit-to-cash ratio. In particular, individuals who perceive it as difficult to find an ATM or a bank in order to withdraw cash tend to hold more deposits relative to cash. In addition, the results confirm the intuition that individuals that receive a larger share of their income in cash have a lower deposit-to-cash ratio.

We also observe large differences in the effects across consumer types. Tech-savvy respondents have a deposit-to-cash ratio 18% higher than individuals who are not tech-savvy. Conversely, cash-affine consumers are associated with a 30% lower ratio of deposits to cash, confirming our presumption that cash-affine individuals would hold more cash in relation to deposits. Finally, the underbanked respondents are associated with a 5% lower ratio of deposits to cash, but the coefficient is not statistically significant.

C.2 Predicted demand under the nested logit model

The nested logit model allows for more flexible substitution patterns, such that a digital euro can be modelled as a closer substitute to deposits or cash, due to the correlated idiosyncratic preferences, as explained in Section 3.2.

Figure E3 plots the aggregate digital euro shares against different levels of correlation between the unobserved utilities of CBDC and deposits or cash, conditional on specific values of CBDC-specific effects. A higher correlation between the unobserved utilities of digital euro and deposits (or cash) implies greater substitutability between the digital euro and deposits (or cash). When the correlation is zero, the predictions are identical to those based on the logit model. Under the nested logit model, the demand for a digital euro depends on both the CBDC-specific effects and on the correlation between digital euro and deposits or cash.

Under the baseline design, the aggregate digital euro take-up ranges between 0.3% and 28% of total household liquid assets based on the nested logit model. Similar to the results under the logit model, we find that the aggregate digital euro share is the highest when the CBDC-specific effects are identical to those of deposits. The same reasoning applies as before. Given that deposits are the preferred liquid asset of individuals in the euro area (they constitute a larger proportion of individuals' total liquid assets), when the digital euro is perceived to be closer to deposits, individuals would demand more of it, as opposed to the case in which it is perceived to be closer to cash.

Furthermore, we find that the correlation between the unobserved utilities of cash and CBDC ($\rho_{cash,CBDC}$) has a much smaller impact on the aggregate digital euro shares, compared to the correlation between the unobserved utilities of deposits and CBDC ($\rho_{deposits,CBDC}$). This is because households only hold a small fraction of their liquid assets in cash. Therefore, in the case that the digital euro has a higher observed utility than cash, the substitution from cash towards the digital euro will be small and therefore will not add much additional demand for the digital euro. On the other hand, the opposite holds in the case that the digital euro and deposits are closer substitutes. The lowest shares are generated when the CBDC-specific effects are identical to those of cash and when the correlation of the unobserved utilities between deposits and CBDC ($\rho_{deposits,CBDC}$) approaches one. Overall, the impact of the correlation between the digital euro and cash or deposits on the aggregate digital euro share depends on the utility difference between digital euro and its closer substitute.

Similar to the case under the logit model, the demand for a digital euro, and hence its impact on the demand for deposits and cash, depends significantly on the CBDC-specific effects. The largest decline in deposits occurs when the digital euro is perceived to be similar to deposits (i.e., CBDC-specific effects are deposit-like). The decline in deposits under the baseline design in the nested logit model varies between 0.03-28%. However, the decline in cash holdings would range between 0.1-33%, which is much higher than under the logit model. Intuitively, this is because cash holdings are much smaller than deposits, and therefore even a small level change would lead to a large percentage change.

C.3 Addressing the potential endogeneity of deposit rate

To address potential endogeneity concerns related to the inclusion of deposit rates, we use an instrumental variable (IV) approach as a robustness. As an instrument for the deposit rate, we use the country-specific pass through of the Euro Short-Term Rate (€STR) to the deposit rate, in the spirit of Villas-Boas (2007), and similar to Egan et al. (2017) and Albertazzi et al. (2020). We construct the instrument as the interaction of the €STR with country-level dummies.

The estimated coefficients are shown in Table D17 in Appendix D. Under this new regression specification, the estimated preferences for product attributes remain mostly unchanged. The coefficient of the deposit rate is smaller compared to our baseline (OLS) estimation and remains statistically insignificant at the 10% level. The constant is higher under this specification.

The estimated CBDC share under the baseline scenario would range between 3% to 35%, depending on whether consumers perceive digital euro to be closer to cash or deposits, respectively. The higher upper bound share relative to our baseline results is mainly driven by the higher regression constant.

D Tables

Table D1: Number and share of respondents across countries

Country	Obs	%
Austria	2049	5.64
Belgium	2377	6.55
Cyprus	673	1.85
Estonia	1285	3.54
Finland	2299	6.33
France	4936	13.59
Germany	3667	10.10
Greece	1460	4.02
Ireland	1576	4.34
Italy	3837	10.57
Latvia	808	2.22
Lithuania	1349	3.71
Luxembourg	836	2.30
Malta	824	2.27
Portugal	1559	4.29
Slovakia	2035	5.60
Slovenia	842	2.32
Spain	3904	10.75

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D2: Distribution of individuals by individual and household level characteristics

Variable	Obs	%
Household size		
1-member	6455	17.77
2-member	12585	34.65
3-member	8024	22.09
4-member	6708	18.47
5 or more	2544	7.01
Age		
18-24	3231	8.90
25-39	2590	7.13
40-54	17805	49.03
55-64	5421	14.93
65 and over	7269	20.02
Gender		
Female	18623	51.28
Male	17666	48.65
Other, non-binary	27	0.07
Education		
Primary/lower secondary	5763	15.87
Upper/post-secondary	16617	45.76
Tertiary	13936	38.37
Occupation		
Employed	22526	62.03
Unemployed	3609	9.94
Student	1856	5.11
Retired	8325	22.92
Income		
EUR 500 or less	2276	6.27
Between EUR 501 and EUR 750	3305	9.10
Between EUR 751 and EUR 1,000	3366	9.27
Between EUR 1,001 and EUR 1,500	8092	22.28
Between EUR 1,501 and EUR 2,000	7464	20.55
Between EUR 2,001 and EUR 2,500	5723	15.76
Between EUR 2,501 and EUR 3,000	2311	6.36
Between EUR 3,001 and EUR 4,000	2719	7.49
Between EUR 4,001 and EUR 6,000	942	2.59
More than EUR 6,000	118	0.32
Internet		
Every day	32098	88.39
Weekly	2775	7.64
Monthly	400	1.10
Less often/Never	1043	2.87
Income in cash		
None	30626	84.33
Half or less	4138	11.39
More than half	1552	4.27
Access to Cash		
DK/Not relevant	362	1.00
Easy	32479	89.43
Difficult	3475	9.57

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D3: Socio-demographics of the consumer types

Variable	Cash-affine	Tech-savvy	Underbanked
Household size			
1-member	19.18	17.24	14.03
2-member	32.13	34.50	30.86
3-member	22.03	22.09	24.51
4-member	18.54	19.05	21.16
5 or more	8.12	7.12	9.43
Age			
18-24	10.57	9.27	16.71
25-39	7.11	7.53	7.74
40-54	49.59	49.35	41.31
55-64	14.50	14.28	13.30
65 and over	18.22	19.58	20.93
Gender			
Female	50.89	51.40	54.03
Male	49.07	48.53	45.79
Other, non-binary	0.04	0.07	0.17
Education			
Primary/lower secondary	18.57	14.54	20.47
Upper/post-secondary	49.43	43.71	45.74
Tertiary	32.00	41.75	33.80
Occupation			
Employed	57.97	64.58	57.03
Unemployed	12.30	8.95	13.80
Student	6.17	5.28	9.84
Retired	23.56	21.19	19.33
Income			
Average income (in euros)	1539.68	1785.78	1335.80
Internet			
Every day	80.96	90.63	82.91
Weekly	10.15	6.90	10.10
Monthly	1.95	0.90	1.98
Less often/Never	6.94	1.56	5.01
Income in cash			
None	72.32	86.91	71.38
Half or less	18.38	10.18	20.87
More than half	9.30	2.91	7.74
Access to Cash			
DK/Not relevant	2.67	0.55	5.97
Easy	88.28	89.73	84.51
Difficult	9.05	9.72	9.52

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D4: Fraction of different types of payments by country

Country	Card Acceptance	Contactless	Online	P2P
Austria	0.82	17.33	18.79	5.33
Belgium	0.84	17.92	22.41	5.40
Cyprus	0.87	27.73	18.38	8.20
Estonia	0.92	25.44	15.25	5.26
Finland	0.95	45.80	16.81	5.73
France	0.86	20.49	17.51	4.06
Germany	0.80	21.97	8.93	4.56
Greece	0.89	27.44	18.28	6.09
Ireland	0.86	25.94	19.07	6.03
Italy	0.84	15.57	14.57	5.03
Latvia	0.82	29.89	13.61	5.85
Lithuania	0.78	19.91	14.68	6.89
Luxembourg	0.89	34.80	16.61	7.11
Malta	0.65	15.47	10.42	6.97
Portugal	0.82	15.36	16.17	4.94
Slovakia	0.77	28.39	16.46	6.60
Slovenia	0.82	19.06	12.24	5.38
Spain	0.86	20.23	14.93	5.10

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D5: Correlation between the three consumer types

	Cash-affine	Tech-savvy	Underbanked
Cash-affine	1		
Tech-savvy	-0.54	1	
Underbanked	0.11	-0.07	1

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D6: Summary statistics of liquid assets by consumer type

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Sight deposits						
Tech-savvy	1	597.0	2501.0	15370.0	11980.0	1000000
Cash-affine	1	419.5	1751.0	8628.0	7001.0	500000
Underbanked	1	412.5	1751.0	10480.0	7948.0	1000000
Cash holdings						
Tech-savvy	1	30.0	75.1	323.8	222.0	11260
Cash-affine	1	63.0	163.9	586.6	436.1	14970
Underbanked	1	40.0	96.0	395.6	274.5	11000
Total liquid assets						
Tech-savvy	1	617.0	2382.0	14730.0	10450.0	1003000
Cash-affine	1	594.5	2021.0	8649.0	7244.0	500200
Underbanked	1	456.0	1782.0	9929.0	6469.0	1003000

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D7: Proportion of consumer types per each country's respondents

Country	Cash-affine	Tech-savvy	Underbanked
Austria	53.44	45.88	7.08
Belgium	30.58	68.53	9.47
Cyprus	47.70	62.11	23.77
Estonia	36.03	67.47	7.86
Finland	15.44	81.51	2.13
France	36.20	68.48	9.79
Germany	43.01	52.44	0.30
Greece	48.08	61.03	15.21
Ireland	42.77	59.14	15.36
Italy	51.84	64.95	12.67
Latvia	42.70	68.94	5.82
Lithuania	51.37	63.53	12.45
Luxembourg	25.12	72.85	7.42
Malta	66.14	52.67	19.42
Portugal	47.02	66.07	15.72
Slovakia	48.35	68.89	5.11
Slovenia	63.42	59.03	12.00
Spain	49.95	59.89	10.86

Note: The percentages do not add up to 100 because the consumer groups are not mutually exclusive.

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D8: Estimated effects of individual and household characteristics

Variable	Log(deposit/cash)
Age	
25-39	-0.054
40-54	-0.232***
55-64	-0.145*
65 and over	0.245***
Income	
Income(log)	0.884***
Household size	
2-member	0.263***
3-member	0.391***
4-member	0.586***
5 or more	0.538***
Gender	
Male	0.055*
Non-binary	0.126
Education	
Upper/post	0.014
Tertiary	0.163***
Internet	
Every day	-0.039
Weekly	-0.22**
Monthly	-0.081
Access to Cash	
Difficult	0.141***
DK/Not relevant	0.457***
Income in cash	
Half or less	-0.403***
More than half	-0.35***
Occupation	
Employed	0.354***
Student	0.278***
Retired	-0.198***
Consumer type	
Tech savvy	0.182***
Cash affine	-0.295***
Underbanked	-0.053

Note: Standard errors are clustered on the individual level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D9: Country fixed effects

Variable	Log(deposit/cash)
Belgium	-0.993
Cyprus	0.208
Estonia	0.845*
Finland	0.626
France	0.069
Germany	1.256**
Greece	0.565***
Ireland	2.273***
Italy	0.64
Latvia	-0.766
Lithuania	1.299***
Luxembourg	1.436**
Malta	0.345
Portugal	1.296***
Slovakia	0.345
Slovenia	1.436***
Spain	0.827***

Note: Standard errors are clustered on the individual level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D10: Distribution of individual digital euro holdings before and after imposing the holding limit

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Without holding limit						
Deposit-like CBDC-specific effecs	0.045750	140.00	564.50	3222.0	2096.0	212200
Cash-like CBDC-specific effecs	0.003395	22.47	82.01	360.0	284.6	39680
With holding limit						
Deposit-like CBDC-specific effecs	0.045750	140.00	564.50	1115.0	2096.0	3000
Cash-like CBDC-specific effecs	0.003395	22.47	82.01	304.6	284.6	3000

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D11: Liquid assets of individuals less or more than 3,000 digital euros

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Less than 3K						
Digital euro holdings	0.05	96.9	353.0	652.0	973.0	3.00e+03
Liquid assets	1.00	432.0	1350.0	3830.0	3560.0	6.54e+04
Digital euro share	4.41	19.1	26.0	28.0	43.3	4.99e+01
More than 3K						
Digital euro holdings	3000.00	4100.0	6430.0	13700.0	13700.0	2.12e+05
Liquid assets	6180.00	15000.0	22800.0	48500.0	51700.0	1.00e+06
Digital euro share	4.48	21.0	26.5	31.8	47.3	4.99e+01

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D12: Socio-demographics of individuals with estimated digital euro holdings less or more than €3,000

Variable	Less than 3000	More than 3000
Household size		
1-member	18.54	14.65
2-member	34.12	36.81
3-member	22.15	21.86
4-member	18.22	19.47
5 or more	6.89	6.93
NA	0.07	0.27
Age		
18-24	9.71	5.59
25-39	7.11	7.22
40-54	48.86	49.69
55-64	15.38	13.08
65 and over	18.93	24.42
Gender		
Female	52.72	45.43
Male	47.20	54.53
Other, non-binary	0.08	0.04
Education		
1	16.96	11.43
2	47.25	39.68
3	35.79	48.90
Occupation		
Employed	60.61	67.78
Retired	22.68	23.93
Student	5.61	3.09
Unemployed	11.10	5.20
Income		
Average income (in euros)	1628.81	2131.57
Internet		
Every day	87.90	90.36
Weekly	7.88	6.65
Monthly	1.11	1.08
Less often/Never	3.11	1.91
Income in cash		
None	83.93	85.97
Half or less	11.74	9.97
More than half	4.33	4.05
Access to Cash		
DK/Not relevant	1.09	0.63
Easy	89.18	90.49
Difficult	9.74	8.89

Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Table D13: Estimated preferences for product attributes, ratio of cashless/cash transaction values

Variable	Log(cashless/cash)
Online payment	0.018***
Acceptance rate	0.778***
Anonymity/privacy	-0.043***
Budgeting usefulness	0.063***
Instant settlement	-0.048***
Speed	0.054***
Security	0.089***
Automatic funding	0.119***
Ease of use	0.041***
P2P payment	0
Contactless	0.014***
Constant	0.473***
Adjusted R-squared	0.798
Observations	36316

Note: Standard errors are clustered on the individual level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D14: Estimated effects of individual and household characteristics, ratio of cashless/cash transaction values

Variable	Log(cashless/cash)
Age	
25-39	-0.001
40-54	0.03
55-64	0.064
65 and over	0.097**
Income	
Income(log)	0.025*
HH size	
2-member	0.053**
3-member	0.035
4-member	0.045*
5 or more	0.099***
Gender	
Male	-0.023
Non-binary	-0.318
Education	
Upper/post	-0.032
Tertiary	-0.001
Internet	
Every day	0.078
Weekly	0.054
Monthly	0.017
Access to Cash	
Difficult	0.062**
DK/Not relevant	0.174**
Income in cash	
Half or less	-0.121***
More than half	-0.098**
Occupation	
Employed	0.048*
Student	0.011
Retired	0.038
Consumer types	
Tech savvy	0.327***
Cash affine	-4.272***
Underbanked	-0.096***

Note: Standard errors are clustered on the individual level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D15: Country fixed effects explaining, ratio of cashless/cash transaction values

Variable	Log(cashless/cash)
Cyprus	-0.094
Estonia	0.303***
Finland	0.476***
France	0.387***
Germany	0.064
Greece	0.008
Ireland	0.081
Italy	-0.006
Latvia	0.035
Lithuania	0.001
Luxembourg	0.513***
Malta	-0.103*
Portugal	0.231***
Slovakia	0.021
Slovenia	-0.127**
Spain	0.011
Adjusted R-squared	0.798

Note: Standard errors are clustered on the individual level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D16: Summary statistics of individuals' estimated digital euro transaction values

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Cash-like CBDC-specific effecs	0.004447	8.422	20.93	45.44	46.49	5228
Card-like CBDC-specific effecs	0.000940	3.932	10.90	27.58	27.11	4985

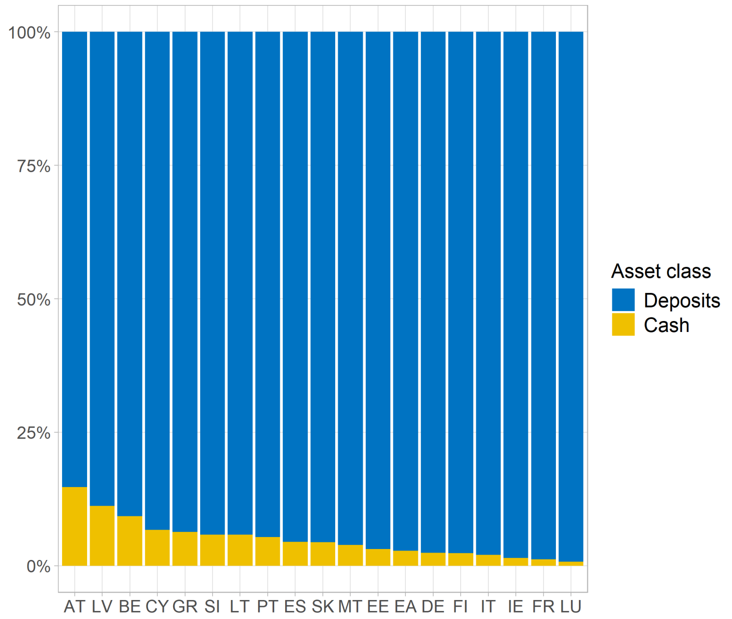
Table D17: Estimated preferences for product attributes based on the IV approach

Variable	Log(deposit/cash)
Deposit rate	1.850
Online payment	0.027***
Acceptance rate	0.013
Anonymity/privacy	-0.201***
Budgeting usefulness	0.095***
Instant settlement	-0.11***
Speed	0.147***
Security	0.151***
Automatic funding	0.148***
Ease of use	0.065***
P2P payment	0
Contactless	0.006***
Constant	0.406

Note: Standard errors are clustered on the individual level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

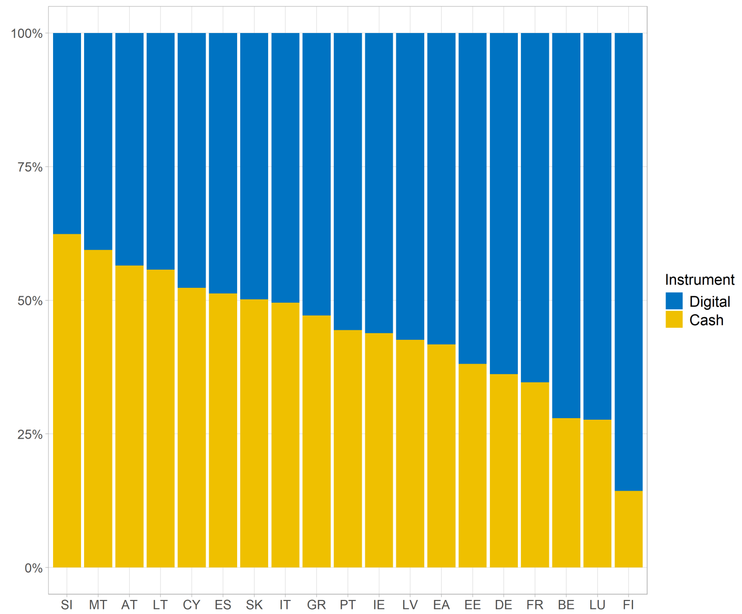
E Figures

Figure 6: Share of sight deposits and cash holdings in liquid assets by country



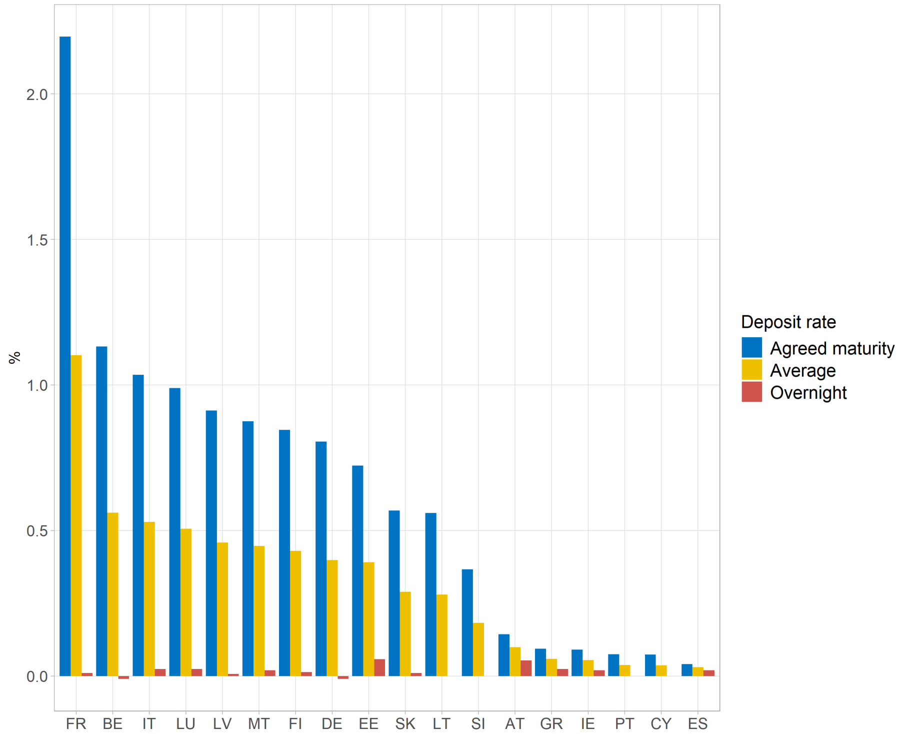
Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Figure 7: Share of payment instruments in retail transaction values by country



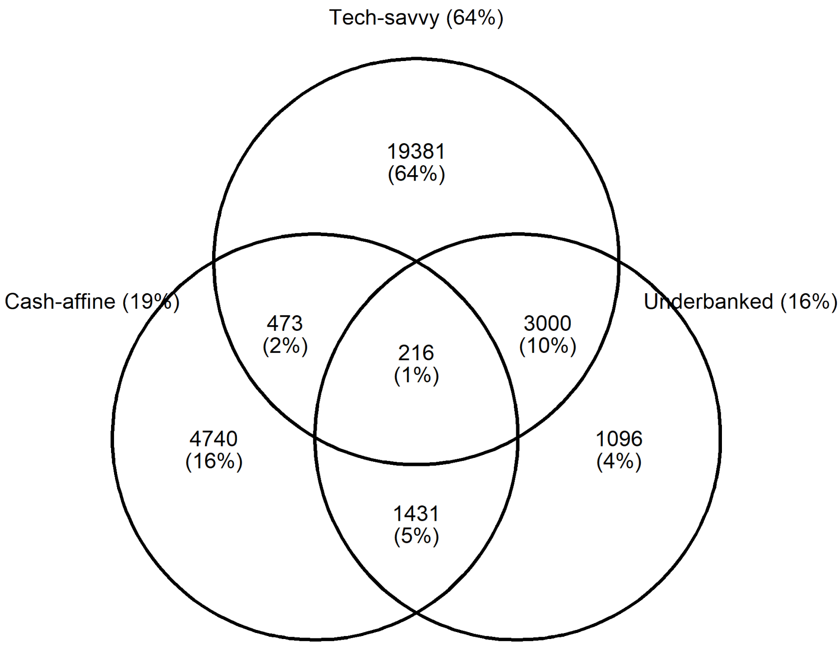
Sources: ECB, SPACE (2022), HFCS (2023) and Bundesbank, Payment behaviour in Germany (2022).

Figure E1: Deposit rates by country



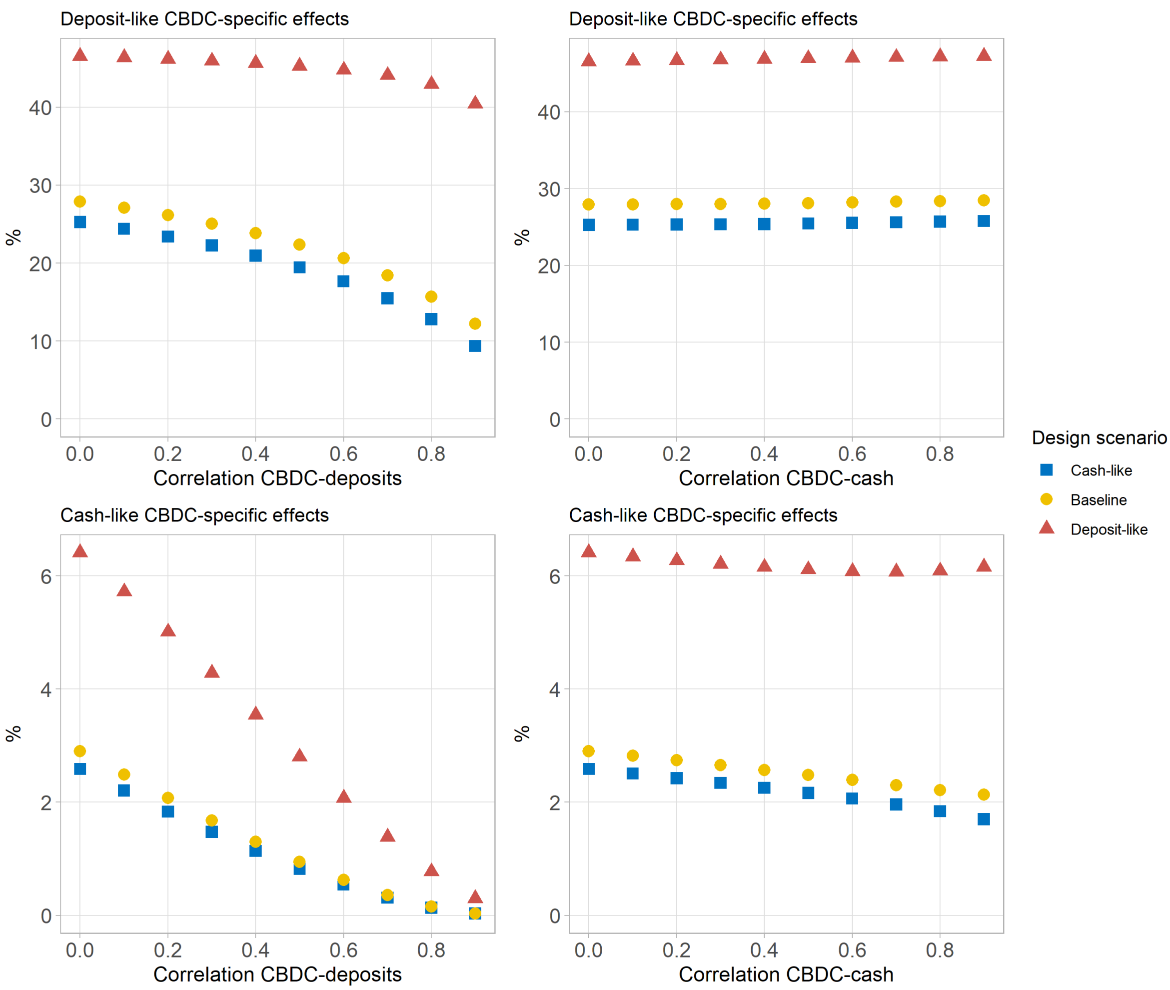
Source: ECB, MFI Interest Rate Statistics.

Figure E2: Venn diagram of the consumer types



None of the consumer types: 5979 (16%).

Figure E3: Aggregate digital euro shares of total household liquid assets based on the nested logit model



Note: The left (right) panel plots the aggregate CBDC shares against different levels of correlation between the unobseved utilities for CBDC and deposits (cash), conditional on different values for the CBDC-specific effects. The correlation ranges from 0-0.99. A higher correlation implies greater substitutability between CBDC and deposits (cash).

Figure E4: Median digital euro holdings by demographic groups: digital euro perceived to be deposit-like (cash-like) on the left (right) panel

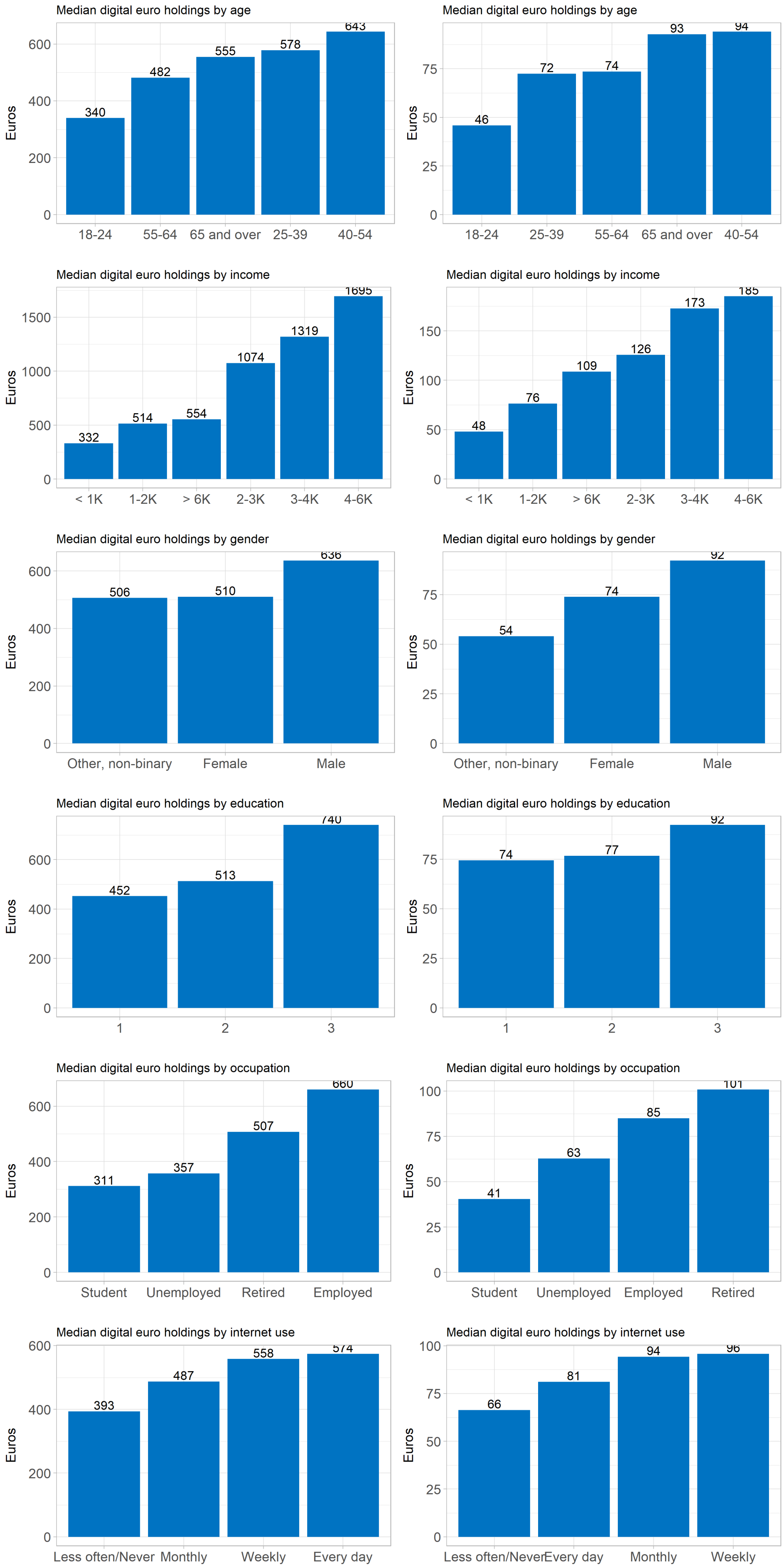
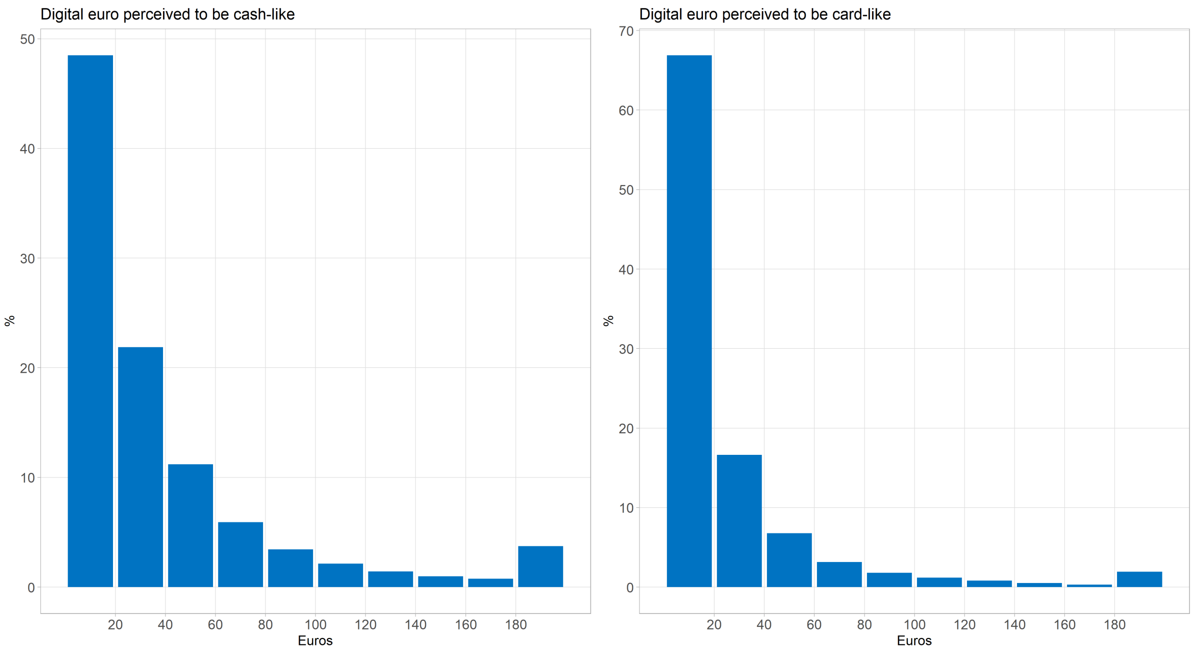


Figure E5: Distribution of estimated digital euro transaction values



Acknowledgements

We are especially grateful to Katrin Assenmacher, Paul Hiebert and Anton Van der Kraaij for their invaluable insights and guidance throughout the preparation of this paper. We also thank Ulrich Bindseil, Andrea Pinna, Ignacio Terol, seminar participants at the European Central Bank, colleagues from the Directorate General Financial Stability and Macroprudential Policy as well as Directorate General Monetary Policy. Moreover, we thank Juha Honkkila and the rest of the ECB's SPACE team as well as Martina Eschelbach from Deutsche Bundesbank for providing assistance on data related matters.
This research is independently conducted by the authors and not directly connected to the Eurosystem's digital euro project. It should not be interpreted as reflecting the ECB's position on the design of the digital euro.

Claudia Lambert
European Central Bank, Frankfurt am Main, Germany; email: Claudia.Lambert@ecb.europa.eu

Chloe Larkou
European Central Bank, Frankfurt am Main, Germany; email: Chloe.Larkou@ecb.europa.eu

Cosimo Pancaro
European Central Bank, Frankfurt am Main, Germany; email: Cosimo.Pancaro@ecb.europa.eu

Antonella Pellicani
European Central Bank, Frankfurt am Main, Germany; email: Antonella.Pellicani@ecb.europa.eu

Meri Sintonen
European Central Bank, Frankfurt am Main, Germany; email: Meri.Sintonen@ecb.europa.eu

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

PDF ISBN 978-92-899-6830-0 ISSN 1725-2806 doi:10.2866/397241 QB-AR-24-097-EN-N