

Exploring the Financial Implications of the Digital Euro: Opportunities for Future Research and Analysis

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Abstract

This paper explores the financial implications of the potential introduction of a digital euro, a central bank digital currency (CBDC) designed to complement cash and bank deposits. The research employs a comprehensive review of existing literature on CBDCs, qualitative analysis of their economic impacts, and scenario-based modeling to project possible outcomes. The study identifies key benefits, such as enhanced financial inclusion and reduced reliance on non-euro digital currencies, alongside challenges related to regulatory frameworks and technological risks. It also proposes a research agenda for future analysis in policy and regulatory developments.

Keywords

Digital Euro, Central Bank Digital Currency (CBDC), Financial Implications, Monetary Policy, Financial Stability, Regulatory Frameworks, Digital Payments, Financial Inclusion, Technology Risks

1. Introduction

Central banks are increasingly interested in the potential adoption of digital currency. In this context, the Eurosystem has launched a public consultation on the possible introduction of a digital euro and revealed its analysis and findings recently. The present paper proposes a research agenda and briefly discusses the financial implications of the issuance of a digital euro. Central banks are increasingly interested in the potential issuance of a central bank digital currency. As a complement to cash and bank deposits, a digital euro could help to meet the digitalization trends of payments and reduce euro area dependencies on alternative

digital forms of money issued by foreign private or public institutions. Today, citizens and businesses can use a variety of forms of money with familiarity and convenience. However, there are important differences between the money issued by a central bank that constitutes a direct claim on the central bank and other forms of money that constitute indirect claims on the banks or the digital service providers issuing the money and that expose the users to the credit risk of the banks or the digital service providers. The introduction of a digital euro could help to mitigate this disparity.

1.1. Background and Rationale

A central bank digital currency (CBDC) is a digital form of central bank money that attempts to provide the advantages of physical cash but in digital form. The public interest in digital currencies has grown rapidly in the past few years, largely in response to the growing use of private digital currencies. As a result of recent technological advances, private digital currencies—in particular, so-called global stablecoins may become more viable and achieve broader use. Many questions about the implications of these developments for the international monetary and financial architecture remain open (Lee et al., 2021; Ozili, 2023). The text considers the implications of digital currencies for the conduct of monetary policy, the stability and safety of payment systems, the soundness of the financial system, and the economy, as well as for the international monetary and financial structure.

1.2. Research Objectives

A digital euro would facilitate the fulfillment of certain public policy goals to which the euro area is committed. These could be related to financial inclusion, payment efficiency, or the ability to provide a digital version of central bank money at a time when the demand for it is significant. Future research and analysis that could generate valuable insights for the public and for central banks are surveys and consultation exercises that provide information on the demand from agents, as well as real-world business cases that contribute to the exploration of design and pilot testing in a future trial phase. These research projects would enable communication with the broader public and stakeholders, as well as an experimental approach to learning more about human and business behavior (Wong et al., 2022; Bindseil et al., 2021). The current interest from the public, stakeholders, and central banks in exploring the potential and cost of the digital euro presents an opportunity to strengthen citizens' trust by engaging in an open and informed assessment (Auer et al., 2022). The learning process should go beyond the design of the digital euro in the context of the euro area and should strengthen the relationship between central banks and citizens. Given that the last period of transformation was marked by an increased demand for central bank money, the thorough contemplation of a digital euro is appropriate at this stage. With the "what", "why", and "when" of the exploration of the digital euro relatively clear, the "how" and the "who" are important questions to address next.

2. Understanding the Digital Euro

The term “digital euro” refers to a digital form of central bank money that is accessible to households and firms for general-purpose use. The “digital euro” concept has received widespread attention and engagement from a wide range of stakeholders, touching on several key monetary and financial implications. A digital euro would be a new form of money, complementary to cash and current deposits. The underlying technology facilitates the transfer of deposits between digital wallets 24/7. If launched within the EU, the digital euro would be designed to be available to everyone seeking access and utilized as a common “representative” of central bank money in the digital domain (Minesso et al., 2022; Brunnermeier & Landau, 2023).

The ECB is considering the possibility of issuing a digital euro as a new form of central bank money. If issued, a digital euro would mainly involve the settlement and storage of users’ digital funds on the ECB’s balance sheet. The issuance and uptake of a digital euro would be centralized, maintaining the decentralized structure of the currency and delivering a high level of privacy. Based on this approach, the ECB envisages the creation of a digital euro that is universally accessible, costless to use, and offers payment functionalities (Mooij, 2023). A digital euro would be available to wholesale and retail potential users in times of normal operation and in stress situations. It would seek to support a range of uses and use cases in a gradual transition towards further harnessing the benefits of digital payment technologies in euros. It is the task of the Eurosystem to ensure its role as a producer of a resilient, efficient, and universally accessible form of central bank money, contributing to the fulfillment of the Eurosystem’s mandate.

2.1. Definition and Features

The term “digital euro” is defined as currency that the central bank makes available in digital form for general purpose use by both individuals and businesses. It is the liability of the central bank serving as the digital equivalent to physical banknotes. “Digital euro” does not imply any changes that would affect the nature of money creation in the euro area. A digital euro would be digital money issued by the Eurosystem and accessible to non-financial corporations, households, and the public sector (Auer et al., 2020). It would be a novel type of central bank money supplemented by the existing means of payments. It would allow for a wider range of use cases owing to its technical capabilities. However, the priority for consumers should not be innovation, but the maintenance of the features of cash with which they are familiar and the integrity of the money they use to make payments. In particular, the main purpose of a digital euro is to assist in maintaining a safe, accessible, and reliable form of central bank money in the digital age, which should continue to be available to all in the euro area (Cunha et al., 2021). Given the increasing use of digital payments and the issue of global stablecoins, the Eurosystem is exploring the possibility of issuing a digital euro to be able to respond to any future payment needs that may arise. Some potential benefits of a digital

euro would only be realized in case of an adverse development of the current payment ecosystem.

2.2. Comparison with Traditional Currency

Let us put the proposal for a digital euro in a broader context of currency analyses. The analogy between digital currency and cash makes our task easier and more understandable, but it is necessary to contribute to a thorough understanding and possible accounting in national accounts. When faced with digital currencies, we often face responsibilities that, until now, have rested with private sector entities. This is a radical change, which can have other repercussions in other monetary accounting statistics. In fact, with the creation of base money, we ask whether this adds responsibilities or reinforces existing ones, as is the case with traditional currency. Let's delve into this inquiry.

In recent times, the key transformation in the monetary and financial environment is the technological advance that opens the perspective of using digital technologies and future innovations to create a general-purpose digital currency. This transforms concepts and renews analyses. The proposal to create a digital euro raises new questions about basic economic and accounting concepts, such as currency, banknotes, and deposits, given the new activities in which the central bank can interfere. It is difficult to ignore the monetary, accounting, strategic, and practical issues that such flexibility may introduce. The digital currency supported by the central bank facilitates the direct handling of currencies and interbank transactions. It can bring new business opportunities to counteract negative returns and further claims. In addition, in crisis situations, a more direct relationship than traditional currency between the central bank, the system, and citizens can be achieved (Auer et al., 2020; Li et al., 2020). (Table 1)

Table 1. Comparison between digital euro and traditional currency.

Criteria	Digital Euro	Traditional Currency
Issuance	Central Bank-issued digital currency	Central Bank-issued physical currency (banknotes, coins)
Accessibility	Accessible through digital wallets and apps	Requires physical handling (cash or deposits)
Usage	24/7 transfer between digital wallets	Limited by banking hours or physical availability
Risk	Exposed to technology and cybersecurity risks	Exposed to theft or loss, less technological dependency
Financial Stability	Can support financial inclusion and reduce reliance on non-euro digital forms	Less flexibility in addressing digital needs, stable under traditional systems
Privacy	Digital, with potential privacy trade-offs	Ful anonymity with physical cash transactions

3. Historical Context of Central Bank Digital Currencies (CBDCs)

Since the emergence of cryptocurrencies such as Bitcoin, digitalized money has re-entered the realm of public and academic interest and even political discussions. These non-governmental cryptocurrencies were designed to operate in a decentralized manner, not supervised by a central bank or any private entity that manages currency. There are problems related to cryptocurrencies. In examining these problems, governments have looked at the blockchain system, which is the underlying technology of cryptocurrencies. Using blockchain technology, it is thought that it is desirable to create digital equivalents of paper and coin money issued by a central bank (Clavin et al., 2020). These collective works are defined as Central Bank Digital Currencies (CBDCs). If CBDCs come into being, this new form would be atypical forms of money that are widely used or could become a source of competition for the traditional forms of money currently in use.

These impacts make the studies that provide the EU with a handle on the digital euro process important in financial terms. When we look at the literature on this very new issue, it is seen that there are plenty of studies examining the opinions on CBDCs. Most of the studies aim to contribute to the literature by questioning the users and the managers who oversee the CBDC process. The European Central Bank has also started to evaluate the thoughts of the stakeholders in its area regarding the digital euro process via different platforms (Soderberg et al., 2022). There are also studies investigating the digital taxpayer process in terms of possible terrorism financing. On the other hand, in these studies aiming to find the economic effects of CBDCs in the real world, it is generally limited to the CBDCs, which is very low, due to the legal regulations made by the central banks (Wagner et al., 2021; Nosratabadi et al., 2020). In summary, there is not yet a study investigating the possible positive and negative economic reflections of the digital taxpayer process in the financial field.

3.1. Evolution of CBDCs

The five most likely general forms of Central Bank Digital Currencies (CBDC) comprise “a general purpose (retail) CBDC” in which digital currency would be directly transferred to non-bank units (including natural persons, firms, and government) and CBDC “is perceived as a fully-fledged substitute for the physical currency, both as ultimate settlement medium and as store of value.” A “financial market infrastructure purpose (wholesale) restricted to a specific list of financial entities would also be created so that it could interact with the central bank and “operate as a complementary delivery-versus-payment system.” In contrast to a general purpose (retail) CBDC, the account balances of the holders of a wholesale CBDC would not appear as money on the central bank balance sheet (Lee et al., 2021; Calle & Eidan, 2020). An “interbank purpose, i.e., a fully-fledged liability of the central bank that is only accessible to a closed group.” A “fast and competitive payment technology purpose, provided by the private sector.” and finally an

“innovation purpose designed for experimentation phases with new technologies.”

3.2. Global Trends and Initiatives

The exploration of the potential impact of advanced digital payment solutions for the euro area must also be viewed in a global context. In recent years, various countries have been exploring similar or innovative means to further digitalize payments, including through the issuance of official forms of digital money. Added relevance is then gained by recent announcements and pilot projects by foreign central banks, which have stimulated the direct debate about the potential issuance of central bank digital currency, or CBDC, in the euro area (Khalatur et al., 2022).

Research activities focus mostly on exploring or developing the respective implementations that contribute to a better understanding of the opportunities, risks, and impact of digital payments. Yet it remains outside the scope of this opinion to assess or explore these wider initiatives in detail. Such an exploration does, however, appear to be warranted, particularly where spatial interlinkages between potential future initiatives would be prone to leading to complex feedback effects. This section briefly examines two perspectives that add salience in this direction, i.e., an economic and a technical perspective. It is emphasized that solutions to policy challenges do not become less complex in a cross-border setting, quite the opposite. Hence, a more detailed examination of cross-border CBDC and DLT research proposals may be warranted, particularly in a context that extends to Union-wide criticism (Khando et al., 2022; Saxena & Tripathi, 2021; Horn et al., 2020).

4. Benefits and Challenges of a Digital Euro

The introduction of a digital euro could have various implications for the euro area financial system. We look specifically at a digital euro that would be issued to households by the central bank, which would be available to non-bank payment service providers, and which would support innovative blockchain-based technology. The examination focuses on how responding to a growing demand for digital euro would contribute to the central bank’s public policy objectives, including protecting market participants and fostering the integrity of payment systems and market stability, as well as sustaining trust in the currency (Fernández-Villaverde et al., 2021). While the focus is on the direct impact of a digital euro rather than the welfare improvements that it may bring, it articulates the implications for the financial system.

However, the discussion does not end there. Provided the digital euro strengthens the single currency and our payment systems, a crucial aspect will be analyzing the challenges and potential immediate risks linked to their financial implications. Speeding ahead with new opportunities should not mean ignoring considerations on risks and effects that need to be appropriately managed. Hence, this serves as a starting point for further reflection and concentration on the various matters

and difficulties that will need to receive further analysis over time. To this end, we offer a series of consistent financial services and forwarding studies that could contribute to the current debate on the digital euro. We investigate the main opportunities and challenges facing the impact of the euro's digitalization strategy.

4.1. Economic Benefits

One particularly debated question is the extent to which central bank money is a natural choke point for a digital money ecosystem or whether the private sector is best suited, in whole or in part, to augment central bank money. Another particularly relevant development lies in the enhancement of the ability of banks and fintechs to offer new digital and data-intensive value-added services beyond payments on the grounds that it reduces customers' exposure to unstable redeemable money-like balances from several venues at once (Cunha et al., 2021).

To the degree that customers want to reduce their money-like balances since they are not interested in spending this type of money, the economy can potentially benefit from various valuation uplifts across security markets. The increased safety and security offered to consumers raises national welfare by providing a new source of low-cost social and economic value (Park, 2021). While banks and fintechs would arguably lose net income from other data markets that either benefit depositors or require positive externalities to be maintained, they have often cited concerns regarding the implications that the increasing consolidation of social media data and analytical expertise has on banking and possibly financial vulnerability if these concerns are not counterbalanced.

To the degree that the use of a CBDC during periods when retail investors convert their deposit-heavy balance sheets forms a viable policy tool influencing the level and direction of net outflows to retail institutional money market funds, the invention of CBDC might represent an enhancement to the classic idea of liquidity provision if used in tandem with appropriate existing or additional penal reforms. Using M0 in this manner would therefore reduce economic fragility over time but also compensate for the greater significant deposit funding cost to fund an increased low-cost equity base for the banking system (Juks, 2020).

4.2. Technological Challenges

The digital euro must be designed to support, not compete with, private sector innovation and customer solutions. It is particularly important that the digital euro is designed and implemented in a way that ensures coexistence with competing proprietary solutions with similar features, such as the many potential stable-coin solutions currently being developed. It is desirable that the digital euro general purpose CBDC is as user-agnostic as possible and able to support the development of such user-friendly services not only or primarily offered by the central bank (Brunnermeier & Landau, 2023). The introduction of the digital euro could reduce the barriers for non-banks to provide digital services to end users without having to work with intermediaries that maintain traditional bank accounts.

Several central banks are considering multiple implementation options for the digital euro and are also collaborating with different technological solutions. In this research, we present instance-specific individual components of the digital euro and focus particularly on financial intermediation and other related aspects that should inform the public sector on how to create, manage and maintain a user-friendly digital euro. The focus on specifics and rather detailed recordings of technology and procedure requires a tolerant attitude in terms of potential obsolescence. The various qualities are indicated through regular updates of the research (Sandner et al., 2020). Acknowledging technology, cybersecurity and processing capabilities, we further present the principles for financial intermediation of the digital euro.

5. Regulatory and Legal Frameworks

The legal and regulatory frameworks that would apply to the issuance of a digital euro are extensive and complex. This section identifies key regulatory and legal issues related to the digital euro's introduction, highlighting areas where further clarification is required. The focus is on the proposed digital euro from the perspective of EU Member States. Many of the legal issues depend on the specific form the digital euro would take and how it would be made available to users (Bindseil et al., 2021).

The objective of the issuer, such as the European Central Bank (ECB), will significantly shape the legal and regulatory framework. There are three main pillars for potential digital euro initiatives: 1) a central bank digital currency (CBDC), 2) a centralized payment service using distributed ledger technology (DLT), and 3) a shared infrastructure for cross-border settlements. The legal definition of the digital euro will affect not only regulatory and legal aspects, such as licensing under financial services laws, but also broader monetary policy and prudential objectives (Chaum et al., 2021; Bindseil et al., 2021).

5.1. European Union Regulations

The introduction of a digital euro may necessitate revisiting several European Union regulations. Key areas that may need to be reconsidered include:

Regulatory Perimeter: The issuance of a digital euro raises questions about the existing regulatory boundaries. If the digital euro enters the same space as private digital currencies, should the central bank also regulate these? This overlap could lead to regulatory adjustments aimed at protecting consumers while maintaining competitive payment landscapes (Bindseil et al., 2021).

Anti-Money Laundering (AML) and Counter-Terrorist Financing (CTF) Regulations: The digital euro would need to comply with existing AML and CTF regulations. However, its unique characteristics as a digital currency may require specific adjustments or extensions of these frameworks to mitigate the risk of misuse (Chaum et al., 2021).

Payment Systems Access: Regulations governing access to both large-value and

retail payment systems would likely need revision. The digital euro would add another layer of complexity to the payment landscape, requiring systems to ensure fair access and maintain the integrity of the monetary system (Ferrari, 2020).

Additionally, privacy concerns, particularly with respect to data security and individual anonymity, must be addressed within the EU's General Data Protection Regulation (GDPR). The balance between privacy rights and the need for transparency in financial transactions will be a key consideration (Bindseil et al., 2021).

5.2. International Standards

The digital euro would also need to adhere to several international standards. These include cybersecurity protocols, secure messaging systems, and interoperability with other financial infrastructures (Bindseil et al., 2021). Ensuring compliance with international standards will be crucial for the cross-border functionality of the digital euro, as well as for maintaining trust in the global financial system (Chaum et al., 2021; Ferrari, 2020).

6. Implications for Monetary Policy

The introduction of a digital euro introduces far-reaching implications for monetary policy across the Eurozone. Central banks are now navigating uncharted territory, where digital currencies like the digital euro could fundamentally alter traditional tools used to manage the economy. Among the most significant areas of impact are interest rates, money supply, and the overall transmission of monetary policy through the economy. By providing a new form of central bank money accessible to the public, the digital euro could shift financial landscapes and force policymakers to rethink traditional mechanisms used to maintain financial stability (Brunnermeier & Landau, 2023; Mosteanu & Faccia, 2020).

One of the critical challenges for central banks will be managing the coexistence of a digital currency with physical money and bank deposits. The introduction of a digital euro could lead to a reduction in the reliance on commercial banks, as citizens might prefer holding digital euros directly with the central bank. This scenario would reduce the role of banks as financial intermediaries, affecting their ability to create credit, which in turn impacts economic growth. Central banks will need to adjust their approach to monetary policy to ensure that the banking system remains stable while integrating the digital euro into broader financial ecosystems (Mosteanu & Faccia, 2020).

In addition to reshaping the money supply, a digital euro could introduce a safer and more liquid form of asset, which may replace traditional bank deposits for many individuals and businesses. This change in behavior could significantly alter the way liquidity moves within the economy. While the digital euro offers benefits such as increased security and accessibility, its widespread adoption could destabilize traditional banking models, leading to reduced credit availability. Consequently, central banks might be required to intervene more frequently to inject liquidity into the financial system, ensuring that the economy continues to

function smoothly even in the presence of this new currency (Omarova, 2020).

Moreover, CBDCs, like the digital euro, provide unique opportunities to enhance the efficiency of payment systems. By reducing transaction costs, expediting settlement processes, and offering a more inclusive financial system, the digital euro could drive innovation within the monetary system. However, these benefits come with the risk of increasing volatility in financial markets if the adoption of the digital euro is not managed carefully. If individuals and businesses begin to bypass traditional banking services, it could result in the contraction of the banking sector, which would require policymakers to develop new strategies to mitigate the economic risks (Brunnermeier & Landau, 2023).

6.1. Impact on Interest Rates

Interest rates, as a central tool of monetary policy, would also experience significant shifts with the introduction of a digital euro. Central banks typically influence economic activity by adjusting interest rates, which in turn affect borrowing and lending. However, if citizens can hold their digital euros directly with the central bank, the traditional banking system might lose its primary source of funds—customer deposits. As a result, banks may need to offer higher interest rates on deposits to attract funds, leading to increased costs for lending and other financial services (Imamov & Semenikhina, 2021).

Furthermore, central banks could gain new tools to directly influence economic behavior. By using the digital euro, central banks may be able to apply negative interest rates more efficiently, directly reducing the balances held by individuals or businesses in digital euro accounts. This approach could provide a more immediate and effective method for stimulating economic activity during periods of deflation or recession, compared to the indirect measures currently in use, such as quantitative easing or adjusting reserve requirements (Mosteanu & Faccia, 2020). However, this introduces challenges, as negative interest rates might push users towards holding alternative assets, including foreign currencies or cryptocurrencies, which would reduce the efficacy of this policy tool.

The risk associated with managing liquidity in the banking sector also rises with the digital euro's introduction. If the public moves substantial funds into digital euros, banks could face liquidity shortages, leading to higher borrowing costs or even bank failures if not addressed swiftly. Central banks may need to implement new liquidity support measures, such as offering digital euro-based credit lines, to ensure that banks have adequate reserves to continue lending and supporting economic growth (Brunnermeier & Landau, 2023). These shifts would mark a profound change in how central banks conduct monetary policy, requiring innovative solutions to maintain balance between digital and traditional banking systems.

6.2. Exchange Rate Stability

In addition to affecting domestic monetary policy, the digital euro is likely to have a significant impact on exchange rate stability, both within the Eurozone and

globally. The introduction of a widely used digital euro could alter the demand for foreign currencies, potentially enhancing the Euro's role as a global reserve currency. As businesses and governments adopt the digital euro for cross-border transactions, it could reduce reliance on other currencies, particularly the U.S. dollar, which currently dominates global trade (Taskinsoy, 2020).

While this shift could provide the Euro with increased global influence, it also introduces risks. Exchange rate volatility may arise if the digital euro becomes the preferred medium for international trade, displacing traditional currencies and creating imbalances in the global monetary system. In particular, emerging markets that rely heavily on foreign currency reserves may experience instability if the digital euro changes the dynamics of capital flows (Omarova, 2020). European policymakers must, therefore, ensure that the introduction of the digital euro is accompanied by coordinated efforts with other central banks to maintain stability in international markets.

Furthermore, maintaining exchange rate stability would require the digital euro to be interoperable with other CBDCs, enabling smooth cross-border transactions. International coordination and the development of global standards for digital currencies will be crucial in ensuring that the digital euro does not create new barriers to trade or financial cooperation. Failure to achieve this could lead to fragmentation in the global financial system, with different regions adopting incompatible digital currency frameworks (Mosteanu & Faccia, 2020).

6.3. Implications for Financial Stability

Financial stability remains one of the central concerns surrounding the adoption of a digital euro. As a risk-free asset that competes directly with bank deposits, the digital euro could weaken the traditional banking system, potentially reducing banks' ability to create credit and support economic growth. If a significant portion of bank deposits were to be converted into digital euros, banks would face increased funding costs, leading to higher interest rates for borrowers and reduced access to credit for consumers and businesses (Brunnermeier & Landau, 2023).

The digital euro could also pose risks to financial inclusion. While it aims to enhance access to central bank money, particularly for unbanked or underbanked populations, its introduction could unintentionally exacerbate financial inequality if it is not designed with inclusivity in mind. Policymakers will need to ensure that the digital euro is accessible to all citizens, regardless of their technological capabilities or geographic location. Failure to do so could result in a widening gap between those who have access to the financial system and those who remain excluded (Mosteanu & Faccia, 2020).

Central banks will need to develop new tools and regulatory frameworks to ensure that the digital euro contributes positively to financial stability. This might include creating safeguards to prevent bank runs, offering liquidity support to banks, and monitoring the use of the digital euro to ensure that it does not disrupt the broader financial system. By carefully managing these risks, policymakers can

ensure that the digital euro serves as a complement to traditional forms of money, rather than a source of instability (Brunnermeier & Landau, 2023).

6.4. Connections to Sections 7-9

The implications discussed in Section 6 set the stage for the themes explored in Sections 7-9. In Section 7, the focus on financial inclusion and accessibility builds on the monetary policy concerns of equitable access to central bank money, a critical issue with the digital euro. Section 8, which addresses cybersecurity and data privacy, highlights the challenges of securing digital currencies, directly impacting monetary stability. Finally, Section 9 explores case studies and pilot programs, offering practical insights into how the theoretical monetary implications discussed here might unfold in real-world scenarios.

7. Financial Inclusion and Accessibility

Financial inclusion is a key aspect of the digital euro's design, and it removes a technical barrier to implementing financial inclusion policies. A digital euro can help address exclusion from physical cash usage. It can circumvent deposit requirements by directly providing people with a secure digital asset. The digital euro can be used by people with physical or cognitive disabilities to pay without cash. It can simplify payment transactions for people in financial trouble. Finally, it can help address 'locked' funds for people with no access to basic financial services. This paper highlights the financial exclusion issues of a potential digital euro. The issue of financial inclusion frequently arises in discussions about electronic money. In particular, the elimination of cash may have a negative impact on financial inclusion because it would close off a solution for people who want to store value prominently outside the banking system or would have a high cost in using bank accounts (Plaitakis & Staschen, 2020; Mooij, 2023). The digital euro can help address exclusion from cash usage. It may become particularly important in the most remote areas where the local bank branch has closed and there is little incentive for banking services to use cash surrogates, i.e., broader access and faster international minimum public services. The question arises whether the digital euro can be programmable to allow the growth of innovative digital payments and new ecosystems with personalized legal frameworks at its core to the speed of traditional central bank money (Khera et al., 2022).

7.1. Addressing the Unbanked Population

Introducing the digital euro may raise costs for the unbanked. The introduction of a digital euro could lead to significant changes in the cost of cash transactions and their providers. With a potentially lower-cost digital form of the euro, a key policy issue will be whether society is willing to provide some form of support to ensure that the unbanked can continue to have access to digital or physical currency. This paper hopes to stimulate a conversation around the potential costs and benefits for each stakeholder, including the unbanked, by pointing to some

potentially overlooked implications. It should be noted that one way to value one of the benefits of a digital euro, namely the irreversible nature of digital transactions, is to contrast the social cost of fraud under the physical and virtual forms of currency. Assuming that digital cash will lead to smaller instances of fraud, net social benefits could potentially be positive because of future savings (Fareed et al., 2022; Danisman & Tarazi, 2020).

It is the case that physical and digital euros provide different characteristics, and in the event that there is a shift from the former to the latter, it will be necessary to ensure that consumers understand the different attributes they offer. Educating consumers about this shift is useful before this technological transition is made, so that they can make a clear choice of using the asset that best suits their needs. However, one valuable characteristic of branch staff is that community dollars are provided regardless of account balance. This paper recognizes that a digital euro would also offer this valuable feature, given account limits, and that shared access to a mobile phone would allow individuals to access this feature with limited intervention from the central bank (Fareed et al., 2022; Khera et al., 2021). However, there are costs associated with this split cash solution, and stakeholders should be conscious of them before a decision is implemented.

7.2. User Experience and Interface Design

A potential digital euro must respond to the high-quality user experience offered by modern payment services if it is to achieve the right level of acceptance. In this chapter, by user experience and interface design, we refer to the way in which citizens, shops, and other digital euro users interact with the service, particularly through digital devices such as smartphones and smart cards. It is, of course, crucial that digital euro payments are secure, private, and efficient. But they must also be easy, intuitive, and attractive: user experience and interface design play an essential role in ensuring that digital euro enhances not only the convenience of European citizens and merchants but also the visibility of the euro in a digital and global world, asserting European values and adopting a forward-looking stance (Barajas et al., 2020; Shaikh et al., 2023).

Several factors contribute to the high-quality user experience offered by modern payment services. These include, but are not limited to, excellent design and ergonomics, comprehensive and attractive functionality, instant and continuously available responses to user requests, flexibility to support the wide range of real-life operations that citizens and merchants may engage in, and transparent and predictable operations that the users can understand and control. For example, users want to use their wallets to identify themselves with the systems that are available with their mobile devices; that smart cards work through large-scale terminal infrastructures, with high expectations of what these will deliver; and that innovative invisible and token solutions provide another level of interaction with a wide number of use cases. The list is not exhaustive. But the general insight is that new payment systems have to be user-centric (Gabor & Brooks, 2020).

Moreover, user experience is not only a must for the consumer market. Even in business-to-business use cases, where different considerations are of the essence, an outstanding payment service experience is becoming strategic, enabling firms to concentrate only on their core business. It is the experience of the underlying payments that is often decisive in shaping the customer experience, for example, in terms of speed, security, currency conversion, and transaction fees.

8. Cybersecurity and Data Privacy Concerns

In addition to assessing the appropriateness of the existing legal and regulatory frameworks in which the ECB's mandate is embedded, based on careful policy analysis and empirical evidence, another question for future research is whether a digital euro could have possible implications for the overall robustness of the financial system. In this context, cybersecurity and data privacy in the context of data centralization constitute important considerations. Centralization of data in the context of a central bank digital currency may not only pose day-to-day operational problems, but it could also have potential negative consequences for the overall robustness of a country's payments system (Gabor & Brooks, 2020). As it stands, when payment data are fragmented across a variety of commercial entities—the current situation—the overall system is more resilient to attack. As with the digital euro, the central bank's implementing platform would be attractive for cybercriminals, seeking to hold a very high-value target at ransom. A single point of failure at the central bank would lead to the entire awe-inspiring power of the national currency being compromised, with the potential for significant real-world impacts (Grünewald et al., 2021). Although it is tempting to think of national resilience as a costless perspective, costs would in fact be substantial. Technology investment in security would be significant in order to counter the evolving threats, and the cost of securing these large, attractive targets would likely be passed along to the counterparty.

8.1. Threats and Vulnerabilities

In summary, the digital euro would attract cyberattacks from different types of criminals. These could range from common thieves of digital currency to rival countries trying to disrupt the digital reserve currency's operations. The cyber-attack would be carried out in two general cases. In the first case, the attacker modifies the software of the digital wallet application to fraudulently obtain a benefit from the digital euro system. In order to do so, he tries to reverse-engineer the application and then exploits any software bugs to defraud the digital wallet. In the second case, the attack seeks to undermine confidence throughout the digital euro ecosystem by causing users to not trust or use the digital wallet application. It may be that the attacker tries to sabotage the digital wallet in order to discredit the issuer or his software's liability.

At the same time, all of the plausible attack vectors can be avoided or detected without causing significant damage by using the appropriate technical countermeasures.

The knowledge of the properties of the potential error vectors due to enhanced transparency and monitoring capabilities, active digital euro software updates, which are enforced whenever vulnerabilities are discovered, will minimize attacks (Natile, 2020). The public key management scheme suitable for large-scale deployment of the digital euro system issues the entries securely and permits recovery from a large fraction of the keys associated with false certifications without the need for the keys or querying the entries of a trusted entity. Such efforts to maximize the level of security can be underlined by a proof of correctness of the underlying digital euro system and its implementation, scrutinized in a detailed audit of the digital euro software before its deployment.

8.2. Mitigation Strategies

As mentioned above, issuer limitations and limited functionality of the digital euro could reduce the attractiveness of digital euro financial products to investors and, as a result, limit the potential asset liability management efficiency gains that could otherwise be realized. There are several strategies to mitigate any 'limited functionality' effects that could arise by imposing restrictions on the scale of digital euro holdings by individual users, making the paper euro yield curves more attractive, or explicitly designing digital euro product restrictions into the digital euro. It is important to think through and share potential restrictions at an early stage and also to evaluate the impact and unintended consequences imposed on the design of potential digital euro financial products, and the transmission of monetary policy more generally. One challenge related to the ongoing efforts to enhance and strengthen large value interbank payment systems participation is to ensure that these offerings will remain credible substitutes for other types of financial market products, as and when future asset liability management opportunities could arise. Judged in this light, the digital euro could reduce settlement, operational, and liquidity risks in the euro money markets. However, to be effective backstops for euro money market activities, the digital euro would need to be readily available and safe for: payments, disbursements of ECB loans, contributions to the EU's coffers, settlement of over-the-counter derivative trades, transactions cleared by CCPs, or as collateral at central banks in both regular items as well as during periods of extreme market volatility. Defining how and when digital euro balances will help facilitate the organization and functioning of financial market infrastructures could be an important area of future research (Chaum et al., 2021; Adrian & Mancini-Griffoli, 2021).

9. Case Studies and Pilot Programs

Case studies and, under the appropriate conditions, even smaller pilot programs should have a meaningful role in the broader analytical process. Fifty years ago, the Baldwin congressional committee report pushed for "field studies." Specifically, this could manifest itself in that a full nationwide rollout would likely wait sometime after system design is finalized while policymakers and others take time

to evaluate the possible real-world experiential implications of a digital euro. Not only might lessons from pilot programs inform how to optimize the final design, but the presence of a credible pilot program solving the economy may entertainingly discipline the current expansion of some global private currencies. Assuming that nothing can be kept secret that is known by more than two people, these pilot programs would need to be larger than proof-of-concept trials, both for us to learn from them and to establish security.

Unfortunately, in the current environment, despite how critically important it is to listen to unique and interesting experimental economic research, my advice is that it is the responsibility of the public sector, in close contact with the public, to take the lead and for the public to be open to learning from history using modern tools. If there is a delay in digital currency rollout, then it would seem that both public and private sectors should make plans for a retained-capacity-both-scenarios situation in which the introduction of the euro has made it harder for monetary policy to respond in their individual countries, and that difficulty should be eliminated. On the other hand, unless the common currency government is willing to make transitory proportional expenditures across members to return their influence on what it was pre-EMU, it can only devolve that influence within the monetary political family.

9.1. Experiences from Other Countries

The adoption of a digital euro in the Eurozone may be considered a genuine innovation in the context of central banking. Currently, only a comparatively small number of central banks have taken practical steps towards research on digital currencies, such as introducing concepts for designing retail CBDCs or launching pilot projects aimed at implementing digital money in a retail context. Some central banks have developed strategy papers on digital currencies; a limited number have clearly stated that they will not implement a retail central bank digital currency, and a few central banks are looking at wholesale CBDCs, which would be addressed to payment services providers in financial markets for transactions involving distributed ledger technology or other innovative solutions (Cunha et al., 2021). Even fewer central banks have policies supporting the introduction of privately issued digital currencies with central bank money used as a settlement asset, and only one central bank has a policy that would consider such currencies to be equivalent assets to traditional bank deposits and M2, creating a sort of digital money on tap.

9.2. Lessons Learned

A central lesson learned from our work is that successful scientific research must leverage both traditional insights into the foundational principles of our work and the latest tools and analytic capabilities. Here we highlight several promising research strategies that have the potential to contribute to a modern synthesis. This modern synthesis combines the strengths of economic models, empirical analysis,

generational accounts, and market evaluations. The first priority is to update monetary models to current realities. For example, monetary year-end bonuses to the central government have been historically important but are not modeled in standard economic models. Similarly, we have come to rely on the central bank as the lender of last resort during periods of financial crisis.

Modern models also pair improvements of existing financial issues with the challenges posed by unconventional new policies. Note that while central bank liabilities can be large in normal times, they explode in order to finance emergency lending to the interbank market. Our simulations strongly suggest that increasing the role of the digital euro could be a risky choice for this emergency policy function of the central bank. Available empirical findings are a second promising outlook. For example, prior to our work, we were puzzled by the fact of very low cash costs in comparison with credit and debit cards. This led to low demand for the digital euro in the fiscal studies. It encourages us to propose multiple outlets as a way to reduce cash usage and speculate that the digital euro issues may have similarly low costs. Yet risk-sharing between financial intermediaries and a central bank through multiple outlets is rigidly constrained. Can current research expectations be extended to describe the conflict of interests between commercial banks and digital money that are the relevant deposit market players?

10. Future Research Directions

The analysis presented throughout this paper highlights several key financial implications of introducing a digital euro. A digital euro could support liquidity, enhance the operational security of financial market infrastructures, and foster cross-border digital financial services. Furthermore, it may catalyze core bank intermediation functions and provide targeted liquidity to key economic sectors. The design and implementation of this new form of central bank money will have lasting impacts on the Eurozone's financial stability and the broader monetary system.

However, the adoption of a digital euro is contingent upon many factors, including future interest rate environments, specific design features, and the regulatory framework that will govern it. Significant uncertainties remain regarding the public's demand for a digital euro, its interaction with existing forms of money, and how it will be integrated within existing digital asset ecosystems.

10.1. Future Research and Regulatory Focus

Future research should aim to clarify these uncertainties through both quantitative and qualitative analyses. On the quantitative side, demand models for the digital euro should be explored, particularly focusing on how the euro will compete with other digital and traditional financial products. Elasticity estimates for cash demand, as well as the broader impact on the banking sector's liquidity, will be critical areas of study.

Regulatory considerations are another crucial area of focus. Policymakers need

to assess the implications of the digital euro for monetary policy, including the risks associated with monetary transmission, negative interest rates, and financial stability. As the digital euro intersects with global CBDC initiatives, coordination on international standards and regulations will be essential to ensure interoperability and prevent regulatory arbitrage.

Additionally, qualitative studies should focus on public and institutional responses to the digital euro. Surveys and pilot programs can provide insights into public satisfaction, trust in the new digital currency, and the impacts on financial inclusion. Case studies of similar implementations in other regions or countries will offer valuable lessons for the Eurozone.

10.2. Practical Testing and Real-World Pilot Programs

Real-world pilot programs will be especially important as the Eurosystem moves forward with the potential rollout of a digital euro. Testing the digital euro in controlled environments can help policymakers identify operational challenges, assess cybersecurity vulnerabilities, and evaluate its impact on payment systems and financial intermediaries. These pilot programs should also explore the social impacts of a digital euro, particularly its effects on marginalized or unbanked populations.

In conclusion, while the implementation of a digital euro presents exciting opportunities, it also poses significant challenges that must be addressed through careful design, thorough regulatory planning, and robust testing. By focusing future research on these areas, policymakers can ensure that the digital euro meets the broader goals of financial stability, inclusion, and security in an increasingly digitalized global economy.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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