Finanzplatz München Initiative

Frankfurt School Blockchain Center

Dr Philipp Sandner, Jonas Groß, Jong-Chan Chung

The Programmable Euro: Review and Outlook

Study for the Finanzplatz München Initiative (fpmi)

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Contents

Summary

- This study sets out how DLT-based payment systems and a programmable euro can promote innovative business models for the real economy and the financial sector. To this end, such business models and their fields of application are discussed using practical examples. Furthermore, the document recommends actions to strengthen Germany as a financial centre.

- Business processes in Germany's real economy and in the financial sector are becoming increasingly complex, with automation and digitalisation taking centre stage. Current payment infrastructures such as the SEPA or TARGET2 systems cannot fully address the needs of new business models because complex data synchronisation processes lead to system discontinuities, and counterparty risks arising from the asynchrony between delivery and payment cannot yet be entirely avoided. Accordingly, there is a growing demand for payment solutions that eliminate the inefficiencies of current infrastructures and lay a foundation for promising business models.

- A timely solution in the form of a programmable euro is essential to promote innovative business models for Germany as an industrial location, and the private sector is called on to develop it. We should not wait for the development of a digital euro by the European Central Bank (ECB), which is unlikely to occur before 2026.

- A programmable euro developed using Distributed Ledger Technology (DLT) by institutions in the private sector would meet the requirements of the real economy and the financial sector and address the limitations of the current monetary system. Potential configurations for this are (1) stablecoins issued by (as yet) unregulated companies, (2) tokenised commercial bank money issued by financial institutions, (3) tokenised e-money issued by e-money institutions, and (4) trigger solutions combining conventional payment infrastructures and DLT.

- This study demonstrates how euro payment solutions based on DLT can address inefficiencies in the current payment system and enable innovative business models. It describes specific use cases and recommends actions for the proactive support of corresponding innovations. DLT infrastructure enables, among other things, immediate, secure, and automated transactions. In future, DLT-based payment solutions will supplement traditional payment systems to keep pace with the increasing digitalisation of business processes.

- A programmable euro supports numerous innovative use cases for the financial sector and the real economy. Within the manufacturing industry, business models involving pay-per-use and tokenisation can contribute to effective liquidity management and create new lines of business. The decentralised nature of DLT

also implies that efficiency gains can be achieved in supply chain management, as parties need not trust one another but only the underlying technology. In the energy industry, smart contracts enable the automated and efficient purchase and sale of electricity. The financial sector profits from DLT-based digital securities and from more efficient securities settlements and interbank payment processing. Furthermore, DLT also harbours enormous potential for the insurance sector. For all of these DLT applications, a programmable euro would represent an efficient payment option, enabling micropayments and digital DvP transactions (among others), providing the building blocks for the industry of the future.

- To promote the development of the programmable euro, it is essential to remain in close consultation with all relevant stakeholders, including policymakers, financial supervisory authorities, financial sector organisations, private companies, and consumers. Cross-company collaboration within industries is also necessary to guarantee the standardisation, interoperability and fungibility of the payment solutions. In particular, the interoperability of the various DLT protocols should be a focus for all parties since the potential of DLT can only be fully realised through services that can be used interoperably. The European business community should agree on a common solution so that the euro can remain a global means of payment. To this end, a far-sighted, transparent and technology-neutral legal framework for the programmable euro is essential. Key points include the compatibility of the programmable euro with data protection provisions, contract law and securities law. The resulting legal certainty is required to gain the trust of investors and advance practical projects involving the programmable euro, and is advocated by this study and by the *Finanzplatz München Initiative* (Munich Financial Centre Initiative – FPMI).

Glossary

Anti-money laundering (AML)	Measures for the prevention, pursuit and prosecution of money laundering, which is the concealment and relocation of assets from illegal activities.
Atomic swaps	Atomic swaps provide a way to exchange data from different blockchains peer-to-peer without a third party such as an exchange platform being required.
Blockchain	Blockchain is a subtype of distributed ledger technology based on cryptography. It refers to the decentrally distributed, encrypted and unchanging storage of data, structured in blocks that are strung together.
Cash-to-cash cycle	The cash-to-cash cycle refers to the period between payment to suppliers and receipt of payment from customers.
Central bank digital currency (CBDC)	A CBDC is a digital currency that is issued by a central bank and is available to the general public.
Customer relationship management (CRM) system	CRM systems model marketing and sales processes and provide a user interface for customer data.
Decentralized oracle network (DON)	A decentralized oracle network is a decentral service that collects and validates external data and is available for smart contracts on a blockchain.
Delivery versus payment (DvP) mechanism	Delivery-versus-payment processing is a transaction mode whereby a consideration is only paid when a service has been rendered.
Distributed ledger technology (DLT)	Distributed ledger technology designates both an infrastructure and a protocol for the secure and decentralised validation, storage and updating of data.
Enterprise resource planning (ERP) system	ERP systems permit the modelling of business processes from HR management to machinery and procurement planning.
Industry 4.0	Industry 4.0 is a designation for the networking of machines and processes by means of advanced technology and communications.

Internet of Things (IoT)	The Internet of Things refers to networks of devices, machines, sensors and entire systems that can communicate and interact with each other autonomously over the internet.
Machine economy	The machine economy is a type of economy that is based on a network of intelligent, autonomous and communications-enabled end devices and minimises the need for human intervention.
Micropayments	Micropayments are transactions in the amount of a fraction of a currency unit.
Mining	In the context of crypto assets, mining, a term adopted from gold production, is the validation of transactions in accordance with the proof of work method (PoW) by miners, for which they are remunerated in the form of crypto assets.
Machine-to-machine payment (M2M payment)	An M2M payment is an autonomous payment made without human intervention between two or more machines that have digital identities.
Nodes	In the context of DLT, nodes are electronic devices which are connected to a decentral network as communication end points. Nodes can process transactions and participate in the network's validation process.
Pay-per-use payment	A pay-per-use payment is a cost-efficient use-based payment structure in which only the actual consumption of a good or service is invoiced.
Programmable payment	Programmable payments are payments linked to specific predefined conditions (if-then logic).
Proof of stake (PoS)	Proof of stake is a consensus mechanism for blockchains whereby a validator is randomly granted the right to mine a block. The probability of being selected increases in proportion with the use of the underlying cryptocurrency: the more ether that is used, the higher the probability. Proof of stake is significantly more resource-efficient than proof of work.
Proof of work (PoW)	Proof of work is a consensus mechanism for blockchain applications whereby a party is selected to confirm transactions (and thus to "mine" the next block) once this party has performed a specific task. With bitcoin, this involves solving a cryptographic puzzle.

Single source of truth (SSOT)	SSOT is the principle of always saving information reliably in precisely one central location in order to guarantee that it is up to date and correct and to avoid misinformation and version conflicts.
Smart contracts	Smart contracts are programs executed on a blockchain that are frequently simple but are theoretically of unlimited complexity. They can model contract arrangements and agreements between any number of parties, including automated payment.
Stablecoin	A stablecoin is a crypto asset that uses price stabilisation mechanisms to minimise fluctuations and is frequently linked to a key currency such as the US dollar.
Streaming money	In the case of streaming money applications, payments for a service are made constantly and not on a discretionary basis. An example application is the streaming of a feature film.
Telematics	The integration of information technology and telecommunications to acquire, store and/or process data.
Tokenised e-money	Tokenised e-money is a new form of money in which existing e-money is issued on a blockchain and thus "tokenised".
Tokenisation	In the context of DLT, tokenisation is the digital representation of assets and rights in the form of a token.

1. Introduction

Advancing digitalisation. In the coming years and decades, innovations associated with Industry 4.0, the Internet of Things (IoT) and the machine economy will change the German economy. The associated automation of processes, which is being advanced by distributed ledger technology (DLT) and blockchain technology (a cryptography-based subcategory of DLT), is impacting both the real economy and the financial sector. To exploit the full potential of digitalisation, a symbiosis between digitalised and automated business processes and efficient methods for payment processing is required. DLT-based euro payment solutions in the form of a programmable euro present a promising opportunity to enhance efficiencies in industrial and financial companies and enable new, innovative business models. For example, micropayments, digital delivery versus payment (DvP) transactions and even machine-to-machine (M2M) payments can be executed efficiently while simultaneously creating new lines of business such as pay-per-use transactions or tokenisation.

Content of this study. This study examines the opportunities offered by a programmable euro for the German real economy and the financial sector. In particular, it examines the extent to which current payment systems are prepared for the digitalisation of the real economy and the financial sector and which measures must be implemented for their adaptation. Programmable payments and a programmable euro play a key role in this regard. For the implementation of such a programmable euro, the possibilities outlined below include in particular a trigger solution connecting conventional payment systems with a DLT, along with euro stablecoins, tokenised e-money, tokenised commercial bank money and a central bank digital currency (CBDC). In addition to the analysis of these implementations, the need for the programmable euro in various industrial and business sectors is also analysed and corresponding applications are discussed.

Need for a DLT-based euro. This study shows that the possibilities of the IoT and Industry 4.0 in particular, and the increasing digitalisation of business processes in general, call for a DLT-based payment solution. Current payment solutions exhibit inefficiencies and limitations, for example in the form of system discontinuities and asynchrony between the provision of and payment for services, which can be remedied by innovative automation and digitalisation capabilities. To make programmable payment solutions available in as timely and effective a manner as possible, the study makes specific recommendations, including recommendations for policymakers.

Recommended actions. Given the transformative potential of a programmable euro for society and the economy, coordinated action by all interest groups involved is required at both the national and European level. Effective knowledge transfer and cooperation should take place in the form of discussions, consultations, working

groups, projects, and real-world tests. Actors from both the public sector (policymakers, national and supranational central banks, financial supervisory authorities) and the private sector (experts from civil society and academia as well as from private companies and associations) must complement each other and deliver new findings and feasibility studies. Furthermore, changes to the legal framework will be needed to promote the programmable euro's innovational benefits but also, for example, to reflect the changed requirements for the prevention of money-laundering and terrorism financing and for ensuring consumer protection. In this process, new legislative initiatives must be designed to be as technologically neutral as possible to enable fair competition by providing a level playing field. A further condition for secure investment is the development of uniform technological standards for the programmable euro to ensure interoperability between different DLT infrastructures and the convertibility of the programmable euro. All these measures will contribute towards strengthening the competitiveness and attractiveness of Germany and the European Union (EU) as a financial centre. Thanks to its strong industrial sector, Germany stands to profit from the many possible applications of a digital euro.

2. Status quo of digitalisation and automation

2.1 Increasing automation and digitalisation

Change in the financial sector. The number of German fintechs – technology-based financial service providers – rose to 946[1] in 2021, a rise of more than 60%[2] since 2015. In addition, the digitalisation of operational processes such as support, core, and management processes[3], allows financial institutions to lower their operating costs and increase their competitive edge.[4] Now the wave of digitalisation is increasingly spreading – driven in part by blockchain technology – to the core areas of financial institutions. Apart from the changing behaviour and needs of customers, who increasingly expect digital interfaces such as smartphone apps for quick and convenient financial transactions, new competitors are entering the market. These include fintech and big tech companies and large payment service providers, who are increasingly taking over the processing of payment transactions

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[1] Comdirect, 2021.

[2] Dorfleitner et al., 2020.

[3] Fischermanns, 2013.

[4] This study primarily addresses the advantages of digitalisation. However, increasing digitalisation brings with it rising costs for employee training and IT infrastructure, for example the procurement of new systems or the installation of fibre optics for adequate data transmission. In addition, a higher level of digitalisation means a potentially larger target for hacker and espionage attacks. The consequence of this is higher costs to guarantee the cyber security of a company. In extreme cases, there are even new resource-intensive, supervisory requirements, which can only be outlined in this study. In 2018, BaFin presented a digitalisation strategy, which deals with the increasing supervisory requirements on companies and explains the guidelines governing the guarantee of information, IT and cyber security (BaFin, 2018).

and who are working on the development of their own payment solutions and platforms. The public sector is also on hand with potentially influential payment solutions such as CBDCs. Overall, then, the dependence on financial institutions for payment processing will lessen in the medium term. Furthermore, a persistent capital outflow from the traditional banking sector to the crypto sector, supported by both consumers and institutional investors, is foreseeable.

The digitalisation of the real economy continues apace. In the real economy, the first three industrial revolutions – mechanisation, mass production and automation – are now giving way to the fourth: Industry 4.0. As a rule, this is something companies have already been dealing with for many years.[5] Bavarian companies, in particular, responded to the digitalisation of the real economy at an early stage and are now addressing new challenges. Thus, the Free State of Bavaria aims to become an international leader in the development of the 6G mobile phone standard.[6] Industry 4.0 refers to the networking of machines and processes by means of advanced technology and communications. These networked and automated machines can achieve more flexible production, a customer-centred production process and efficiency gains. Germany's Federal Ministry for Economic Affairs and Energy (*Bundesministerium für Wirtschaft und Energie* – BMWi) expects the implementation of applications based on Industry 4.0 to yield an increase in gross value added of €23 billion.[7] A study conducted by the digital industry association Bitkom concluded that 81% of German industrial companies are currently working on applications relating to Industry 4.0 or are planning such work in the near future.[8]

The Internet of Things (IoT) as a prime example of the automation of the real economy. The phrase Internet of Things refers to networks of devices, machines, sensors and entire systems (power stations, refineries, steelworks, etc.) that can communicate and interact with each other autonomously over the internet. Devices, machines and sensors are hereby given a digital identity and can thus perform transactions and processes autonomously – without the need for manual human intervention.[9] For example, an IoT device could autonomously order and pay for required spare parts. The networking of machines also enables the autonomous creation of detailed process analyses resulting in improvement suggestions. This includes predictive maintenance, whereby a machine autonomously determines when maintenance is required.[10] According to assessments by IoT Analytics (2020), more than 30 billion IoT devices will be connected to the Internet worldwide by 2025 (see Figure 1).

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[5] Klein, 2020.
[6] StMWi, 2021.
[7] BMWi, 2019.
[8] Berg, 2020; Industrial companies with 100 employees or more. Sample size: 552.
[9] FinTechRat, 2020; Bechtel et al., 2020.
[10] Ayvaz & Alpay, 2021.

Figure 1: IoT devices connected to the internet worldwide
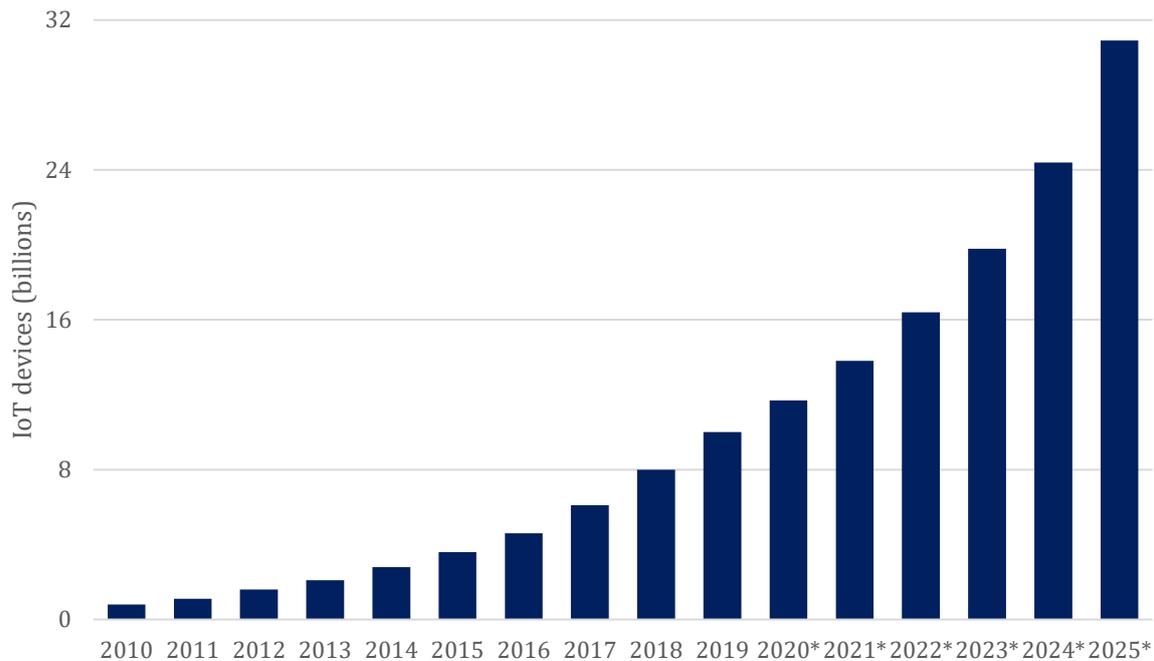
Source: IoT Analytics (2020, translated).

Increasing automation and digitalisation as a result of Industry 4.0 and the IoT will lead to substantial changes in the real economy, especially through innovative business models and efficiency improvements. Companies could also profit from significant network effects if the networking of production machinery and supply chains that were previously isolated from one another prevails throughout the industrial sector. The complete automation of supply processes could eliminate bottlenecks caused by material shortages, allow more efficient utilisation of personnel resources, and reduce costs, thus making processes more efficient, dynamic and flexible.[11]

2.2 Current payment systems are not completely tailored for digitalisation

Existing payment systems must be optimised. In addition to the growth of digitalisation and automation, the efficient integration of digitalised business processes with corresponding payment options also plays an essential role in the future competitiveness of Germany as a business location.[12] To realize the full potential of digitalisation and automation, the current Single Europe Payments Area (SEPA) payment system must be optimised further. Such efforts must also be

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[11] BMWi, 2021; Paulsen & Eylers, 2020.

[12] Although straight-through processing (STP) approaches can in part eliminate the need for manual interventions in business processes, cross-company data integration, for example, still represents a significant barrier.

accompanied by expansion of the underlying infrastructure including extensive installation of optical fibre cables and the establishment of a complete 5G network.

Complex business models currently result in system discontinuities. At present, the synchronisation of (transaction) data from various IT systems still regularly leads to system discontinuities, meaning that automated processes have to be interrupted so that data can be aligned and transferred manually. The reasons for these system discontinuities include limited – or in some cases entirely lacking – integration of payment processes in enterprise resource planning (ERP) and customer relationship management (CRM) systems and also data privacy concerns.[13]

System discontinuities when paying for services via the current banking system. To process a payment through conventional payment systems such as the SEPA system, an intermediary – such as a financial institution – is required to confirm the payment. In this process, the money is not sent directly from Customer A to Customer B (peer-to-peer), but instead via the payment sender's bank to the payment recipient's bank. In addition, clearing houses are typically involved in the final processing of payments between the financial institutions. The need for such intermediaries means the process chain is interrupted and payments are delayed – an obstacle to fully automated transactions. In 2019 alone, 98 billion cashless payments with a cumulative volume of €162.1 trillion[14] were processed in the euro area, an increase of 8.1% over the previous year. The change in payment behaviour as a consequence of the COVID-19 pandemic will further accelerate the development and strengthen the role of cashless payment transactions.

Time delay between performance and payment leads to counterparty risks. The current SEPA system is regulated[15] such that the monetary amount to be transferred must be credited to the account of the payment recipient after no more than one working day.[16] At the same time, the process of debiting the account of the party making the payment must also take no more than one working day after performance has been rendered. If parties intend to process delivery vs. payment (DvP) transactions, i.e., transactions in which consideration (e.g., a payment) is only made once performance (e.g., a delivery) has been rendered, via the SEPA system, counterparty risks arise for both parties. On the one hand, there is the risk of scenarios in which the payer pays in advance, before goods or services are delivered (payment before delivery). On the other, the goods could also be delivered without the required payment being made (delivery before payment). This counterparty risk can be minimised by payment guarantees or real-time transfers but

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[13] FinTechRat, 2020.

[14] ECB, 2020b.

[15] Possible disadvantages of a programmable euro are discussed in Table 1 on p. 15ff., including the difficulties in relation to conflict resolution and the assertion of legal rights.

[16] Forster et al., 2021.

cannot be completely eliminated. Payment guarantees imply for the merchant that the agreed payment conditions are guaranteed even if the customer does not pay. However, payment guarantees tend to be expensive and transfer only the transaction information, not the actual monetary value.[17] Unlike payment guarantees, with real-time transfers the actual value is transferred in less than ten seconds. With real-time transfers, (virtually) digital DvP transactions can be realised, but many financial institutions are still not connected to this payment option.[18] In the case of the real-time payment system SEPA Instant Payments Systems, only 62% of payment transaction service providers that offer traditional SEPA transactions are currently connected to the system.[19]

A lack of standards is complicating the digitalisation of payment processes. Recipients of a SEPA payment can currently only be addressed via their IBAN. However, it would be much more convenient to be able to select alternative identification options for transactions, such as e-mail addresses or mobile phone numbers.[20] For industrial transactions between machines (M2M transactions), an essential application of the IoT, there is a lack of standardisation and options for machines to participate in payment transactions. Payment systems such as SEPA cannot currently address machine identities and thus cannot assign transactions initiated by IoT devices.[21] Machines can therefore only be connected to the payment cycle in limited circumstances and transactions cannot be initiated autonomously. M2M transactions are not possible in this arrangement as an intermediary is required for payment confirmation. M2M payments are also made more difficult by the regulatory requirement for two-factor authentication, which also applies to machines.

Micropayments are not possible. In addition, the labour-intensive comparison of incoming payments and outstanding invoices leads to significant transaction costs for the parties involved. As these transaction costs are incurred irrespective of the amount of the transaction, payments in the cent and sub-cent range, known as micropayments, cannot currently be performed economically since there are no standards or efficient options for payment processing. SEPA transactions, for example, cannot efficiently handle amounts smaller than one cent.[22]

Opportunities for programmable payments are limited. Initial practical examples from Industry 4.0 show that digitally linked machines can offer advantages in the development of more efficient production logistics for complex systems and the reduction of idle time. Integration in the payment cycle is a key element here, particularly where flexible payment triggering processes can be specified. Machines

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[17] Forster et al., 2021.
[18] Forster et al., 2021.
[19] As at: May 2021; BEUC, 2021.
[20] Forster et al., 2021.
[21] Forster et al., 2021.
[22] FinTechRat, 2020; Forster et al., 2021.

could then send and receive payments independently. However, current payment systems cannot yet handle the complex processes for payment triggering.[23] Simple conditional programmable payments, i.e., payments that can be triggered when certain conditions are met, can already be handled by current payment systems. For example, standing orders can be set up that trigger a payment on a certain date, but a transfer cannot typically be triggered more than once monthly. More complex, programmable payments, such as multiple or phased conditions for payment triggering, cannot be efficiently implemented in today's systems. As a result, such systems are inadequate for innovative business models involving the IoT and micropayments.

Not all new and innovative business models can be implemented with traditional infrastructures. Overall, integrating the payment processes of more complex business models such as pay-per-use[24] leads to difficulties in processing payments via conventional channels. However, it is precisely these business models that are, with increasing digitalisation and automation of processes, becoming more and more relevant (see Section 6).[25] However, these models deviate from traditional models, particularly in their payment arrangements. Against the backdrop of the previously described limitations of current payment systems, pay-per-use business models therefore have faced and continue to face significant challenges.

3. How DLT can drive digitalisation

3.1 Definition and role of DLT for digitalisation

Importance of DLT and blockchain. DLT will play a vital role in addressing the described limitations and driving digitalisation forward. The term DLT describes a special form of decentralised and distributed electronic data processing and storage. Blockchain technology is a subtype of DLT. In a blockchain, data is collected in data blocks that are cryptographically linked together.[26] In this study, the terms DLT and blockchain are used synonymously.

Public and private DLTs. Public DLTs permit every network participant to read out transaction data on a distributed database. It is therefore possible to identify which party made which specific transaction at what time. Participants can also add nodes themselves to participate in the calculation of the next block by providing computing capacity and are rewarded for this with coins. As this creates a security risk for fraudulent practices, cryptographic puzzles are introduced as a security guarantee to

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[23] FinTechRat, 2020.
[24] Pay-per-use customers pay for a service based on the actual use of the product.
[25] Bechtel et al., 2020.
[26] Brühl, 2017.

counteract a 51% attack[27]. This makes public blockchains very computation- and energy-intensive. For the private sector, public DLTs have little practical use due to, among other things, data protection concerns and data confidentiality. This is because on public DLTs data is saved permanently in pseudonymised form and transaction costs and speeds are not suitable for all business needs. Furthermore, the current high energy usage and lack of scalability of proof-of-work-based DLTs pose significant obstacles to business adoption (see Section 3.7). In addition to public DLTs, there are also more centralised private DLTs. In private DLTs, read and write authorisations are generally granted by corporate consortia in accordance with internal agreements and participation is by invitation only. In contrast to public DLTs, private DLTs are more energy-efficient and scalable due to the manageable size of the selected node points. Private blockchains are thus particularly suitable for business associations and closed networks. Lately, "public-permissioned" blockchains have also been under discussion. These semi-public blockchains try to combine the advantages of both systems, for example by using alternative consensus mechanisms such as proof-of-stake (PoS). Read rights are publicly assigned, while only a controlled number of participants is allowed to add nodes. Thus data is published transparently and in a way that builds confidence, but in principle a 51% attack is prevented. In such a configuration, the blockchain can be operated with great energy efficiency while still offering users the advantages of a blockchain.

The role of DLT for digitalisation and resilience. Data in a DLT-based database is protected from manipulation through the cryptographic methods used and the stipulated decentralised consensus mechanism. In the case of public DLTs, there is therefore no need for any trust between the transaction parties. In access-restricted systems – in contrast to current centralised systems – there is no need to trust an individual entity, namely the system operator. Data is saved on DLT systems in a decentralised and geographically distributed manner. As there is no single point of failure in such systems, their resilience is increased. Should a validating instance fail or be unavailable, e.g., due to lack of an internet connection, the system continues to be operational without restriction. Payment validations are performed in a decentralised manner on DLT systems and can operate despite such failures. Thanks to this distributed mechanism, efficiency gains can also be achieved if parties in the system fail or are unreachable. This failure can then be compensated by other network participants.

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[27] A 51% attack is an attack on a blockchain network in which a miner or a group of miners gains control of more than 50% of the entire hash rate or computing power of the network and can thus compromise the premise of honest transaction execution in the long-term. Following such an attack, fraudulent and unauthorised transactions can be performed.

3.2 Automation of processes by DLT

Automation via smart contracts. The need for intermediaries in traditional finance results in additional steps for transaction confirmation, increasing susceptibiity to error and the likelihood of system discontinuities at infrastructural interfaces. This is where DLT systems can provide assistance.[28] Completely DLT-based solutions can enable seamless and automated payment execution directly between two parties since they can implement process logic using smart contracts without the process logic being interrupted by an outstanding transaction confirmation from an intermediary. Smart contracts are scripts saved and executed on a DLT, which use the blockchain and thus the distributed computing capacity of the nodes as a system environment. All smart contract programming languages are Turing-complete; they can thus theoretically implement any program logic, no matter how complex. Smart contracts are only limited by the computing capacity (and the associated fees) of their blockchains and the ingenuity of their developers. Most smart contracts use only classic if-then logic, i.e., they trigger certain actions when circumstances that are defined in advance occur, which when combined with DLT can also be reliably documented.

While there are some security concerns regarding the complexity of the programming language and the associated security loopholes, two thirds of smart contracts could be executed even in a less complex programming environment thanks to their simple source code.[29]

Programmable payments. Conditional, programmable payments via smart contracts offer great automation potential and are much more flexible than the simpler, currently familiar types of automation using programmable payments such as standing orders. Inventories can, for example, be precisely controlled without any human input using sensors and corresponding framework contracts.[30] Based on such measurements, a payment can be made directly and instantaneously via the DLT to the supplier upon actual consumption. There is thus no temporary asynchrony between performance and payment, which can reduce counterparty risk. Overall, DLTs make it possible to efficiently implement complex business models that are based on automated payments (for example, in the context of pay-per-use), and to connect them with the corresponding payments.

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[28] Welzel et al., 2017.

[29] Jansen et al., 2019.

[30] However, the integration of physical events in the blockchain via oracles poses a challenge in some cases, as this requires the highest possible level of congruence between the data measured by sensors and the actual situation. When connecting the physical world to the blockchain by means of oracles, a smart contract also requires an external trigger.

3.3 Delivery versus payment (DvP) transactions

Digital DvP transactions. In addition to the higher level of automation and the associated efficiency improvements, DLT-based smart contracts also enable digital DvP transactions. One example of a physical DvP transaction is a cash payment, whereby goods or services (performance) are paid for directly (consideration). For transactions of this type, a consideration is directly rendered at the same time as the actual performance. If the exchange of performance and consideration is processed asynchronously, efficiency losses occur. With DvP transactions, there is therefore no counterparty risk that payment is made for a service that is not rendered or that no payment is made for a service rendered.

The role of blockchain for DvP transactions. Digital DvP transactions are currently not yet widespread. For example, processing a security purchase still typically takes several days (D+2). With a security purchase, a central securities depositary, for example Clearstream, performs the settlement task (processing) and provides for a lawful transfer of ownership of money and security. The transfer of the security does not, however, take place at the same time as the payment is made, but instead takes place in a separate infrastructure, which is why the transaction is frequently not finally and legally settled by the clearing house until a few days later.[31] This also occurs because the payment performance and the exchange of the security take place in two different technical infrastructures. For digital DvP transactions, DLT and smart contracts can play an important role. Here the money to pay for a performance is held or "locked" within the blockchain in a smart contract until the performance has been rendered and confirmed. It is not technically possible for the delivery to take place without the payment being rendered in the same moment and vice versa. This means that if the payment process or the delivery is interrupted, regardless of the reason, no business transaction takes place. The assets granted in the interim by the smart contract then return to the business partners.

A platform for services and payment. The use of blockchain technology makes it possible to process both the service/delivery (e.g., the transfer of a security) and the corresponding payment (e.g., payment for the security) via the same platform. In such a situation, the time-intensive and often error-prone reconciliation of various infrastructures is no longer required. Examples from practice include applications from Decentralized Finance (DeFi). Here applications are generally developed on the Ethereum blockchain which perform the business process and the payment via the same blockchain platform. In the interim, almost USD 100 billion has been invested in capital in the DeFi universe.[32]

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[31] Deutsche Börse, 2021.
[32] DeFi Pulse, 2021.

Role of tokenisation. The full potential of digital DvP transactions is only realised in combination with the tokenisation of assets (see Section 6.1.2). For physical deliveries, for example, it is necessary in individual cases to clarify who must bear any return transport costs if the transaction is abandoned. Either external oracles, e.g., decentralized oracle networks (DONs), or the two business partners are responsible for entering the triggering information.

Figure 2: The role of DLT in payment processing
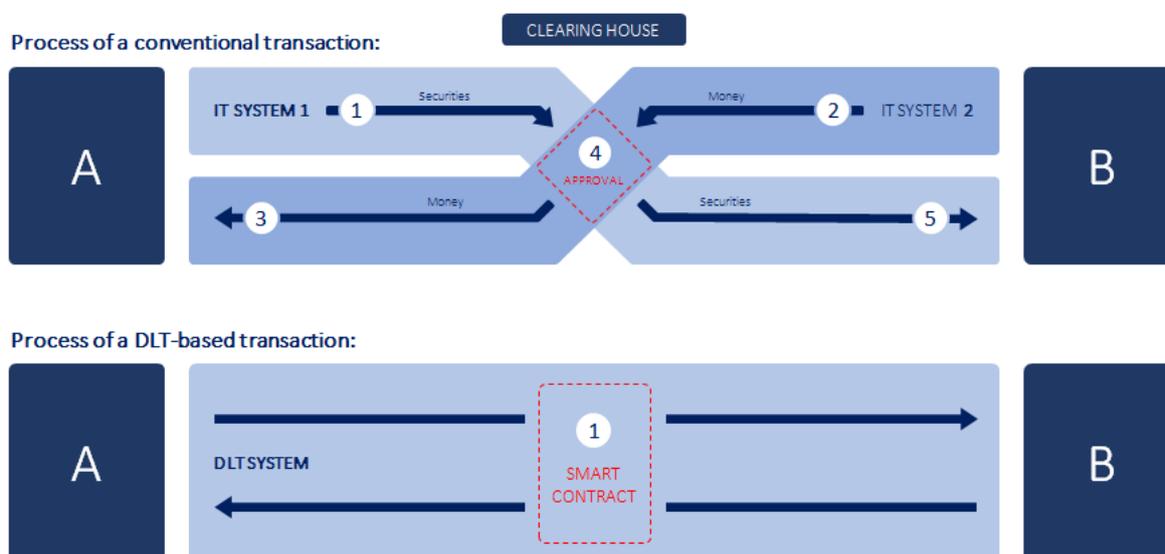
Source: The authors.

Atomic swaps. For blockchain-based DvP transactions, atomic swaps play a key role. Atomic swaps make it possible to exchange assets represented on a blockchain, for example digital securities, peer-to-peer between different DLT protocols. Despite the lack of an intermediary, the payment is ensured for both parties in that the transaction is executed via a hashed timelock contract (HTC), a specific type of smart contract. This requires a compatible, interoperable blockchain and assigns a time limit to the transaction within which it must be completed by both parties. If, for example, the performance is not rendered, the transaction is automatically cancelled. Due to this property, the atomic swap is particularly suitable for transactions in which an immediate, two-sided transaction (i.e., DvP transactions) is to take place.[33] The underlying process is represented in Figure 2 using a security purchase as an example. While in conventional transactions the payment is finally settled via a clearing house, in the case of a DLT platform, this task is performed by the smart contract itself, reducing the required intermediaries and intermediate stages of a transaction to a minimum.

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[33] Bitpanda, 2021b.

3.4 Micropayments and streaming money

The fractionalisation of DLT-based means of payment. DLT makes it possible to activate efficient payments in the sub-cent range, i.e., micropayments, as there are no intermediaries and the costs are correspondingly reduced. By mapping assets on a DLT basis, they are theoretically infinitely divisible, i.e., technically "fractionalisable". Thus, it is possible to map the euro not only in euro and cent, but also in smaller amounts, i.e., less than one cent. By fractionalising the money, payment would also be possible in tiny amounts. One example to illustrate the technological opportunities of the divisibility of DLT-based payment instruments would be ether, the "monetary unit" of the Ethereum blockchain. Ether units can be divided into the subunit wei, which corresponds to 10^{-18} ether. An ether is thus theoretically divisible trillions of times.[34] However, the transaction costs of public blockchains are currently still high, which is restricting the adoption of DLT-based micropayments. The system adjustments made to Ethereum as part of the update to Ethereum 2.0 promise to reduce the transaction costs significantly in the near future.

The advantages of fractionalisation. The division of monetary amounts into even smaller units enables a more precise quantification of the service rendered and thus guarantees more efficient settlement, as there is no longer any need for a "rough estimate" of the amount as was the case previously. As the number of pay-per-use transactions increases in the future, greater automation with efficient payment processing of the smallest amounts is enabled. Through the further development of the machine economy[35] and the associated increase in automation processes of machines, the implementation of micropayments will allow for transactions such as invoicing for the use of computing-power. This should be in the interest of both the consumer and the service provider/manufacturer: At present, purchasers pay more due to amounts being rounded up to the nearest cent and sellers take in less than they should because sub-cent amounts cannot currently be settled. Currently, payments are typically aggregated and then, for example, processed together at the end of the day. However, this leads to high book-keeping and administration costs. Transactions could be processed particularly efficiently immediately and in the smallest of amounts via DLT, as the provision of service, the payment, invoicing and book-keeping can all be implemented atomically.

Streaming money as a use case. Micropayments are also of major importance for business models involving streaming money. Here a service is not paid for on a

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[34] This is required in the case of the Ethereum network, in order to ensure network security by pricing transaction orders. On the one hand, transaction orders to the network validators should ideally be very inexpensive, the more so because the automation of asset transfer processes also implies a large number of transactions. On the other hand, such transaction orders should not be free in order to deter malicious parties from launching network attacks by overloading the network with an endless number of transactions.

[35] Machine economy designates the complete integration and participation of completely autonomously functioning machines on the basis of the implementation of an innovative technology, such as blockchain (Fraunhofer Institut, 2020).

discretionary basis, but on a continuous basis instead.[36] Specific consumer-related examples would be the use of information sources such as eBooks or online articles, or music streaming. Here the customer pays for every second that they are using the source or streaming the music. Consequently, such opportunities increase the interest of customer groups who only want to use individual parts of the information source and for whom the complete acquisition of the source would not be economically justified. Further examples include the use-based settlement of consumables, which are not regularly used and are only used individually, for which payments in the sub-cent range are required. Streaming money would only be particularly beneficial if the monetary unit used could be sufficiently fractionalised to adequately represent a constant flow of money, even in the sub-cent range.[37] Only DLT-based payment instruments currently achieve such granularity, but other systems are also able to map sub-cent amounts to a certain degree. The tick size regime of the European Securities and Markets Authority (ESMA) defines that stock market prices must be listed with four decimal places and thus shows that trading and settlement systems can map sub-cent amounts, even if such payment options do not currently exist for the real economy.

3.5 Connecting machines

Single source of truth (SSOT) as unique selling point of DLT. The efficient mapping of streaming money applications and micropayments can, particularly by equipping machines and sensors with their own wallets, lead to a significant increase in the importance of the industrial applications of pay-per-use supported business models. DLT can assume a significant role here to efficiently enable the onboarding of machines via wallets.[38] In addition, the use of blockchain technology guarantees the integrity and authenticity of the data. As a result, the blockchain is assigned the role of a single source of truth (SSOT).

The assignment of machine identities. A complete implementation of Industry 4.0 and of the IoT is difficult to imagine without DLT-based machine identities. They are necessary to be able to identify sensors, devices, machines and systems and to manage access to (sensitive) data. This is facilitated using public key cryptography usually implemented in DLT, which can provide evidence of the authenticity of the message sender by means of digital signatures. Furthermore, machines can use these identities to authenticate themselves and to authorise data and asset transfers. Only through the assignment of these identities do machines become autonomous, (communicative and transaction-capable participants in the machine economy),

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[36] FinTechRat, 2020.

[37] In open, PoW-based systems such as Bitcoin or Ethereum, the transaction costs are currently still too high to map streaming money applications efficiently. Therefore, the use of private blockchain systems is recommended for this, which use a centralised consensus mechanism which significantly reduces the transaction costs.

[38] Forster et al., 2021.

within which DLT assumes the transaction-validating notary function. DLT brings together the information from the agreements made regarding payments, local data from machines (e.g., from sensors), and external data from oracles such as DONs. In this context, DLTs gather this external information, validate it and finally feed it into the DLT network. Through the combination of blockchain technology and external data, a previously unseen degree of automation can be achieved.

3.6 Interim conclusion: The advantages and disadvantages of DLTs for payment processing

In the following table, the advantages of DLTs for payment processing, which have been described in detail in Section 3, are summarised in aggregated form. In addition, the corresponding risks that arise from the use of DLTs are outlined and described briefly.

Table 1: The advantages and disadvantages of DLTs for payment processing

	Argument	Description
Advantages	Greater resilience	The payment system can continue to function smoothly even if individual parties drop out, are not available or are compromised.
	Seamless systems / no system failures	Service (e.g., transfer of an asset) and corresponding payment can be processed via the same platform (cash leg and asset leg in the same system).
	Higher efficiency of payment processing	Faster payment processing, e.g., as part of a security transfer, as there is no further need to synchronise different infrastructures with one another; lower counterparty risks through DLT-based DvP transactions in (nearly) real time; clearing houses are no longer required (role assumed by smart contracts)
	Standardised and trust-based technological basis	Creation of a platform for the exchange of assets, on which no party can change the rules independently as the rules are transparently stipulated in the protocol. In this way, trust in the technological basis can be increased so that cooperating companies can more easily come to an agreement on a technological basis.
	High level of automation through smart contracts and oracles	Smart contracts are programs executed on a DLT system, which can perform payments. They are triggered by internal events such as payments or external events that are fed into the blockchain via oracles. In this way, highly complex programming, contract and transaction logic can be implemented.
	Efficient mapping of micropayments and streaming money	Due to the advantages described, payments in the (sub)cent range can be efficiently mapped via private (and in the future also via public) blockchain systems, whereby streaming money use cases can be efficiently and reliably implemented.

Disadvantages	Blockchain as a new form of infrastructure with new operating risks	Blockchains are a new type of database system with thus far unknown operating risks, for example with respect to infrastructure, programming and smart contracts.
	New acquisition costs	As databases that are generally independent of centralised infrastructure, blockchains require significant initial investment in the early stages in addition to the infrastructure costs of centralised systems. In addition, new types of interfaces must be developed.
	Sourcing of new expertise is required	Blockchain projects can in general not be performed without external expertise, such as technology providers or software developers.
	High transaction costs	For public blockchains (such as Bitcoin or Ethereum), the transaction costs are currently very high, so that micropayments or streaming money use cases cannot be implemented efficiently. Second-layer solutions such as the Bitcoin lightning network, or the changes that accompanied the update to Ethereum 2.0, promise to lower transaction costs in the future.
	Complicated conflict clarification	Conflict clarification is easier in systems with intermediaries, as intermediaries function as points of contact and legal judgements can be implemented centrally. In peer-to-peer networks, there are no such points of contact, i.e., conflicts or special cases not considered by the program logic are (technically) more difficult to resolve.
	Legal situation partly unclear	Legal questions are not always clearly or definitively regulated in the case of a blockchain-based euro or where smart contracts are involved, which represents a disadvantage compared to conventional payment systems.

3.7 Limitations of crypto assets

Crypto assets are not the solution for the real economy. Blockchain-based payments that are triggered by smart contracts have been possible now for several years. However, these are only processed via crypto assets such as bitcoin or ether, but rarely via fiat currencies such as the euro.[39] For companies, payments in the well-known crypto assets are problematic for the following three reasons, which are explained here using the example of bitcoin.

> **High volatility of crypto assets.** Crypto assets such as bitcoin are extremely volatile and thus involve significant price change risks. In contrast to the stablecoin, a crypto asset that maintains its value (see Section 5.3.2), classic crypto assets are not backed by securities such as government bonds or fiat currencies, which would strengthen trust in their stability and stabilise their value. Due to their strong price fluctuations, crypto assets such as bitcoin are (still) not suitable as a payment instrument or store of purchasing power.

> **Low scalability.** The term scalability refers in the context of DLT in principle to the number of transactions that can be performed per time interval. At present, the bitcoin system only permits seven transactions per second due to the restrictions with respect to block size and the consensus mechanism, while the payment infrastructures of Visa or Mastercard can process several thousand transactions per second.[40] For this reason, bitcoin payments are (still) not scalable, a further reason why bitcoin is currently not a valid means of payment for the real economy or the financial sector.

> **High energy consumption.** Bitcoin transactions and the mining of bitcoin are incredibly energy-intensive. A single bitcoin transaction consumes approximately 1600 kilowatt-hours of electricity.[41] By comparison, it takes an average German single-person household one year to use 1600 kilowatt-hours of electricity.[42] The reason for the high energy consumption is the validation of the blockchain transactions. The proof-of-work (PoW) consensus method requires a great deal of computing power and thus electricity, as every validator of a transaction must solve a cryptographic puzzle in competition with other validators of the network. Thus PoW-based procedures of this type consume more electricity than transactions that are processed via centralised systems. This high energy consumption is a fundamental limitation of blockchain-based payment systems and is standing in the way of bitcoin being used as a means of payment. However, there are already alternative consensus mechanisms that use very little energy. For this reason, the high

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[39] While it is true that the first euro stablecoins that enable euro transactions on a DLT basis already exist, they are still fraught with legal uncertainties and default risks.
[40] Bitpanda, 2021a.
[41] De Best, 2021.
[42] WEMAG, 2020.

energy consumption issue does not affect blockchain-based systems in general, but instead affects PoW-based crypto assets such as bitcoin.

Blockchain-based euro payments are required. The limitations described above suggest that crypto assets are (currently) not a suitable means of payment for the real economy and the financial sector. For this reason, solutions that bring fiat currencies onto a DLT are required so that smart contracts can trigger payments in euro to address the limitations described in Section 2.2. In this way, it would then be possible to build on the outlined advantages of DLT-based payment instruments and on the stability of the euro.

4. The public digital euro of the European Central Bank (ECB)

4.1 Classification and objectives

A DLT-based CBDC as a potential solution. One option to bring the euro onto a blockchain would be a DLT-based euro payment instrument, issued by the public sector, i.e., by the ECB. In the following, this variant is designated as the public digital euro (see Figure 3). Specifically, currently 86% of central banks worldwide, including the ECB, are working on the introduction of their own CBDCs.[43]

Figure 3: Taxonomy of the digital euro
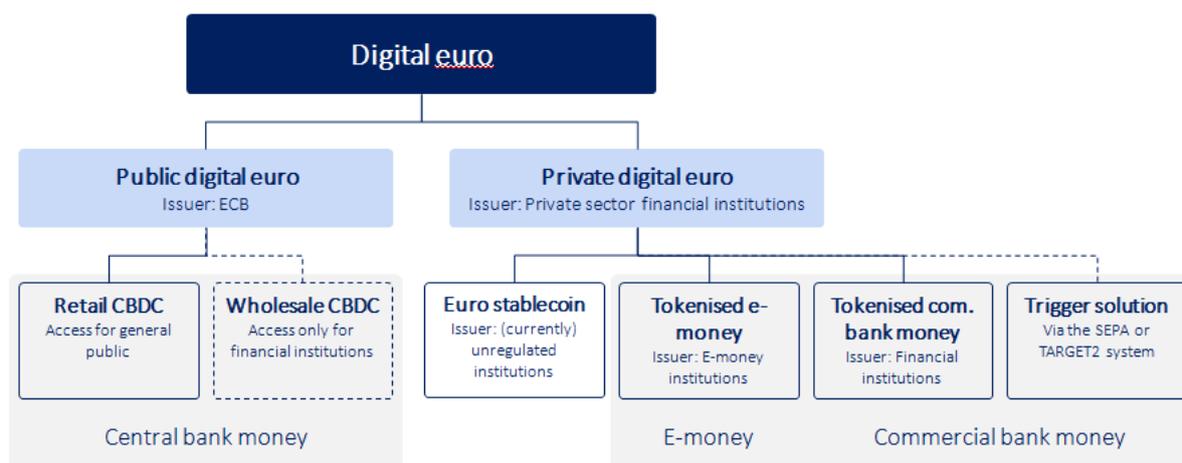
Source: Based on Forster et al., 2021.

CBDC as risk-free central bank money. A CBDC is a digital currency created by the central bank, which – when using a DLT as a technological basis – can also achieve the advantages described in Section 3. In this process, the central bank acts

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[43] Boar & Wehrli, 2021.

as the issuer of the digital euro. A CBDC is therefore central bank money, which is how it differs from bank money. Bank money, which is issued by financial institutions, is available in the form of bank deposits. If a payment is made today by credit card, mobile payment, direct debit or transfer, payments are always made in the background between the bank accounts of the sender and the recipient via the transfer of bank deposits. If the central bank acts as an issuer of a currency, this results in the holder of the money having a claim against the central bank and not, as in the case of commercial bank money, against a commercial bank, which can be reflected in a lower risk.[44]

Difference between wholesale and retail CBDC. With CBDCs, a differentiation must be drawn between a wholesale and a retail CBDC (see Figure 3). A wholesale CBDC is a CBDC that is exclusively available for interbank trade and could be based on a DLT. The aim of a wholesale CBDC is to have efficiency gains in the interbank payment transactions and in the processing of digital securities, primarily determined by the option of DLT-based DvP transactions.[45] A retail CBDC, on the other hand, describes a CBDC that is made publicly accessible in digital form.[46] It thus combines the characteristics of cash, which exists physically and is accessible to the public, and digital central bank reserves, which are digital in nature but only available to financial institutions.

Digital euro to strengthen the role of the central bank. One main reason the ECB is considering the introduction of a CBDC is the declining significance of cash as a means of payment in the euro area, and the consequent waning of the central bank's influence in the market for payments.[47] The share of cash transactions is declining both in the EU[48] (2017: 74%, 2020: 60%) and in Germany[49] (2016: 79%, 2019: 73%). The COVID-19 pandemic further accelerated this trend, as online trade leapt in importance following the closure of a sizeable portion of brick-and-mortar retailers and cash was additionally avoided as a potential carrier of germs and the virus. With this, the use of payment options provided by the private sector, such as mobile payments and EC and credit card payments increased enormously. The share of credit card transactions in Germany rose by 14% between 2018 and 2019.[50] The introduction of a CBDC should therefore serve as a supplement to cash and reinforce the role of the ECB vis-a-vis the private sector.[51]

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[44] To qualify this statement, it is important to mention that commercial bank deposits are protected by a statutorily prescribed deposit guarantee of €100,000 per investor. In addition, certain banks, for example cooperative banks, have their own deposit guarantees of more than €100,000 per investor.

[45] Bundesbank, 2021a.

[46] Gross et al., 2020.

[47] ECB, 2020a.

[48] Pietrowiak et al., 2021.

[49] ECB, 2020c.

[50] Statista, 2021.

[51] ECB, 2020a.

Improved resilience of payment systems with a digital euro. The ECB having a more important role in the market for payments would result in improved resilience of payment systems. Infrastructure made available by the private sector is less resilient in times of crisis as these payment channels can, for example, only be used where there is an internet connection.[52] Offline payments, on the other hand, are currently only possible with cash, as an internet connection is likewise always required to process payments using commercial bank money. A CBDC could likewise facilitate payments without an internet connection, for example via hardware-based systems, and thus offer greater resilience in times of crisis, if in extreme cases it were not possible to establish an internet connection.[53]

Monetary sovereignty as a further objective of the ECB. The ECB can, through the digitalisation of cash in the form of a CBDC, provide a payment infrastructure, which permits convenient, quick and cost-effective transactions. As this payment infrastructure would be operated without the influence of third states or third parties, the ECB can in this way retain its sovereignty. Additionally, this would work to counteract the increasing role of big-tech companies.[54] Users who currently pay via methods such as Google Pay, Apple Pay or PayPal provide confidential customer information to the payment service provider during a transaction. An autonomous payment infrastructure provided by the ECB can make the euro area independent of companies from the private sector and third countries and thus offer users a higher level of data protection.[55] In addition, it is the view of the ECB that stablecoins and other crypto assets endanger the monetary sovereignty of the ECB.[56] A CBDC would counteract this development, as the ECB would be able to offer an alternative to the payment systems and currencies of the private sector.

4.2 Current project status

Start of a digital euro project announced. According to surveys conducted by the Bank for International Settlements (BIS), central banks whose shared monetary jurisdiction represents one fifth of the world's population want to launch a CBDC in the next three years.[57] Current CBDC pioneers include the Bahamas, China and Sweden. At the end of 2020, the central bank of the Bahamas became the first in the world to launch a CBDC.[58] While China and Sweden have already been working specifically on a CBDC since 2014 and 2017 respectively, the ECB did not make its first public statement regarding a potential digital euro until it released research

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[52] Sandner et al., 2021b.
[53] Christodorescu et al., 2020.
[54] Sandner & Blassl, 2021.
[55] Sandner & Blassl, 2021.
[56] ECB, 2020a.
[57] Boar & Wehrli, 2021.
[58] Boar & Wehrli, 2021.

papers in 2019 and its Report on the Digital Euro in 2020.[59] In July 2021, the ECB finally announced the start of a digital euro project.[60] Initially, conceptual analyses regarding the fundamental design requirements of the digital euro will be performed during a two-year investigation phase. Thereafter, the ECB will decide on introducing the digital euro. During the investigation phase, the focus will be on the design and identification of the use cases of the digital euro. Further tests will be conducted to determine the technological basis to be used, i.e., whether a DLT or central infrastructure will be used. Moreover, the role of financial institutions in such a CBDC system will also be examined.

The role of credit institutions in the CBDC ecosystem. In its publications, the ECB have thus far made it clear that intermediaries, for example financial institutions, are to play a key role in the CBDC system. Firstly, it should be possible for existing offers such as electronic bank services and applications to be based on a CBDC. Secondly, a public digital euro offers financial institutions the opportunity to offer innovative and efficient products, for example payment processing. Financial institutions could, for example, take over the distribution of CBDC units, the performance of anti-money laundering (AML) measures and identity checks (know-your-customer method, KYC). Financial institutions have already been doing these tasks for many years and have significant expertise and data which the ECB would like to access. In addition, the ECB has no interest in assuming these operational tasks.

Risks for the financial sector. In addition to this important role in the CBDC system, experts also fear negative consequences for financial institutions. In times of crisis, for example, there could be a substantial, CBDC-determined restructuring of bank money into CBDC. The more attractive the digital euro is for users, the greater the negative impact on bank deposits.[61] There are two potential risks here that are of particular importance: digital bank runs and a disintermediation of the financial sector.

> **Digital bank runs.** Bank runs describe the short-term redeployment of a large number of bank deposits into central bank money, which is typically triggered by a lack of trust in the financial sector. If a CBDC is introduced, the likelihood of bank runs may increase.[62] The literature argues that the probability of a bank run will increase as problems such as a closed bank, lack of cash reserves in branches, restricted pay-outs via cash machines or non-monetary transaction costs, e.g., incurred en route to the financial institution, cannot be

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[59] ECB, 2021a.
[60] ECB, 2021b.
[61] Sander et al., 2021a; Bundesbank, 2021a.
[62] Bindseil, 2020; Bitter, 2020.

ruled out. Given that commercial bank money can be redeployed 24/7 with a mouse-click in large amounts to CBDC, runs could spread faster.[63]

Disintermediation of the financial sector and focus of the ECB. In A CBDC could lead to a disintermediation of the financial sector, whereby a substantial share of bank deposits would be converted into CBDC.[64] Should such a disintermediation occur, the importance of financial institutions in the payment market would diminish. In addition, financial institutions would face the threat of liquidity bottlenecks and higher refinancing costs.[65] Before introducing a CBDC, the ECB must analyse these potential risks in detail and address them so as not to jeopardise the stability of the financial market.

Measures to avoid disintermediation and digital bank runs. To avoid disintermediation and digital bank runs or reduce the effects of same, a two-stage interest rate is one measure currently under discussion.[66] A maximum CBDC holding amount – the ECB is increasingly talking about a CBDC holding limit of €3000[67] – and an increased allocation of central bank liquidity to financial institutes have also been considered.[68]

4.3 Limitations

4.3.1 Time-to-Market

The digital euro will be available by 2026 at the earliest. We estimate that the introduction of a public digital euro by the ECB will take approximately five years. This coincides with the personal assessment of ECB President Christine Lagarde and the statements made by the ECB at the start of the project.[69] This time horizon conforms with comparable projects across the globe. China started with the digital currency e-CNY in 2014 with the first CBDC analyses. In 2020, they were able to run advanced system tests. Thus, the project went through a development phase that lasted just under six years.[70]

Long road to the introduction of a CBDC. A digital euro, irrespective of its form, also requires regulatory adjustments. Data protection and the legal status of a CBDC as an official means of payment must be regulated. In addition to strategic

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[63] Bitter, 2020.
[64] Bundesbank, 2021a.
[65] Bindseil, 2020.
[66] Bindseil, 2020.
[67] Panetta, 2021.
[68] Brunnermeier & Niepelt, 2019; Gross & Schiller, 2020.
[69] Siedenbiedel, 2021; ESZB, 2021b.
[70] Sandner et al., 2021a.

considerations and required regulatory adjustments, a CBDC's technical infrastructure must also be developed and tested.

4.3.2 Technological basis

ECB may not provide digital euro on a DLT basis. A digital euro based on a DLT would deliver the advantages described in Section 3 with respect to DvP transactions, micropayments, etc. However, DLT is only one option available for the technological design. The digital euro could also be issued via a central infrastructure and, for example, be integrated in the current Target Instant Payment System (TIPS). The ECB currently appears to prefer the use of a centralised, non-DLT-based infrastructure, so it currently seems unlikely that the public digital euro will be DLT-based. If this proves to be the case, this may mean that certain use cases such as innovative pay-per-use-based business models, will not be compatible with this form of digital euro. However, no final decision has yet been made regarding the technical configuration, even after the ECB announcement of the start of the project.

Account-based digital euro not necessarily interoperable with the DLT system. Should a public digital euro be integrated in a currently available payment system, for example in the TIPS system, the digital euro would be account-based.[71] With an account-based system, every user with an account must verify their legitimate ownership of an account by confirming their own identity, i.e., by logging in, in order to perform a transaction.[72] With a CBDC, unlike commercial bank money, the customer consequently holds central bank money and has an account with the central bank. However, these central bank accounts could also be managed by financial institutions on behalf of the ECB. In such a case, the financial institutions would take care of contact with end customers and assume administrative tasks. Such a private-public partnership appears probable. On the other hand, performing transactions with a token-based CBDC requires evidence of the legitimacy of the means of payment. An account-based CBDC is not directly interoperable with other DLT systems. It would not necessarily facilitate innovative use cases such as integration in the IoT. While bridging solutions (see Section 5.3.1) could be used to establish interoperability, system discontinuities could still occur which would have an impact on efficiency and automation. Insufficient interoperability of the digital euro could lead to instances where foreign payment infrastructures and even crypto assets could be used for DLT-based payments. This could, in extreme cases, have a deleterious effect on the role of the euro.

The private sector is needed for a digital DLT-based euro. Based on current information, it can be assumed that the ECB will not launch a DLT-based digital

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[71] Bechtel et al., 2020
[72] Bechtel et al., 2020.

euro. However, if it does decide in favour of a DLT-based technological configuration, an expected introduction in 2026 would be too late since the demand for DLT-based euro payment solutions is already rising considerably. For this reason, private industry must develop and make available timely solutions for rising demand from the private sector. In the interim, financial institutions could provide a private, DLT-based digital euro, which serves the needs of the real economy and realises the advantages addressed in Section 3. How the private sector can contribute to this is set out in the next section.

5. The private sector's programmable euro

5.1 Definition of private sector programmable euro and delimitation

Definition of the private digital euro. In contrast to the public digital euro, the private digital euro would not be issued by the ECB, but instead by companies in the private sector, such as financial or e-money institutions. The issue of a private digital euro underpinned by DLT would lend itself towards meeting the requirements of the real economy and overcoming the limitations of the current monetary system.[73] The term "programmable euro" is used below for such a blockchain-based euro and refers to a euro-denominated means of payment that enables programmable payments.

Programmable payments in current payment systems. Programmable payments are payments that are executed when certain predefined criteria are fulfilled and could thus be triggered by a smart contract.[74] A classic example of this is the standing order, which triggers the transfer of a specific amount on a certain date or an interest payment that is automatically calculated at an appointed time and transferred. Thanks to the use of smart contracts, however, programmable payments based on DLT permit much more flexible and more complex payment logic. Furthermore, such a programmable euro offers further advantages due to having DLT as its technological basis, e.g., DvP mechanisms (see Section 3).

Programmable money with inherent logic. Programmable payments must be differentiated from programmable money.[75] Programmable money is money that has an inherent logic. Tokens, which are issued via a DLT, can have such an inherent logic. A token can, for example, be programmed so that it can be used only for specific purposes such as investment in training or consumer spending, or within a specific timeframe, for example for temporary COVID-19 aid payments.[76] With the logic anchored in the token, policy makers can prescribe the exclusive use of the

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[73] Forster et al., 2021.
[74] Sandner et al., 2020a.
[75] Sandner et al., 2020a.
[76] Sandner et al., 2020a.

token for a predefined purpose, e.g. to issue subsidies for electromobility or training. The use of the money for other unintended purposes is then technically impossible. Furthermore, a token can directly map inherently programmed value gains (or losses) and thus, e.g., represent ongoing interest payments.[77] This study focuses on programmable payments. The implications of programmable money are not discussed further here.

Classification of the programmable euro. Overall, it is important to understand that a programmable euro – a euro-denominated means of payment that permits programmable payments – does not represent a new type of currency.[78] DLT serves here as a carrier platform and represents the euro solely on a distributed infrastructure. When using a DLT, the programmable euro will not, as is currently the norm, be saved on a centralised database, but would instead be on a blockchain and would be accessible via the private keys stored in wallets. Accordingly, a programmable euro is clearly differentiated from crypto assets such as bitcoin, which, from the ground up, represent independent and newly created payment instruments. In comparison to bitcoin, the energy consumption of a blockchain-based euro is also significantly lower. The reason for this is that only a small number of parties – or in the extreme case, only one party – validates transactions, which obviates the need for energy-intensive PoW methods to find consensus.

5.2 Taxonomy of the programmable euro

In this section, a taxonomy is outlined for the programmable euro, to be able to compare and categorise its various configuration forms. The process of a DLT-based payment can be categorised according to Figure 4 using three pillars: (1) the contract execution system; (2) the digital payment infrastructure; and (3) the monetary unit used.[79]

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[77] Sandner et al., 2020b.
[78] FinTechRat, 2020.
[79] Sandner et al., 2020a; Bechtel et al., 2020.

Figure 4: Taxonomy of the programmable euro
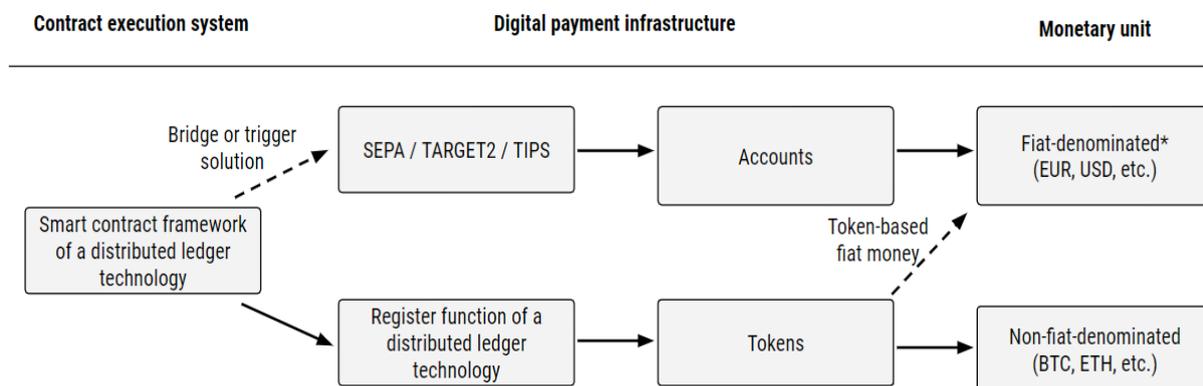
Source: Bechtel et al. (2020).

Contract execution system. In the schematic payment process illustrated above, the contract execution system embodies the first pillar of a payment. This pillar is the basic module of the subsequently unfolding payment process, as it defines both a large share of the logic of the payment process and the conditions that ultimately trigger a payment. Here an underlying DLT-based business process is assumed. An example from the IoT: A machine is connected to a blockchain and is to be paid for based on how much it is used (pay-per-use). In the contract execution system, a smart contract would specify the logic of payment processing, i.e., the composition of the usage fee, for example based on the duration of use and the quality of maintenance.

Digital payment infrastructure. The digital payment infrastructure as the second pillar indicates the payment path. This can be realised by two different means. Firstly, the infrastructure can be implemented via conventional account-based payment infrastructures such as TIPS, SEPA and TARGET2[80]. Secondly, payment processing via a DLT is possible.

Monetary unit. The choice of digital payment infrastructure has a significant influence on the underlying monetary unit used (third pillar). This can be either a fiat currency or a crypto asset. While only DLT-based means of payment, particularly crypto assets, can be sent via DLT, all known fiat currencies can be transferred via traditional systems.

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[80] "TARGET2" stands for "Trans-European Automated Real-time Gross Settlement Express Transfer System".

5.3 Forms of programmable euro

Overall, there are four different options as to how a DLT-based euro can be provided by the private sector (see Figure 5). In addition to the issue of euro stablecoins, there is the option of tokenised e-money and tokenised commercial bank money. A fourth option, similarly based on commercial bank money, is a trigger or bridging solution.

Figure 5: Overview of the forms of a private digital euro
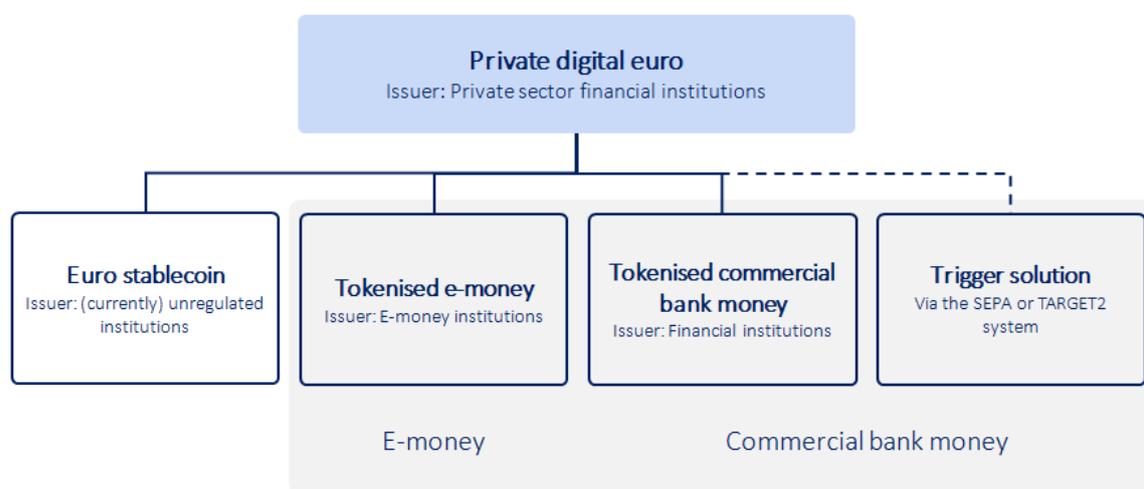
Source: Based on Forster et al., 2021.

5.3.1 Trigger solution as synthetic, programmable euro

Mode of operation of the trigger solution. The trigger or bridging solution can be classified as follows in the taxonomy described in Section 5.2: (1) Contract execution system: DLT; (2) Digital payment infrastructure: SEPA, TARGET2 or TIPS; and (3) Monetary unit used: fiat currency / euro. Here the payment process is triggered by a DLT-based smart contract. However, the payment is then ultimately processed via conventional payment channels. In the bridging solution, the infrastructure of traditional payment systems, for example the SEPA system or the TARGET2 system, is connected with a DLT system.[81] Thus the previously explained temporal asynchrony between performance and consideration, and the associated counterparty risk, can be reduced. The smart contracts specified via DLT act in this case as a payment trigger forwarding transaction-relevant information and thus triggering a payment within the traditional payment systems.[82] The German Bundesbank in cooperation with Deutsche Börse (German Stock Exchange) successfully tested such a trigger solution for the connection of a DLT system to the

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[81] Bundesbank, 2021b.
[82] Forster et al., 2021.

TARGET2 payment system in early 2021.[83] The Bundesbank emphasised that the development and implementation of trigger solutions can be achieved in a much shorter time frame than a digital euro from the ECB.[84]

A trigger solution can be integrated quickly into existing systems. Bridging solutions can be implemented relatively easily and quickly as they are not based on the tokenisation of monetary units but on traditional payment systems. Already there are, in addition to the pilot project being conducted by the Bundesbank in cooperation with the Deutsche Börse, serious efforts underway on a prototype basis that could already be realised in market-ready versions by the end of this year. The tokens used in the bridging solution only represent a claim vis-a-vis a bank and are settled by a downstream SEPA transfer.[85] There is a short-term asymmetry here between performance and consideration, as the bank must check the required account and/or credit facility via the SEPA system before an asset can be transferred. After a successful check, a DLT-based token is created with a credit balance and is technically destroyed as soon as it is cashed in. This initiates the SEPA transfer.[86] One disadvantage of the bridging solution, however, is that DvP transactions are not optimally mapped.[87] In addition, the payment of tiny amounts in the context of streaming money is not supported, as the payment infrastructure is still ultimately based on the SEPA system. The same argument also applies with respect to a desirable acceleration of the payment transfer, whereas trigger solutions also need up to one day for payment processing.

5.3.2 Native DLT-based programmable euro

Possible configurations of a native DLT-based programmable euro. In addition to the trigger solution, in which a DLT is connected to the conventional payment systems, the programmable euro can also be issued directly via a DLT. This option can be classified as follows in the taxonomy: (1) Contract execution system: DLT; (2) Digital payment infrastructure: DLT; and (3) Monetary unit used: fiat currency / euro. In this way, the advantages set out in Section 3 can be realised to an even greater degree, for example, actual digital DvP transactions, higher transaction speed and streaming money use cases. Such native DLT-based forms of the programmable euro can be implemented through stablecoins, tokenised e-money, tokenised commercial bank money or DLT-based CBDCs.[88]

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[83] Bundesbank, 2021a.
[84] Bundesbank, 2021a.
[85] Forster et al., 2021.
[86] Forster et al., 2021.
[87] Sandner et al., 2020b.
[88] CBDCs have already been discussed in Section 4, which is why they are not addressed again in this section.

Stablecoins and tokenised e-money. Stablecoins are crypto assets that retain their value and replicate assets or fiat currencies, such as the euro, through a token on a DLT platform. The token thus functions as a value unit that can be converted into the underlying currency. Due to this characteristic, the stablecoin should be covered completely by the relevant currency. This option for the programmable euro differs from the trigger solution in that the payment is processed via a DLT platform and not via the SEPA system. Currently, US dollar-based stablecoins dominate the market, first and foremost USDT with a market capitalisation of almost USD 70 billion, followed by USDC and BUSD. [89] There is no euro stablecoin in the top 10 stablecoins by market capitalisation.[90]

Markets in crypto assets (MiCA) regulation by the European Commission. The MiCA regulation proposed by the EU Commission in 2020 aims to regulate the digital representation of assets and rights that can be electronically distributed and saved on the basis of DLT, and supplements existing legal bases such as MiFID II.[91] MiCA places a particular focus on the regulation of stablecoins, which can be secured by the euro currency as part of the reserve assets of the issuer.[92] This draft law is currently being discussed in the national parliaments. If the draft law is accepted in the proposed form, stablecoins would be classified as tokenised e-money and fall under the e-money directive[93], according to which the issuer of the e-money token must be approved as an e-money or financial institution[94] and comply with the resultant governance and redemption regulations. Euro stablecoins that do not meet the regulatory requirements of the MiCA may neither be publicly offered nor permitted for trade on a trading platform for crypto assets in the EU. Consequently, it is essential that all stablecoins are completely secured, similar to e-money today. Through MiCA, Europe has the opportunity to become one of the first jurisdictions to offer legal certainty to both the issuers and the users of privately issued stablecoins. The e-money token or stablecoins must in principle be issued at their nominal value. In addition, the holders have a claim against the issuer and a right of redemption for any amount and at any time. With a stable legal framework and the certainty it provides, obstacles to innovation can be reduced and new companies attracted.

Risks of stablecoins. Stablecoins can theoretically impact negatively on financial stability, the transmission of monetary measures and the sovereignty of central banks, which severely reduces their attractiveness.[95]

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[89] CoinGecko, 2021.
[90] CoinMarketCap, 2021.
[91] Kerkmann, 2020; European Commission, 2020.
[92] European Commission, 2020.
[93] European Parliament & Council of the European Union, 2009.
[94] European Parliament & Council of the European Union, 2009.
[95] European Commission, 2021; Arner et al., 2020.

Risks for central banks. The financial stability can be put at risk if the stablecoin issuer has such market power that the consequences of a total failure cannot be borne from a fiscal perspective (the "too big to fail" scenario). The implementation of monetary measures could also be influenced, as central banks do not have the direct ability to manage demand and supply of stablecoins, which could result in the payment channels of the central bank or of the conventional financial sector becoming less important.

Issuer risks. Privately issued stablecoins are generally fraught with issuer risks, as the issuers are not currently regulated. For example, consider the US-Dollar Stablecoins Tether (USDT), for which there is neither a legal claim nor a guarantee of redemption or exchange into US dollars on equal terms. With more than 62 billion tokens currently in circulation, which according to the private company Tether Operations Limited are linked 1:1 to the USD, it is important for investors to know whether Tether is actually 100% secured and whether this full collateralisation will also be maintained.[96] As USDT is less than 4% secured by cash[97], there is significant uncertainty and scepticism with respect to price support. A further disadvantage of stablecoins and, according to MiCA, also of tokenised e-money, is that the token is not multi-bank compatible. This is because stablecoins issued by different financial institutions pose different risks and consequently there is no complete and automatic fungibility as it is not central bank money that is used primarily in payment processing in interbank transactions as is currently the case.[98]

The stablecoin EURB issued by Bankhaus von der Heydt. One example of a euro stablecoin is that issued by the von der Heydt Group at the end of 2020 in cooperation with the technology company Bitbond, which is an in-house, DLT-based stablecoin.[99] The EURB is the first crypto asset to be issued by a financial institution on the basis of the Stellar DLT protocol for test purposes. Nonetheless, despite the fact that EURB is, in contrast to USDT, 100% backed by the euro, there is still a certain amount of issuer risk as stablecoins continue to be unregulated until MiCA comes into effect.

Tokenised commercial bank money. Financial institutions also have the option to issue a programmable euro in the form of tokenised commercial bank money – commercial bank money on a DLT basis. Here, commercial bank money would not be created in a centralised database but via a DLT. Such a digital euro could be used for programmable applications. The central differentiating criterion between stablecoins / tokenised e-money and tokenised commercial bank money is that tokenised commercial bank money does not require complete monetary

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[96] Tether, 2021a.
[97] Tether, 2021b.
[98] Bechtel et al., 2020.
[99] Weniger, 2020.

collateralisation. Accordingly, financial institutions are empowered to continuously create money on a DLT platform – even without underlying collateralisation – within the context of the fractional reserve system. In this process, the various financial institutions, in their role as issuers of tokenised commercial bank money, must agree among themselves on a common standard (and on a common processing system), because different DLT systems imply different configurations of tokenised commercial bank money so that it is not possible to assume automatically that the fungibility of the commercial bank money tokens and interoperability between various DLT systems is a given. Ensuring fungibility is therefore critically important, as without fungibility, two tokens issued by different financial institutions would not be convertible 1:1, which would then imply exchange rates between the tokens.[100] Currently, a handful of financial institutions are starting to develop tokenised commercial bank money. An actual launch is unlikely before 2023, however.[101]

5.3.3 Trigger solution vs. (native) DLT-based programmable euro

Table 2: Advantages of the trigger solution and a (native) DLT-based programmable euro

	Argument
Advantages of a trigger solution	Timely implementation of the trigger solution is possible*
	Low level of disruption to existing payment systems and low initial investment
	High level of legal certainty**
Advantage of DLT-based programmable euro	DvP transactions possible
	Efficient implementation of micropayments
	No system discontinuities in DLT-based business models
	More efficient programming of payment flows

* Does not apply to stablecoins, which are likewise already available.
** Once MiCA comes into effect, a high level of legal certainty will also apply for stablecoins.

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[100] Various options for ensuring fungibility are being discussed by the German Banking Industry Committee (2021).
[101] Bechtel et al., 2020.

6. Selected use cases for the programmable euro

A programmable, DLT-based euro enables innovative use cases for the real economy and the financial sector. The programmable euro is of particular relevance to manufacturing companies, financial institutions and insurance companies. In this section, corresponding use cases are presented and explained. Figure 6 provides an overview of the discussed use cases.

Figure 6: Overview of use cases
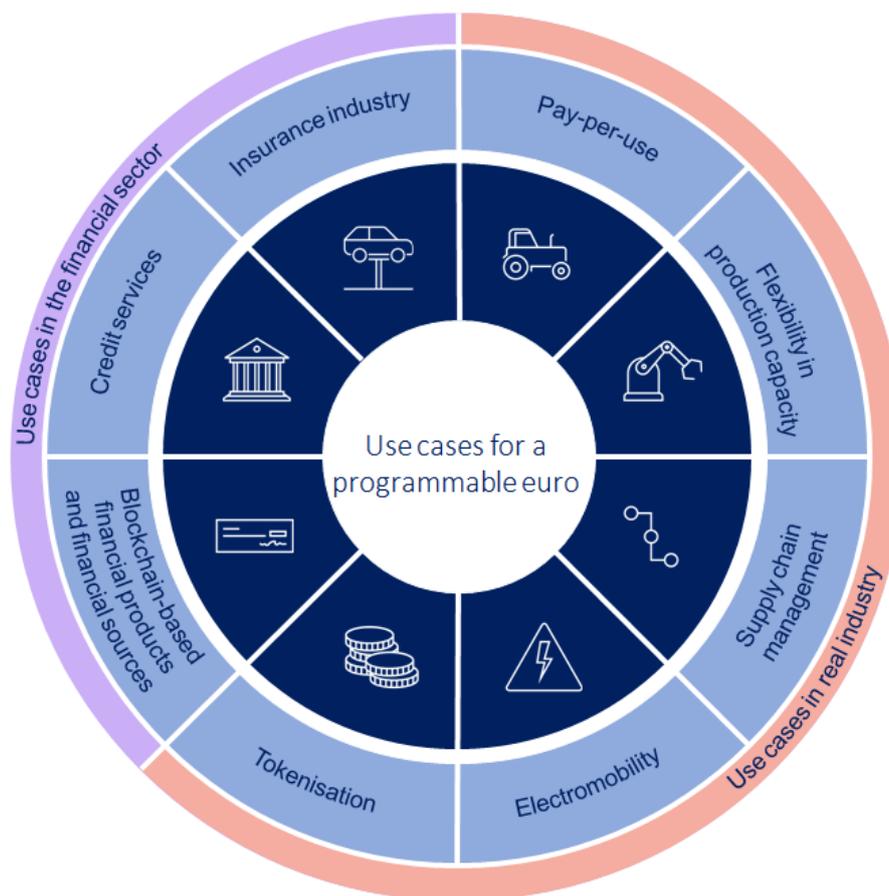
Source: The authors.

6.1 Real economy

6.1.1 Pay-per-use

The role of pay-per-use models. To operate profitably, manufacturing companies require a high level of utilisation of their production capacities. Even small changes in demand can lead to significant profit declines. To counteract this risk, fixed costs can be reduced by utilising the pay-per-use model. In contrast to traditional leasing of

plant and equipment, for which fixed monthly fees are incurred and which generally do not change over the term of a contract, settlement in pay-per-use models is performed purely on a use basis and is therefore variable. A practical example from 2020 comes from Daimler AG, which offers pay-per-use leasing for trucks.[102] This means customers can respond with a great deal of flexibility even to substantial slumps in orders by shutting down parts of their vehicle fleets without incurring high costs independent of use as would be the case with traditional leasing.

Machine manufacturers can profit from pay-per-use models. Pay-per-use models allow machine manufacturers to earn variable but nonetheless continuous income by leasing their machines based on actual use. For the users of such machines, pay-per-use means they can avoid the very high acquisition costs of machines. Lower acquisition costs also enable machine manufacturers to tap into new markets. In addition to industry, pay-per-use also has applications in the following sectors, among others: entertainment, mobility, energy production, agriculture, 3D printing and public local and long-distance transport.[103]

Pay-per-use example: tractor manufacturer Lindner. The Austrian commercial vehicle manufacturer Lindner has implemented a pay-per-use model in cooperation with the Cologne-based financial company CashOnLedger.[104] Lindner's business model allows customers to pay for tractors based on their actual use. For example, it is possible to differentiate whether a tractor is only used as a means of transport or if it is used with a mower, which involves higher wear and is thus charged at a higher rate. Telematics systems equipped with sensors collect usage data, which is managed by CashOnLedger. Using this data and the selected settlement model, for example based on the type or duration of use, customers can be billed in real time. The transactions triggered via DLT are then settled using a traditional business account, with DLT ensuring complete transparency and data authenticity. The availability of a programmable euro would permit debits to be made directly and communicated to the accounting systems. The only possible point of manipulation in this system is the sensors on the machines, like odometers on current automobiles.

Pay-per-use opens up new lines of business for financial institutions. The role of financial institutions in the context of pay-per-use can on the one hand be to offer usage-dependent loans based on the collected industrial data. Here, the use of DLT offers key advantages with respect to data integrity, because pay-per-use business models are only really promising as long as there is certainty that the collected product use data is correct. On the other hand, financial institutions could offer financial products that enable capital investments such as machinery. Commerzbank, for example, offers a credit model in which the repayment amount of

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[102] Daimler Mobility, 2019.
[103] Arnoscht et al., 2011.
[104] Kaiser-Neubauer, 2020.

a loan is based on machine use.[105] Specifically, the repayment amount falls by as much as 50% when capacity utilisation is low. At the same time, the loan can be completely repaid, even before the end of the term, at higher levels of capacity utilisation. This financing option is aimed explicitly at manufacturing companies with high machinery requirements.[106] Such financial products lead to smoother payment management. Furthermore, the investment risk, in this case the risk that machinery will be used less than expected but the costs incurred will remain the same, is reduced.[107]

Pay-per-use and insurance companies. Pay-per-use models can also enable innovative business models and new markets and customer groups for insurance companies. For example, insurance companies can market tailor-made, use-dependent insurance premiums aligned with machine capacity utilisation;[108] the aforementioned pay-per-use business model from Lindner includes an insurance premium along with the actual product. This is, like the rental price for the vehicle, calculated based on use and settled by R+V Versicherung.[109] The cooperation between industrial companies, financial institutions and insurance companies within the framework of DLT-based pay-per-use models thus combines several conventional steps into one, minimising administration costs and time taken.

The role of DLT. A fundamental advantage of DLT compared to centralised technologies is that business and payment processes can be integrated into a single platform. However, this advantage is only realised in combination with concepts such as smart contracts, tokenisation and machine identities. For example, TRUMPF and Munich Re have announced plans for a "pay-per-part model", which provides for the settlement of cut sheet metal parts at a fixed price.[110] Unlike a DLT-based pay-per-use model, however, it is doubtful whether this business model would remedy the asynchrony between performance and consideration and thus the counterparty risks. Instead it can be assumed that the service rendered from the previous month would first be aggregated and only then would TRUMPF submit a monthly invoice to the customer. Payment is only made after that. As described, DLT makes it possible via the concept of streaming money and micropayments to transfer tiny or fractional amounts for services to the machine owner in real time. Through immediate and risk-free transactions guaranteed by the underlying technology, pay-per-use is gaining in relevance for the real economy and making new business models possible.

Data quality. The pay-per-use approach, which is based on accurate measurement of actual use, is only promising if data integrity (validity and reliability) can be

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[105] Commerzbank, 2021b.
[106] Commerzbank, 2021b.
[107] Commerzbank, 2021b.
[108] Schulden et al., 2020.
[109] Kaiser-Neubauer, 2020.
[110] Trumpf, 2020.

guaranteed so that both the machine manufacturer and the purchaser can trust the data measurements taken by the sensors and telematics systems. It is worth noting that such telematics systems have long since proven themselves, for example in the passenger car insurance sector for the evaluation of driving behaviour. The technical structure of a DLT and its SSOT function (see explanation in Section 3.5) can ensure the authenticity, correctness and integrity of the data. To this end, it is possible to build on IoT technologies to read out data directly and in real time from a machine that is connected to the internet. In addition, it is possible to access external data sources, such as weather or economic data, which are fed into the DLT by oracles.

6.1.2 Tokenisation

Definition of tokenisation. In the DLT context, tokenisation is the digital representation and transferability of assets and rights in the form of a token. A token can represent any form of asset, such as ownership rights to real estate, a company or a physical asset.[111] Tokens are generally issued via smart contracts on a blockchain and can be traded on distributed marketplaces; only a digital wallet connected to the internet is required.

> **Tokenised real estate.** An example from the real estate sector: Real estate purchases are currently long-lasting, protracted processes and are generally associated with high administrative and regulatory burdens such as the required land registry changes and the non-divisibility of real estate. The tokenisation of real estate makes it possible to sell property on a peer-to-peer basis without an intermediary. In addition, any degree of partial ownership of a property becomes possible, which is then represented in the form of a token. This fractionalisation is of particular importance with illiquid assets such as real estate and makes it possible for even small-scale investors to invest in such assets. The tokens thus represent the investor's fractional claim to rental income and the right to sell their tokens on a secondary market, but also obligations such as the payment of property tax and insurance premiums. However, changes are still needed to realise practical large-scale tokenisation of real estate that goes beyond feasibility proofs and studies.[112]

> **Meridio as an example of real estate tokenisation.** Tokenised real estate is offered by the US firm Meridio.[113] Meridio's business model brings investors and real estate owners together. A sample business scenario is an attempt by a property owner to quickly liquidate shares in a property in order to finance another project without using loan financing. In this case, the real estate can be tokenised and a certain percentage sold. In the United States, no judges

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[111] Weiß, 2019.
[112] For more information on tokenised real estate, see de la Rubia et al., 2021.
[113] deLisa Coleman, 2018.

are needed to document a change of ownership and the role of notaries – in contrast to standard civil law practice in continental Europe – is restricted to verifying the authenticity of signatures[114], which a DLT can also do. The advantage for the owner lies in the fact that the trade involves very little time or financial commitment. The investor can also make an investment in real estate with little capital. Remuneration paid to the investor, such as rental income, is also paid via token. Thus, not only can fractionalisation take place and costs be reduced but the automation of payments can also be increased.[115]

FINEXITY AG as an example of real estate tokenisation.[116] The German company FINEXITY also tokenises property and other assets via smart contracts, which stipulate capital investment conditions for investors. Of the property price, 65% is financed by a bank; the remaining capital is collected from investors by selling tokens.[117] Manual administrative work or actual visits to a notary or a bank are no longer necessary. Tokens can then be traded on the secondary market platform offered by FINEXITY. It should be stressed here that the investors do not directly invest in the real estate because doing so is not yet permitted under current legislation, for example because land registry entries involving large numbers of people are not currently supported. Furthermore, if the investors were to directly own the property, this would lead to complications in settling the real estate transfer tax. Instead, the investor acquires an investment token (securities according to Section 2 of the Securities Prospectus Act (*Wertpapierprospektgesetz* – WpPG).[118]

Tokenisation of machines. Tokenising machines and other IoT devices via a DLT platform enables them to act as autonomous agents in that uniquely identifiable digital twins are created. These can then initiate actions according to predefined rules and make payments autonomously. For example, smart raw materials silos fitted with sensors could detect whether the levels in the silos have fallen and use this information to send a top-up delivery request to the supplier. On receipt of the goods, a delivery-versus-payment transaction would take place. As part of fractionalisation, any number of machine tokens can be issued to be able to represent even the smallest of partial claims. Together with the availability of a programmable euro, micropayments from machine to machine can be executed quickly and cost-effectively. The prerequisite for the widespread use of tokenisation is a corresponding legal framework that enables a legally secure link between tokens and ownership

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[114] Consiglio Nazionale Del Notariato, o.D.
[115] Meridio, 2021.
[116] Finexity, 2021.
[117] Finexity, 2021.
[118] Ibid.

rights.[119] Should the relevant legislation be changed accordingly, tokenisation could lead to the creation of an uncomplicated and cost-effective form of capital procurement from which manufacturing companies would benefit.

Pay-per-use and tokenisation. In the future, it is also conceivable that it will be possible to purchase and trade tokenised machines or IoT devices in the form of new types of financial products, so that investors can have a stake in the devices. In particular, the combined use of IoT, DLT and artificial intelligence (AI) can lead to synergy effects; for example, AI can supplement human supervisory authorities or indeed replace them entirely. The security risk can thus be reduced while minimising human intervention.[120] This increased security makes it possible for devices to execute transactions autonomously. An example that demonstrates the impressive potential for innovation[121]: In the future, there could be intelligent street lights with their own DLT-based digital identity integrated in the payment cycle as autonomous agents, so that they can not only make independent payments, e.g. to pay for the electricity they use, but also receive use-based payments (e.g. when a self-driving car passes by). These autonomous "profit centres" that independently manage their own income and expenditures can then be offered to investors as financial products so that they can participate in the profits generated by the intelligent devices.

6.1.3 Making production capacity more flexible

Flexible use of production capacity. Companies do not use their infrastructure and resources, such as machinery, exclusively for their own production, but instead sometimes rent them out to other companies.[122] The way in which synergy effects can occur between companies that are actually in competition with one another is evident from a glance at the digital economy, where Netflix now runs its entire infrastructure on Amazon servers.[123] In this way, an apparent competitive relationship is transmuted into an efficient use of server capacity and profit optimisation for both companies. Inter-company partnerships involving production resources can be implemented and administrated via a DLT-based IoT marketplace.

DLT-based IoT marketplace. Such a marketplace offers products at prices based on real-time data from sensors connected to the internet and also takes daily price fluctuations into account.[124] Based on autonomous decisions of the machine fleet, it should be possible to detect when production capacities are required or are not being used. In this respect, the DLT offers the fundamental advantage of data

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[119] FIN LAW, 2021.
[120] Sandner et al., 2020c.
[121] Sandner et al., 2020c.
[122] Kaiser et al., 2020.
[123] Förster, 2016.
[124] Kaiser et al., 2020.

integrity and consequently prevents information asymmetry between the various users of the platform. This integrity is particularly important since modern business relationships are frequently characterised by confidential information such as product and production secrets.

Role of the programmable euro in the flexible use of production capacity. By establishing a marketplace on a DLT basis, the integration of the payment process between individual market participants is also possible via a programmable euro. Its efficient implementation is ultimately based on the use of a DLT-based payment system to guarantee transactions via a uniform infrastructure and without intermediaries.

6.1.4 Supply chain management

Limitations of supply chain management. In the context of supply chain management, companies often struggle to trust other parties with respect to the quality and the current status of a product.[125] In addition, the complexity of supply chains is increasing due to globalisation and high consumer pressure.[126] Modern supply chains also frequently display a lack of transparency with respect to the production, quality and delivery of products. Furthermore, supply chains with numerous participants are prone to fraud and cyberattacks. Unauthorised access to sensitive data can cause negative economic consequences and distrust of producers.[127]

The advantages of DLT-based supply chain management. To address the problems in modern supply chain management discussed above, a DLT can be used as the technological basis for the entire supply chain management process. Firstly, three data channels must be set up: (1) between the retailer and the supplier; (2) between the supplier and the producer; and (3) between all parties.[128] In this way, data protection is ensured through the data sovereignty of each party, so that contractual information, for example, can be shared between the retailer and the supplier but not with the other parties. However, a higher degree of transparency is also achieved through the traceability of products within the channels. In addition, it would enable faster and more transparent supply chains, whereby lower costs would be realised.[129] In this context, a programmable euro would ensure that transactions within the supply chain could be processed quickly and efficiently.

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[125] Kaiser & Sandner, 2020.
[126] Schäffner et al., 2021.
[127] Schäffner et al., 2021.
[128] Schäffner et al., 2021.
[129] Kaiser & Sandner, 2020.

Commerzbank, Evonik and BASF are testing DLT-based supply chain management. A pilot project set up by the three German companies Commerzbank, Evonik and BASF to explore DLT-based supply chain management should enable the efficient processing of bilateral claims.[130] The regular and reciprocal business relationship between Evonik and BASF serves as the basis for the project. Claims and payments are processed in real time via the DLT platform provided by Commerzbank, using a digital euro provided on the platform. The companies report that the automatic data validation via smart contracts and the associated transparency, speed and reliability are the key advantages of using a DLT for supply chain management. The project partners describe the use of a DLT-based platform as an essential component of fully autonomous supply chains.[131]

6.1.5 Electromobility

Electromobility based on DLT. Another use case for the programmable euro and DLT is in the energy sector. Using a DLT, devices, machines and entire systems can make decisions autonomously, for example with respect to power generation. Smart contracts can be used for the efficient purchase and sale of electricity. An example: In the case of electric vehicles, a specific electricity price per kilowatt-hour can be stipulated at which the car connected to the charging station should be charged. Alternatively, the system can also bill for the cheapest charging times. In this case, the vehicle does not charge immediately, but is sufficiently intelligent to start the charging process only when it is favourable from the perspective of the programmed logic, for example at night when the demand and thus the electricity prices are typically lower.[132] In addition to lower costs, the macroeconomic advantage lies in the fact that consumption peaks can be reduced, relieving the burden on the power grid. Payment processing is completely automated up to a specific defined maximum amount for the charging process that is anchored in the logic.[133] This automated and autonomous control would have enormous consequences for existing and future car sharing concepts. Through the interplay of the car sharing system, a DLT-based means of payment, and the AI-driven power grid, it is possible to make improvements in price, range and availability and to enhance the efficiency and attractiveness of car sharing.

Automatic purchase and sale of electricity via smart contracts. The autonomous nature of an efficient ecosystem implies that electric cars can be used as power stores and thus as a source of income.[134] Physically connected electric cars can make available the power stored in them, should the demand and thus the electricity

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[130] Commerzbank, 2021a.
[131] Commerzbank, 2021a.
[132] Kaiser & Gross, 2020a.
[133] Kaiser & Gross, 2020b.
[134] Kaiser & Gross, 2020a.

price be particularly high. When demand and price fall again, the car can return to acquiring power for its own use. The purchase of electricity at low prices and its sale at high prices means a financial profit for the owner of the car. The autonomous electric car can make these decisions itself using smart contracts. Then the customer need no longer negotiate the price of self-produced electricity with the electricity supplier, but can automatically find the best price on a market. As a result, autonomous vehicles can, for example, procure their electricity directly and cost-effectively from the private supplier's photovoltaic system.

Influence of DLT-based electromobility on market participants. The potential of DLT-based electromobility is particularly significant in combination with a programmable, DLT-based payment method. Direct settlement – without the need for an intermediary and without the exchange of the required token into a fiat currency – is possible. The payment processing of the described charging process can also follow the streaming money model, in which money is not transferred on a discretionary basis but as a constant flow. The extremely high level of fractionalisation achievable with DLT-based payment methods means that even fractions of a kilowatt-hour can be efficiently settled.

Eloop as an example of DLT-based participation in electromobility profits. In March 2021, the Vienna-based car sharing company Eloop announced that it intended to issue a DLT-based token that would enable investment in the company's fleet.[135] Holders of the token would finance the procurement of additional vehicles and profit from their revenue share. In this way, Eloop aims to finance 250 Tesla Model 3 cars for their core market of Vienna.[136] In addition, car manufacturers are themselves testing how the DLT can be used in electromobility. BMW has, for example, developed a DLT-based – and thus forgery-proof – vehicle passport called VerifyCar, which aims to prevent mileage manipulation and other fraudulent activities.[137]

6.2 Financial sector

6.2.1 Blockchain-based financial products and financing sources

Digital securities are gaining ground. The transfer of securities currently involves considerable effort and thus expense as changes of ownership are documented by certificates physically held by a central securities depositary in the background. Digital securities, which are for example documented via a DLT, can leverage

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[135] Kasanmascheff, 2021.
[136] Kasanmascheff, 2021.
[137] Kasanmascheff, 2021; Wilhelm & Müller, 2021.

efficiencies in this context, as complex and protracted processes such as clearing, settlement and safe custody can be automated.

The legal situation in Germany. The legal framework for digital securities has been established in Germany with a law on the introduction of electronic securities (*Gesetz zur Einführung elektronischer Wertpapiere* – eWpG) adopted in June 2021. This law permits the use of a DLT as a digital crypto security register without the current obligation to deposit a physical paper document with a central securities depositary.[138] Though only bonds and not shares are currently covered by this law, the adoption of such a law sends a signal to the German capital markets that a first step has been taken in the direction of dematerialisation.

DLT can facilitate financing through equity and borrowing. Currently, SMEs are only rarely listed on European stock exchanges due to the high entry costs (in 2018 only 3,000 of the 20 million SMEs in Europe were listed[139]). A DLT-based trading platform could allow them to float tokenised shares with lower barriers to entry and lower costs.[140] This would eliminate parts of the protracted and expensive initial public offering process. The advantages of financing via digital securities apply not only to financing through equity, but also to borrowing. For example, Daimler successfully processed a DLT-based promissory note loan with the Landesbank Baden-Württemberg (LBBW).[141] Simple and cost-effective DLT-based financing options will have a lasting impact on capital markets and can increase liquidity. This benefit is also a result of access to a broader pool of investors, for example through fractionalisation (see Section 6.1.2), and the essentially global nature of DLT. In addition, DLT accelerates and automates clearing processes by using smart contracts without having to involve intermediaries.

The programmable euro and securities processing. With the eWpG, trading in digital, DLT-based securities now has a legal basis. However, euro payment processing via DLT is currently only possible to a limited degree. To increase efficiency and enable DvP transactions, it should be possible to issue and manage securities via a DLT and also to pay for them. One way to do this is to combine both platforms (DLT and traditional payment infrastructure) via a trigger solution and synchronise them with one another (see Section 5.3.1). Or DLT-based euro payment methods could also be used instead of a trigger solution to address the limitations of trigger solutions. All business processes – issue of the security, payment for the security and interest payments – could then be implemented via the DLT.

Smart derivative contracts as an example of DLT-based financial products. Three years after launching the project, DZ BANK, the Bayerische Landesbank and Deutsche Börse successfully traded their first over-the-counter (OTC) interest rate

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[138] BMJV, 2021; von Zehmen & Kaulartz, 2021.
[139] European Commission, 2018.
[140] Voutsas, 2020.
[141] Krug, 2019.

derivative in the form of a digital, DLT-based smart derivative contract.[142] A key aspect in the development of the smart derivative contract was an agreement on technology and legal certainty, because even a fully automated transaction is of no benefit if it does not enjoy legal recognition. To guarantee an automatically initiated transaction, the value of the derivative is calculated based on the contractually defined algorithm, and daily pre-financing is arranged in order to guarantee payment processing.[143] With this project, the three institutions have proven that such a transaction can be realised entirely digitally. The previously complex and drawn-out process for trading OTC derivatives can thus be simplified and accelerated by the DLT. The financial institutions also explained, however, that a programmable euro – regardless of who issues it – must combine on-chain and off-chain transactions seamlessly.[144]

6.2.2 Credit services sector

Use of DLT in interbank payment processing. The large number of financial institutions from various jurisdictions that are involved in interbank payment processing means different data formats are used to exchange information in cross-border payments. The resultant synchronisation problems generally lead to high costs and inefficiency. The DLT could be used as a common technological basis to harmonise the exchange of information and to establish a common system with uniform rules for transactions between financial institutions. This should also result in efficiency gains in terms of the speed and transparency of transactions. The need for mutual trust is minimised by cryptographic protection against forgery. Instead of trust in the honesty of the transaction participants, all that is required is trust in the DLT protocol.

The Italian Banking Association's Spunta project. The Spunta project by the Italian Banking Association (AIB) is advancing the integration of DLT in the Italian banking sector.[145] The primary motivation for the project, in which 18 financial institutions are currently participating, is the automatic reconciliation of bilateral accounts of two cooperating financial institutions.[146] In the current interbank payment processing system, some of the data is stored in different systems and file formats. The resultant inefficiencies are to be addressed by the Spunta project. Its technology detects cases in which transaction information of the two interacting financial institutions does not match and standardises the data reconciliation. Thus far, 332 million transactions have been processed with the DLT system.[147] Instead of slow and error-prone back-office reconciliation, which has thus far been done on a

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[142] Godenrath, 2021; DZ Bank, 2021.
[143] Godenrath, 2021.
[144] Godenrath, 2021.
[145] EPC, 2021.
[146] EPC, 2021.
[147] Attanasio, 2021.

monthly basis, the system permits daily reconciliation of the information.[148] The key advantages are greater transparency and an integrated communications channel to facilitate dialogue between financial institutions should data discrepancies occur.[149] Such a project would benefit from the integration of a DLT-based means of payment to achieve further efficiency gains. For this reason, the integration of a DLT-based programmable euro is planned as part of the Spunta project, in order to implement the actual processing of payments, and not just the payment instructions, via a DLT.

6.2.3 Insurance sector

Smart contracts in the insurance sector. Smart contracts make it possible to trigger transactions automatically based on external events. As contracts within the insurance sector are generally based on the fulfilment of previously defined events, for example a traffic accident, smart contracts are of particular relevance. The implementation and processing of insurance services through smart contracts has the potential to reduce the organisational, bureaucratic, and investigative business costs for insurance companies, and favours immediate payment in the event of damages. This requires that questions regarding the cause of damage or the party at fault can be answered unambiguously. Many circumstances are quite complex and require the assessment of a loss adjuster. Though smart contracts (like all algorithms) are not yet intelligent enough to emulate the human skills required to make judgements on insurance issues, hybrid models could be used, in which smart contracts merely compare specific aspects of a situation, using telematics and sensor data, with the contents of the contract and can only execute certain transactions, for example, those relating to contract management and the collection of premiums.[150]

DLT core applications in the insurance sector. The insurance sector is, given its high degree of digitalisation and automation, predestined for the integration of DLT in its business processes. The advantages of using DLT – transparency, automation, protection against data manipulation, etc. – are therefore particularly promising for the business processes of the insurance business. Ernst & Young has identified the following key areas of the insurance sector that would profit from the use of DLTs: (1) fraud detection; (2) claims management; (3) IoT; (4) sales and payment processing.

> **Fraud detection.** The distributed test mechanism of a DLT detects and prevents any attempts to manipulate data. This particularly applies to applications involving public blockchains or access-restricted blockchains with

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[148] EPC, 2021.
[149] EPC, 2021.
[150] Möhlenkamp & Wessel, 2018.

a high number of selected network participants. In addition, the manipulation-resistant data can serve as a basis for AI-driven control algorithms. Minimising the risk of fraud increases the trust between the parties involved, as the data situation is accurate and dependable at all times.

Preventing and managing claims. To enable more targeted calculation of the probability of certain loss events and the associated compensation payments, insurance companies are very interested in statistical projections based on user data. For example, device data transmitted and stored on a shared DLT can be used to standardise loss reports and facilitate communication between all the parties involved.[151] The verification of the insurance cover could be determined quickly and securely via a DLT and each transmission of digital exhibits and appraisals can also be held for auditing purposes in chronological order in a distributed inspection protocol.

IoT. If the insurance sector succeeds in exploiting the previously described advantages of the IoT, insurance products can be adjusted more precisely to the requirements of customers. For example, vehicle information with respect to braking and acceleration patterns, distances driven, and other behavioural patterns can be used to identify high-risk drivers.[152] By the same token, more favourable rates can be offered to safer drivers. An insurance company can thus set itself apart with such personalised products and gain a competitive advantage over other providers.

Payment processing. As already explained, the integration of payment processing into a DLT offers efficiency gains and reduces counterparty risk.[153] Consequently, and particularly in combination with a programmable euro, insurance companies can then guarantee transparent and immediate payments and premiums.

7. Recommended actions

7.1 Cooperative approach and networking

Collective discourse and cooperative implementation. When developing and implementing applications involving the programmable euro, the interests of all stakeholders should be taken into consideration. It would not be desirable for companies to develop their own "silo solutions" which would not be widely accepted.

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[151] EY, 2018.
[152] EY, 2018.
[153] EY, 2018.

Rather, dialogue should be sought with future customers, such as industrial companies or private end users, and also with potential business partners, such as financial institutions and insurance companies. Ideally, both the investigation phase and the development and implementation phases should be supported by the financial supervisory authorities and take place in consultation with the euro system. In this process, efficient, transparent and secure solutions for programmable payments should be developed and implemented together; as with the ECB's approach to the digital euro, market actors can be included in expert panels. Discussion forums and working groups are also conceivable; they could, for example, be initiated and coordinated with the federal states, e.g., the Bavarian Ministry for Digital Affairs (*Bayerisches Staatsministerium für Digitales*). In addition, corresponding use cases could even be monetised within the group. A critical discussion focusing on interdisciplinary aspects is particularly important here in order to bring highly innovative solutions to the market. At the EU level too, all stakeholders must act in agreement with the EU bodies participating in the EU legislative process and form a community of interests that is as coherent as possible. This is predicated on a public discourse and on the speedy dissemination of empirical results from research studies and practical digital euro sandbox projects. It is therefore necessary for EU legislators, the euro system, the national central banks of the euro area, and the financial supervisory authorities to work with representatives of the private sector and academia to develop DLT solution models for the programmable euro with which the EU as a whole can emerge strengthened on the international stage.

Identifying opportunities for the programmable euro. Payment solutions involving the programmable euro complement the previously existing payment options for all market participants. These payment solutions undoubtedly have disruptive elements, but they should not lead to a substantial displacement of traditional payment systems and thus to disintermediation of the financial sector. Financial institutions are urged not to lose their connection to digitalisation and to participate actively in opening up new business fields (see Section 6.2). Furthermore, against the backdrop of a foreseeable rise in demand in the financial sector and the real economy for experts who can realise the digital euro via DLT payment infrastructures, Germany's federal states are urged to work with the Federal Ministry of Education and Research (*Bundesministerium für Bildung und Forschung* – BMBF) to promote educational measures for the training of skilled staff. In particular, higher education policy could be adapted for greater emphasis on the digital euro in courses of study such as IT, business administration, and economics. In the medium term, entire courses would be conceivable that deal exclusively with the prerequisites, implementation and implications of blockchain technology, crypto assets and the digital euro, to achieve a systematic and scientifically sound understanding of these topics. For financial supervisory authorities in particular, it would appear desirable to create further jobs for programmers and experts in DLT-based payments in order to respond adequately to reports of suspicious activity in

accordance with the Money Laundering Act and also to assess the legal compliance of smart contracts.

7.2 Adjustments to the legal framework

Legal uncertainty is an obstacle to innovation. Companies aim to avoid costly product modifications due to regulatory changes and require, at both the national and EU level, a clear and transparent legal framework to increase their planning security. In Germany there is still no full legal certainty or clarity regarding the regulation of DLT-based applications such as tokenised commercial bank money or stablecoins. Innovation is inhibited less by a lack of regulations than by uncertainty as to whether projects could be slowed by a more restrictive legal framework in the future. In order to implement new types of business models involving the programmable euro, companies need a regulatory framework that is designed to be as technology-neutral, innovation-friendly and far-sighted as possible.

Core legal aspects. The legal standards should build on the extant legal system and adjust it to the peculiarities of the programmable euro. From the perspective of consumer and investor protection, certain principles, such as data protection and the right to redeem the programmable euro against commercial bank money at nominal value from the issuer, must be anchored in law. The former requires balancing the legal interest in KYC and AML processes on the one hand and the privacy and personal rights of the individual on the other. Harmonisation with the General Data Protection Regulation (GDPR) implies the anonymisation of viewable user data, which can be implemented for example through zero-knowledge proofs or through authorised authorities such as system administrators who can retroactively make changes, for example with respect to deleting data. Both EU and national legislators should also deal with the need for changes to be made to both civil and regulatory law. The question of who must bear the risk of errors in smart contracts must be answered, and these findings are to be anchored in the parts of the German Civil Code (BGB) that relate to contract law. In addition, the dematerialisation of securities law could be further advanced: the private sector could profit from an extension of the scope of the eWpG to shares and not only promissory notes. However, this requires a detailed legal examination of the implications for corporate law with respect to establishing a company, issuing shares, and trading them on international capital markets.[154] Particular attention should be paid to drawing up a legal basis that makes it possible for IoT devices that have been assigned identities and act autonomously to enter into payment transactions.

Promotion of clear and technology-neutral regulation. Legislators should provide the required legal clarity in a timely fashion and introduce a technology-neutral legal framework. The regulation principle of technological neutrality and openness means

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[154] Tönningsen & Adolph, 2021.

that policymakers can set targets but that the technology that ultimately prevails will be determined by innovative competition and the market. The legal framework should permit the integration of DLT across the entire value-added chain of various business models without drastic restrictions and thereby promote the development of the programmable euro.

Which forms of the programmable euro are already legally covered? Transactions that are triggered by DLT-based systems via smart contracts but processed via traditional payment systems are mainly subject to the currently existing legal framework. Accordingly, no substantial changes to the regulatory framework need to be made for such a trigger solution.[155] Furthermore, some other euro-denominated, DLT-based applications also fall under the existing legal framework. However, most of the DLT-based applications involving the programmable euro are outside the current regulatory framework.[156] Even if the MiCA regulations establish legal security for stablecoins / tokenised e-money, not all forms of the programmable euro are covered by the regulations, such as tokenised commercial bank money or CBDCs. Issuers of such digital euro tokens must be subject to information obligations, for example in the form of a prospectus or whitepapers, to provide both financial supervisory authorities and also consumers with sufficient information. A transparent, innovation-friendly legal framework must be created here. This should, if possible, have a supranational character so as not to limit the efficacy and use of the digital euro. European administrative bodies are called on to act here.

7.3 Establishing standards and ensuring interoperability

Practical projects involving the programmable euro. On the basis of the trigger solution and euro stablecoins, it is already possible in principle to represent the euro via a DLT-based platform. Initial use cases in the real economy are also using these solutions, such as the CashOnLedger and Commerzbank projects described above. However, these two examples build on different technological platforms. In the short- to medium-term, it is to be expected that different DLT applications will continue to be based on different DLT protocols and that no one DLT infrastructure will prevail for all DLT use cases, as the technologies are too different for this.

Interoperability is important. For this reason, it is essential to establish interoperability between the various infrastructures. Interoperability refers, in this context, to the ability of different systems to network with one another, communicate with one another and consequently to exchange data seamlessly with one another, even if they are not provided by the same manufacturer or service provider.[157] The

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[155] Bechtel et al., 2020.
[156] Bechtel et al., 2020.
[157] Bechtel et al., 2020.

smooth exchange of information including transaction data between various applications, machines and databases is critical here. If companies opt for fundamentally different platforms, it is important to coordinate the technologies to ensure the highest possible level of interoperability. The reason for this is that the named advantages of a DLT and the programmable euro are only realised when a large network of users has access to the data, contributes to value creation and can develop corresponding applications. Ensuring the interoperability of various DLT protocols is currently a primary focus of the crypto industry, as shown by numerous projects designed for interoperability such as Chainlink or Polkadot and the open competition to establish a technical standard to link different blockchains.[158]

Establishing standards to generate synergies. In addition to guaranteeing interoperability, a certain standardisation and harmonisation of the technologies used is also desirable. It is critical that companies across various industries reach agreement on standards with respect to encryption algorithms, data formats and processes for assigning digital identities. Such an agreement must aim to promote synergies between the users of DLT protocols. In particular, standards for the programmable euro must be defined.[159] Otherwise, it will not be possible to fully capitalise on its advantages.

International cooperation on standardisation. Although initiatives for the standardisation and interoperability of the programmable euro at the national level by specialist standardisation organisations such as the German Institute for Standardisation (*Deutsche Institut für Normierung* – DIN) appear sufficiently promising, cooperation with respect to key design aspects must still take place on an international level. We can, in this respect, learn from the World Wide Web Consortium (W3C), which develops binding standards for the Internet. Meanwhile, the Technical Committee ISO/TC 307 ("Blockchain and distributed ledger technologies") is working on the formulation of fifteen standards, even though only four have been published thus far. These include, in addition to the underlying agreement on shared terminology, the protection of personal data, the interaction between smart contracts, and security management for the administrators of digital assets.[160] A standard that focuses on payment systems would be very welcome, as would the discussion in this context of the question of how foreign payment solutions in foreign trade transactions can be implemented in domestic payment infrastructures or how the synchronisation of different technological infrastructures is to take place and what prerequisites are associated with this. This discourse is also important for positioning European payment solutions as a counterpart to American and Asian initiatives, such as the diem or e-CNY. The private sector's programmable euro could reduce dependencies on foreign payment service providers and in the

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[158] Tse, 2021.
[159] Deutsche Kreditwirtschaft, 2021.
[160] ISO, 2021.

long term boost the digital and monetary sovereignty of Europe. In particular, from the perspective of data privacy legislation, it would appear reasonable for the EU to push on with its own projects given its advanced legislation on data protection and privacy, which meet the data protection requirements of the EU for the benefit of consumers.

Fungibility and multibank compatibility. In addition to the establishment of standards and ensuring interoperability, the multibank capability of payment solutions should also be guaranteed. For this, a fungible exchange of tokens is required, i.e., it must be possible for tokens of different issuers to be exchanged 1:1 without exchange rates. In order to guarantee multibank capability, issuers should work together on corresponding solutions. For example, issuers could agree on a consortial DLT and issue tokens on it that are collateralised by identical reserve assets that are also subject to uniform custody regulations. This would guarantee that the issuer risk for all issuers is equally pronounced, meaning that digital euro tokens would not be subject to mutual exchange rates.

Further measures. It would seem useful to determine the investment required for infrastructure, research, and practical trials of the digital euro for both the public and private sectors. A breakdown by various economic sectors is required so that the relevant peculiarities and different requirements placed on the digital euro are given sufficient consideration. This would also simplify the operationalisation of the next steps.

Bavaria's role. The previously discussed core topics, such as the establishment of new standards and the guarantee of interoperability of the various infrastructures, are of huge significance at the state level. To promote these aspects further, a far-sighted strategy is needed. It should promote horizontal information exchange in the real economy within the scope of programmable euro consortia. The focus of the Bavarian blockchain strategy is on the practical application of research results and could, in later upgrades, also address the issues of standardisation and interoperability.[161]

8. Conclusion

Opportunities for the programmable euro. The programmable euro offers multifaceted opportunities for the real economy and the financial sector. Current payment systems are not yet fully prepared for the continuing advance of digitalisation and automation. The asynchrony of delivery and payment via conventional payment channels results in inefficiencies and counterparty risks. In addition, innovative business models such as those involving micropayments,

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[161] STMD, 2021.

streaming money and tokenisation, cannot be completely implemented in conventional payment systems. DLT is viewed as a feasible technological foundation that opens up opportunities to remedy shortcomings in current payment systems and implement innovative business models. DLT-based crypto assets such as bitcoin exhibit high volatility, minimal scalability and significant energy consumption and thus are (not) yet suitable as an everyday payment instrument. The opportunities for the programmable euro lie in eliminating counterparty risk and promoting innovative business models involving micropayments and tokenisation. A DLT-based payment method will drive developments in Industry 4.0 and the IoT by making production processes highly automated and enabling autonomous trading between machines that are assigned their own identities. The programmable euro thus offers the opportunity to utilise the advantages of innovative business models in the best way possible and to function as a catalyst for digitalisation. Not least, a digital euro serves to guarantee the sovereignty of the eurozone member states and the long-term independence of their consumers from foreign payment solutions, which are not necessarily subject to the same data protection provisions as those of the EU.

Programmable euro use cases and examples. A private sector programmable euro can be implemented as a trigger solution, a euro stablecoin / tokenised e-money, or tokenised commercial bank money. Although many possible implementations exist, they share one common denominator in that they face the same functionality demands if they are to be useful to the real economy and the financial sector in numerous use cases. Specifically, the implementation of pay-per-use business models, improvements in supply chain management, and tokenisation can be driven forward. In addition, the energy sector, interbank payment processing and the insurance sector can profit from a programmable euro, in that data validity can be guaranteed through resilience against manipulation, transparent traceability of transaction histories, and scalability based on the DLT.

Recommended actions for the programmable euro. Currently it is assumed that the ECB will not issue a digital euro before 2026. It is also unclear whether it would be based on a DLT. Accordingly, the innovative power of the private sector is called on to provide a programmable euro in close cooperation with the relevant public institutions at the national, EU and international level so that the described use cases can be implemented and existing limitations removed. Key aspects of the introduction of a widely used programmable euro, such as standardisation and the interoperability of various DLT platforms, require a public and inclusive discussion in which the essential findings are worked out in international working groups, dialogue forums and real-world laboratories. Furthermore, legislators must create a technology-neutral legal framework that ensures the interoperability of a digital euro. On the one hand, technology neutrality will ensure that certain forms of digital euro are not excluded from the outset, a development that could see innovation in the DLT area diminished and potentially promising DLT solutions not even being examined and tested. On the other hand, focussing on interoperability will prevent

the emergence of a DLT patchwork and enable one issuer's digital euro to be used on another issuer's infrastructure. Achieving such a development will require private actors, entire sectors and states to agree uniform standards and regulations that are then incorporated into a formal regulatory framework in the medium term. In the EU, the European Commission, the European Parliament, and the Council of the European Union and, at the national level, the German government and the *Bundestag*, are called on to take the necessary legislative steps to provide legal and investment certainty. Pilot projects must be supported and information platforms created to bring together the different stakeholders and focus their efforts to issue a digital euro for the real economy.

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