

Bindseil, Ulrich

Working Paper

Innovations and the layering of money and payments

SAFE Working Paper, No. 473

Provided in Cooperation with:

Leibniz Institute for Financial Research SAFE

Suggested Citation: Bindseil, Ulrich (2026) : Innovations and the layering of money and payments, SAFE Working Paper, No. 473, Leibniz Institute for Financial Research SAFE, Frankfurt a. M., <https://doi.org/10.2139/ssrn.6477298>

This Version is available at:

<https://hdl.handle.net/10419/339609>

Standard-Nutzungsbedingungen:

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

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

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

Terms of use:

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

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

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

Ulrich Bindseil

Innovations and the Layering of Money and Payments

SAFE Working Paper No. 473 | March 2026

Leibniz Institute for Financial Research SAFE
Sustainable Architecture for Finance in Europe

info@safe-frankfurt.de | www.safe-frankfurt.de

Innovations and the layering of money and payments

U. Bindseil¹

23 March 2026

Abstract

This paper analyses the role of layering in the architecture of money and payment systems and how recent technological innovations affect it. Layering in payments, whereby payment ledgers are hierarchical to each other, and senior ledgers allow for interoperability between junior ledgers, has historically emerged from efficiency, risk management, and governance considerations. The paper develops a framework to classify ledger hierarchies and types of payment ledgers and uses it to assess innovations including central bank digital currencies, instant payment systems, public blockchains, tokenized multi-asset platforms, expanded access of non-bank payment service providers to central bank accounts, and stablecoins. The analysis shows that many innovations do not eliminate layering but instead reorganize it, often preserving the fundamental tiered structure in which central bank money anchors the monetary system. Innovations should normally improve payment efficiency but also introduce new risks and policy challenges that must be addressed, implying the need for regulatory modernization and an evolving role for central banks in shaping payment architectures and safeguarding the singleness of money.

Keywords: Layering of payment systems; Monetary architecture; Central bank money; Stablecoins; Tokenization and payment infrastructures

JEL-Codes: E42, E58, G21

¹ I would like to thank Peter Wierts for suggesting several of the key ideas discussed in the paper. I would also like to thank Anneke Kosse, Peter Wierts, and Takeshi Shirakami for their helpful comments and discussions on earlier versions of this paper. The views expressed are those of the author.

1. Introduction

Layering is a widespread phenomenon in finance. It does not only occur in payments, but also in most financial market infrastructures: CCPs, CSDs, and specialised institutions like CLS have direct members (clearing members) and indirect participants which use the services of the FMI via accounts with the direct members. Most of the time, layering seems to be the result of economic efficiency considerations. Layering can also be imposed by laws or by decisions of authorities, if it is believed that layering is beneficial for efficiency or stability but does not necessarily emerge through market forces.

This note reviews more broadly the role of layering in payments, the current innovations that are believed to challenge the layering architecture, and whether (i) these innovations and their implications should be understood as endangering desirable features of our essentially two-layered payment and monetary architecture, with implied risks for which authorities must find effective responses, or whether instead, (ii) these innovations would allow to overcome the previous technical limitations which made the two-layer system preferable and possibly achieve a higher efficiency and even safety through the re-organisation (and possibly simplification) of the previous architecture.

The paper is structured as follows. Section 2 provides a broad review of financial layering to illustrate its various aspects. Section 3 discusses how current innovations challenge the existing layered architecture, and what policy questions this raises. Section 4 draws conclusions. The paper develops further the conceptual work initiated by Hee, Kosse, Wierts and Wijngaard (2025) to represent and understand payment system architectures “to help central banks, regulators and the payments industry in their understanding, assessment and comparison of architectures and in their exploration and design of new ones” (p. 2).

2. Dimensions of layering

2.1 Ledger hierarchies

In principle, every economic entity has a balance sheet, and a “ledger” was understood before the 21st century as the balance sheet / book of accounts of a company. For the last two decades, the term ledger has however often been used instead as the synonym of “system of accounts for recording ownership positions of assets and transfers between owners of these assets”, i.e. a meaning closer to the one of a payment system, like in the term “distributed ledger technology”. We will also adopt this meaning here. Today we observe zero-layer, single layer, double layer, and triple layer ledger architectures. Consider the following examples.

- **Zero layer:** an IOU economy is one in which everyone enters credit and debit positions with everyone else, as they appear as counterpart to goods and services transactions without associated settlement of a payment leg. These positions may be reversed in case of future opposite transactions, or settlement through commodity money (which is itself a sort of good). In an IOU economy, everybody runs a book of unstructured financial claims and liabilities, without hierarchy and without anyone offering a transfer and settlement mechanism in high credit quality, fungible claims, which could qualify as a “ledger” in the 21st century meaning. An IOU economy persists today in “family and friends” networks and to some extent between business partners.
- **Single layer:** (i) When two bank clients have sight deposits accounts with one bank, and the bank settles a transfer between the two within its own books; (ii) non-banks using central bank money in the form of banknotes or CBDC²; (iii) payments in Bitcoin, e-money or stablecoins within the same ledger and not being cleared afterwards via another ledger; (iv) Interbank wholesale payments:

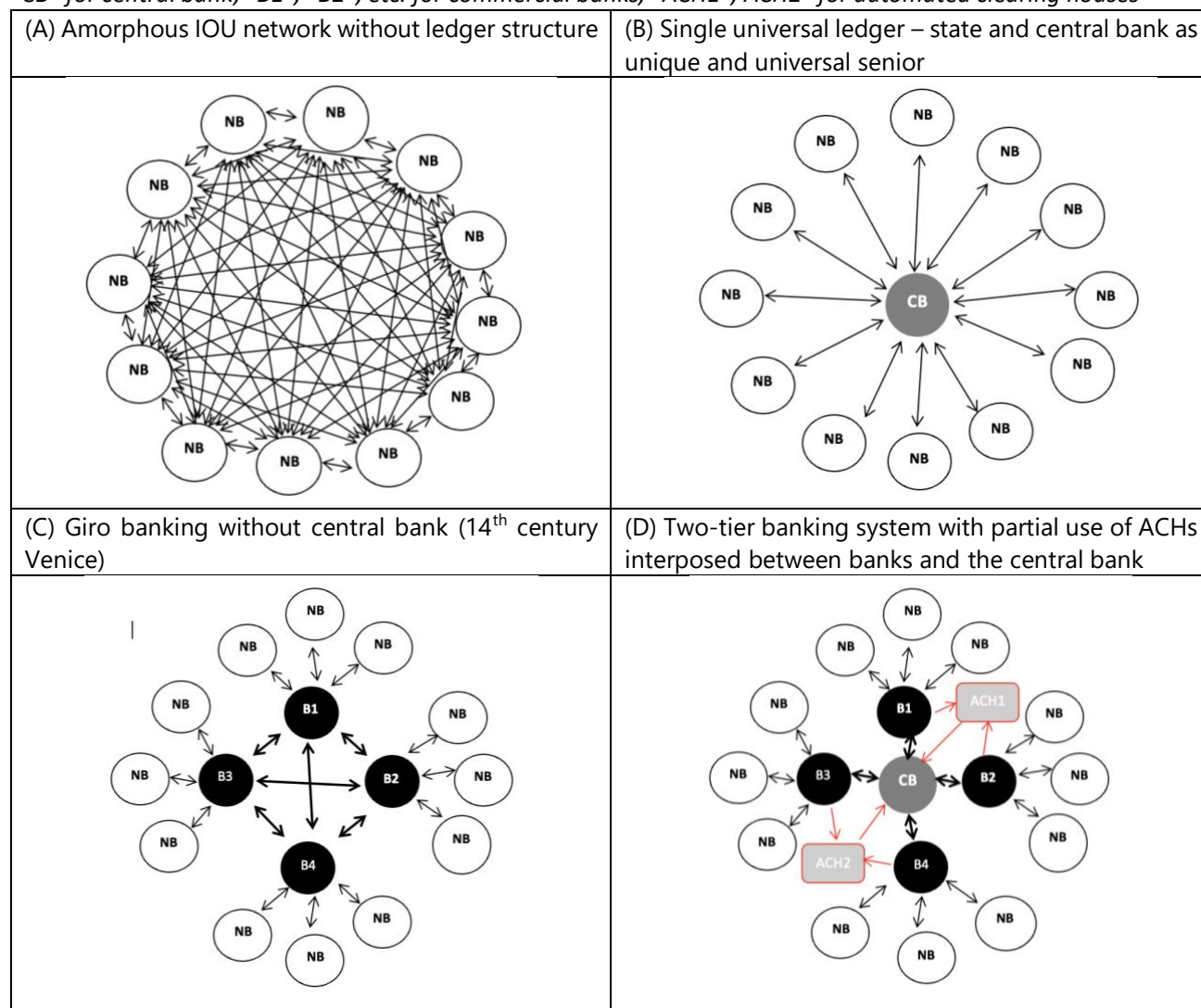
² Relying on a genuine bearer instrument like banknotes is not exactly relying on a ledger, although it is equivalent from the perspective of flows of funds. Relying on CBDC is the same while relying on a ledger.

initiated based on a financial transaction between banks, settled in the books of the central bank (in central bank money).

- **Double layer:** the credit transfer between two clients of different banks is settled in commercial bank money at the level of clients, and in central bank money (via the RTGS system, or via a central bank money based instant payment system like TIPS or FedNow) between the banks.
- **Triple layer:** A triple layer payment flow arises for example if retail credit transfers between bank clients are settled at the interbank level first in a private automated clearing house (ACH) based on net deferred settlement, and only at day-end the net flows are settled once between the banks in the central bank RTGS system. Another triple-layer payment occurs in the case of an on-ramping of funds from a commercial bank deposit account to a stablecoin which holds its reserve with another bank, so that the central bank RTGS system must clear at the end the balances created between these two banks.

Figure 1 illustrates the architectural options with four cases of layering: (A) Amorphous IOU network: everyone has potentially claims and liabilities with everyone else, and there is no specific ledger structure to settle with means of payments to achieve a more concentrated and leaner structure of exposures (zero layer). (B) The opposite, being a single universal and ultimate ledger which is the exclusive provider of means of payments and the universal financial intermediary of the economy, combining a central bank and a state bank in one integrated universal ledger (one layer). (C) Banking without a central bank: Like in e.g. Venice in the 14th century, non-banks rely on Giro-banks, and these Giro-banks are even interoperable in the sense that clients can transfer funds across Giro-banks; between the banks, the resulting claims and liabilities are however managed as IOUs, and settled only from time to time through physical transfers of precious metal coins (two layers). (D) Modern two-tier banking system with central bank as ultimate senior ledger, possibly with daily clearing of payments in automated clearing houses (ACHs) interposed between banks and the central bank (two or three layers). The four examples also illustrate the fact that ledgers can be more focused on organising investment and financial store of value functions, or on payments and settlement (while some seem to combine both, like for example banks' sight deposits held by households and firms).

Figure 1: Four cases of layering and ledger architectures. “NB” stands for non-banks firms and households; “CB” for central bank; “B1”, “B2”, etc. for commercial banks; “ACH1”, “ACH2” for automated clearing houses



We may use the following terms for designating relations between ledgers. We say that Ledger A is *senior* to ledger B if ledger B holds on its asset side liabilities of ledger A and uses these to settle transfers between its clients and clients of other ledgers. This can also be expressed by saying that ledger B is *junior* to ledger A. We say that two ledgers are in a *hierarchy* towards each other if one is senior to the other. Two ledgers B and C are *siblings* if they have no seniority relation between each other and are both junior to ledger A, which enables transfers between clients of ledger B and clients of ledger C. We call two ledgers which allow for transfers between their clients *interoperable*³. Two ledgers B and C are *cousins* if interoperability is enabled via B being junior to a ledger A, and C junior to a ledger D, and A and D both being junior to a ledger E. It can occur that ledgers are neither in a hierarchy, nor are siblings nor cousins. For example, before the eight private European automated clearing houses (ACHs) for instant payments became junior to TIPS (the Eurosystem’s fast payment system) in 2021, they were partially not interoperable, i.e. payments between clients of banks relying on different ACHs were not

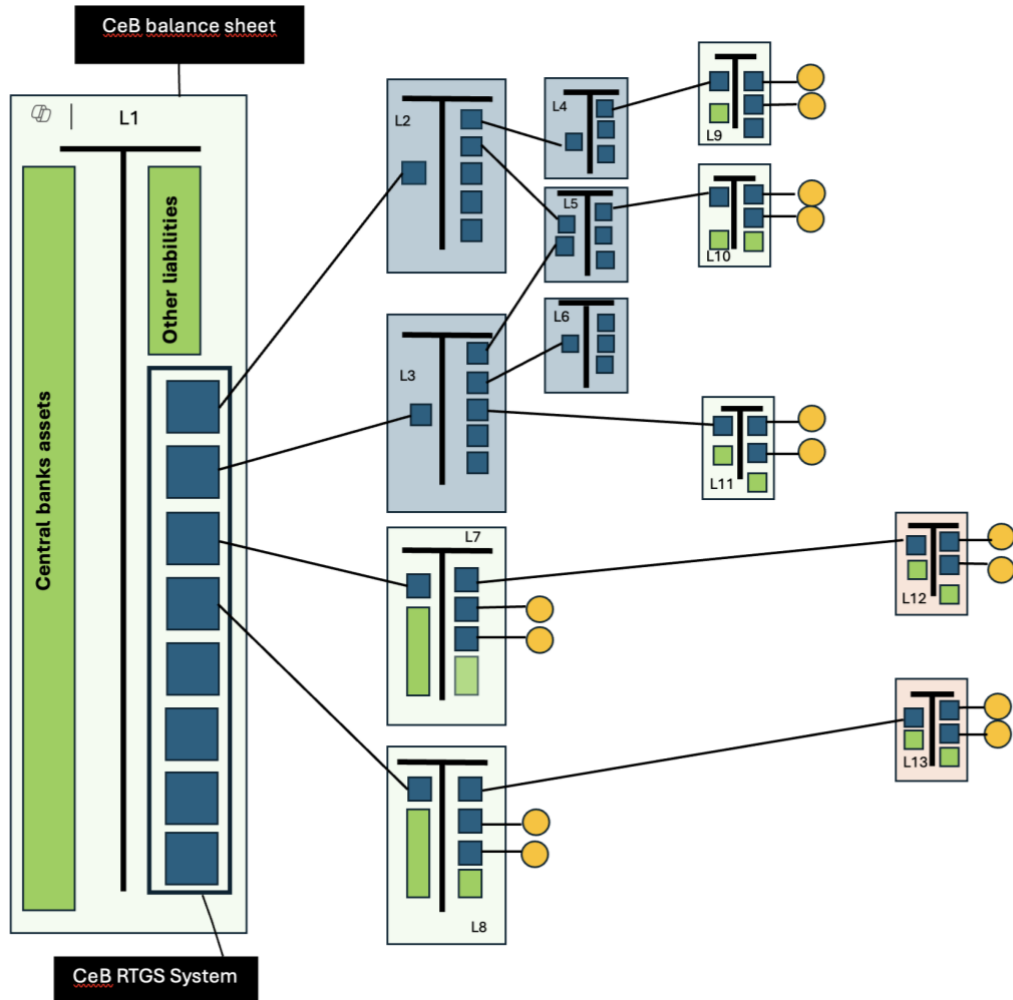
³ Han et al (2025) note that “interoperability can take three forms: through correspondents, intermediaries or a two-tiered system” (p. 3).

possible (ECB, 2020). A case of ledgers which are neither siblings nor cousins but are interoperable occurs if hierarchies are of different length between the ultimate ledger and the payer and payee: For example, in Europe, bank X may decide to connect directly to TIPS, while bank Y connects to a private ACH which is junior to TIPS. Still, instant credit transfers between a client of bank X and a client of bank Y are possible. The *ultimate ledger* is the most senior ledger involved to settle a certain payment. Today, for a certain currency, the central bank normally provides with its RTGS system the “ultimate” ledger (the most senior ledger in the hierarchy). In the 19th century, this was somewhat blurred: on one side, private banks (and other firms at that time) constituted the second layer which had accounts with the central bank for settling between each other. On the other side, both layers were ultimately anchored in a gold convertibility promise, and thereby the central bank money ledger was not ultimate in today’s sense. In the mid of the 19th century, and in the earlier years of the gold standard, private banks (i.e. the banking system beyond the chartered national central bank) also promised direct convertibility of their liabilities into precious metal coins. Over time, there was however a trend towards the convertibility promise of these banks to refer to central bank money, i.e. becoming only indirectly convertible into gold. The Bitcoin network can also be considered as an ultimate ledger (although the perceived settlement asset is fictitious).⁴

The following figure illustrates these concepts. Non-bank users of payment ledgers are represented as orange circles. L1 is the most senior or ultimate ledger – the RTGS system of the central bank. The *blue* ledgers L2, L3, L4, L5, L6 are pure payment ledgers (ledgers of type I or II in the classification of section 2.2), like automated clearing houses or other narrow balance sheet constructs, such as e-money or stablecoins. The *green* ledgers L7 to L11 are ledgers which have on the asset side also positions other than payment positions in senior ledgers. They could be banks having also *liabilities* other than payment positions (L7, L8; L10, L11; Type 4 ledgers in the classification of section 2.2) or e.g. a stablecoin with only payment positions on the liability side but holding some highly liquid securities as reserve (L9; Type 3 ledger in the classification of section 2.2). The red ledgers L12 and L13 are also banks but in two foreign countries. They are depositors with domestic banks (L7, L8) in domestic currency (while banks within one country normally do not have deposits with other banks but settle directly or indirectly via the central bank). Pure payment positions, on the asset or liability side of a ledger, are depicted in blue, while other assets or liabilities are depicted in green. L2 is junior to L1, and so is L3, L7, L8. Ledger L1 is senior to all of them. Ledgers L2, L3, L7, L8 are siblings since they are not hierarchical to each other and can initiate transfers, also on behalf of their clients through L1 (i.e. they are interoperable). L9 and L10 are cousins if clients of L9 can make a direct transfer to clients of L10, relying on interoperability throughout L4/L5 and L2. It is not guaranteed that this is possible. For example, L4 and L5 could be two stablecoins which do not allow for such direct transfers. In that case L4 and L5 are neither in a hierarchy, nor siblings, nor cousins. Ledgers L7 and L11 are neither siblings nor cousins (L7 may be called the aunt of L11) but could be interoperable in the sense that clients of L11 can make funds transfers with clients of L7. L12 and L13, although in different countries, can still be cousins: If the home country is the US, L7 is Morgan Stanley (New York) and L8 is City Bank (New York) and L12 is a bank in Mexico and L13 is a bank in Canada, then it will be possible to make transfers between clients of L12 and L13 relying on the two US correspondent banks and their connection to the Fed’s RTGS system FedWire. As a side remark, ledgers can be junior to more than one senior ledger: L5 is junior to L2 and L3. For example, a stablecoin could hold its reserves in the form of deposits with banks and split them between two banks (this would be possible under MiCAR for non-significant stablecoins). Or banks are typically relying on several payment systems. In Europe, some large banks use both TIPS and EBA Clearing RT1 for instant payments and are moreover connected to the RTGS system T2 and to further systems of EBA Clearing.

⁴ Bolt, Lubbersen and Wierts (2022), as well as Frost, Shin and Wierts (2020), also discuss the evolution of ledger architectures with a view to identify commonality across past and present changes of technology.

Figure 2: Illustration of ledger hierarchies



2.2 Relations between, and types of ledgers

Four types of ledgers can be distinguished from the perspective of their balance sheet:

I. Technical omnibus account ledger: The junior ledger is not only fully backed in terms of reserve positions in the senior ledger but also is a pure technical conduit (an agent, not a principal) subdividing the positions on the omnibus account with the senior ledger into sub-positions of the clients of the junior ledger. The ledger has no legal identity, and it may be misleading to consider that it has a balance sheet. True DeFi “layer 2” solutions are of this type (as DeFi is supposed to rely on “code”, and not on intermediaries with legal personality).

II. Ledger holding assets only in form of senior ledger positions. The junior ledger is fully “prefunded” in positions in the senior ledger but acts as a principal intermediary, i.e. it has liabilities and assets and the liabilities are claims by users (depositors) towards the legal entity that runs the junior ledger (only in case of a bankruptcy of the entity running the ledger, direct access of clients to the reserve may be

granted, bringing it more closely to case I). Bank of England (2023) expresses a preference for UK stablecoins to be structured in this way, notably with a 100% reserve backing in the form of central bank deposits. Euro area private ACHs offering instant payments also fall into this category: they are fully “prefunded” with positions in TIPS. In Figure 2, ledgers L2 to L6 are of this type (or of type I)

III. Ledgers by specialised narrow entities holding also securities as assets: the junior ledger has no other business than providing payment services, and its assets only serve as a liquid reserve to match the liability side and be able to pay out funds in case of withdrawals. The assets are however not completely in the form of deposits in the senior ledger but also contains some remunerated high-quality securities (or other assets) which need to be liquidated before obtaining positions in the senior ledger that could be used for settling payment outflows. E-money institutions (in the sense of the EU regulatory framework; including e-money tokens) and payment stablecoins in the sense of the Genius Act fall under this category. In Figure 1, L9 would seem to fall into this category (e.g. stablecoins also holding Treasuries).

IV. The ledger providing payment services is a subset of the liabilities of the entity (typically a bank): the assets and liabilities of the entity providing the ledger go far beyond the payment system ledger positions, both on the asset and on the liability side. Assets in the form of positions on the senior payment ledger are typically less than the payment ledger liabilities (e.g. sight deposits with banks typically exceed the banks’ deposits with the central bank (and in intermediary payment systems).

We summarise this typology of junior ledgers in figure 3.

Figure 3: Key features of four types of ledgers across three main dimensions

Ledger Type			
I	II	III	IV
“Code”, “technical” split of omnibus account; control as agent	Legal entity, principal intermediary, balance sheet		
Assets are 100% in the form of monetary liabilities of senior ledger		Assets mixed, including some that need to be liquidated before serving as settlement asset	
Narrow balance sheet: issuing means of payment is sole purpose, no other liabilities.			Broad balance sheet, liabilities go beyond payments ledger

One would assume that vulnerabilities increase when moving from I to IV, but this requires qualification: Type I ledgers are subject to operational and legal risks – and maybe more than the other ledger types. For example, true DeFi platforms lack (on purpose) an accountable legal entity which can be addressed through regulation, and which could be taken to court by users who for example would have lost their funds due to some vulnerability of the ledger resulting from poor programming. Regulations such as the EU’s MiCAR, or banking regulation standards such as outlined in BCBS (2024), aim to indirectly impact on the soundness of type I ledgers by addressing regulated entities (crypto-service providers and banks, respectively) relying on such ledgers. Ledgers of type II overcome this weakness. Stablecoins of this type are sometimes considered creating financial stability risks for banks if they have all their deposits with the central bank, because of their implied perceived solidity and thus appeal as safe haven. Stablecoins of type III (e.g. stablecoins holding also securities) are sometimes considered riskier than banks (which are type IV-ledgers), in particular if regulation of the former would be very light or absent because of an offshore location chosen by the stablecoin issuer. Generally, type II ledgers, i.e. narrow ledgers fully funded in senior ledger position, including a legal entity that is accountable to also ensure operational

safety and legal certainty, and relying on the central bank as senior ledger, could appear to be the least risky type of ledger (which is consistent with the conclusion of the Bank of England regarding the best reserve asset of stablecoins, see Bank of England 2023).

Figure 4 illustrates how access of different (junior) ledger types to central banks as ultimate ledger is currently considered or implemented, providing few selective examples without aiming at completeness.

Figure 4: Access of junior ledgers of type I-IV to the central bank as ultimate ledger: selective illustrations

Central bank account access:	Type I ledger	Type II ledger	Type III ledger	Type IV ledger
Reserve accounts including store of value and credit				Banks Euro area CCPs
Reserve account including store of value, but no credit	Permissioned DLTs	ECB: for SCT INST ACHs; BoE (2023) preference for stablecoins		
Reserve account only for settlement purposes, no store of value, no credit			EU non-bank PSP as of 2025	
No access to central bank account	DeFi (public blockchains)		EU e-money before 2025	Non-domestic banks

2.3 Economics of financial layering

Layering is common in payment systems and financial market infrastructures. For example, CLS has around 70 settlement members, but 37,000 institutions access its services indirectly via the settlement members. Voluntary layering (through criteria established by the infrastructures, or through the decisions of users in view of the costs of fulfilling operational requirements to be a direct participant) allows the infrastructure to reach a very high degree of safety by interacting only with high-credit quality, high-reputation and sophisticated entities, allowing it to focus on its key tasks, instead of on complex and discretionary risk management towards a multitude of complex and heterogeneous participants. Filtering, monitoring, collateral transformation, etc. can be left to an intermediary layer, where entities have specific expertise in dealing with various types of (indirect) participants. This is even more relevant in cases in which the financial market infrastructure incurs some possible credit exposure to its clients (see also section 2.7).

Layering in the access to financial market infrastructure must be understood also against the fact that financial market infrastructures (like money) operate under strong network effects and exhibit public good characteristics such as declining marginal costs. This explains why there is typically only one or two CSD per country, one leading global CCP per financial instrument, only one CLS globally, one RTGS system per currency, etc. Therefore, the ledger architecture tries to reconcile on one side specialisation in managing client relationships, related innovation, technical user interfaces, and use cases, i.e. allowing each ledger to focus on its core comparative advantage, while on the other side nevertheless channel all

client orders from an as broad as possible client base via junior and intermediary ledgers into the same ultimate ledger.

The question of the economics of optimal ledger architectures – horizontal and vertical – could be approached with the tools of the industrial organisation literature, which looks at the boundaries of the firm, vertical and horizontal integration, and the make-or-buy decision (as initiated by R. Coase and O. E. Williamson, see e.g. Joskow, 2012). Rosenbaum et al (2017) analyse the specific case of market structure of fast payment systems.⁵ When technology changes, then also the optimal organisation of any affected industry changes, and it would therefore come as a surprise if the enormous improvements in computing power, communications, database architecture, etc., would not have deep effects on the optimal organisation of the payments and settlement industry which relies heavily on those elements.⁶ As a starting point, such change should be expected to be positive: even if there are trade-offs, new, more efficient technology should be expected to push the efficient frontier further out and enable implementing better options for society. For example, retail CBDC maximalists (outside central banks) have argued that the ease with which central bank money could be distributed today (electronically) implies that the optimal monetary architecture would be one in which commercial bank money would be discontinued and all payments would become single layer payments in CBDC. Similarly, DeFi maximalist would argue that the discovery of permissionless blockchain technology allows transforming the organisation of trading, payments and settlement from a complex world of a multiplicity of infrastructures and ledgers (functionally, horizontally and vertically) into a simple and effective single one-layer ledger system with incredible efficiency gains.

However, the positive effects of new technology should not be taken for granted: money, payments and financial infrastructures constitute an industry remote from the ideal-type of a granular competitive market that naturally reaches a Pareto-optimum. Instead, this industry is characterised by extreme network effects, market concentration, often abuse of market power by dominant private players, negative externalities (e.g. of risk taking), path dependencies, and inertia of inferior equilibria. Therefore, the public sector heavily intervenes in this industry as regulator, catalyst and operator (with the central bank and its provision of the RTGS system, issuance of banknotes, and the lender of last resort function being the most prominent illustration of the latter). This implies that changes of technology will trigger changes of market structure, including ledger structures, that will not necessarily be optimal. Therefore, such changes will have to be carefully analysed by authorities and most likely such analysis will lead to the conclusion that the new market outcome (e.g. in terms of layering) deviates from the one that would seem best from a social perspective, and that adjustments of the public regulatory, catalyst and operator functions are required to improve upon the market outcome and to ensure that the new structure is on the new efficient frontier that became achievable thanks to new technology.

⁵ In particular section 2.1.1, page 10-13, including the industrial organisation literature quoted there. Network effects, economies of scale and scope, switching costs and product differentiation are identified as key driver of the *horizontal* organisation of layers.

⁶ In the words of Rosenbaum et al (2017, 13): “Technological change may diminish the importance of some of these economic forces and enable alternate arrangements or business models that do not involve a traditional operator. Innovation may reduce economies of scale or scope in some aspects of the production process. For example, decreasing fixed costs for communications and computer processing may obviate the need for centralized message processing and computing resources. Similarly, distributed ledger technologies may reduce the cost or security advantages of operator-run directory and clearing services. Additionally, faster payments settled on a near-real-time (transaction-by-transaction) basis may remove the need for many traditional clearing functions, such as batch processing and multilateral netting.”

2.4 Layering in the access to central bank money

Access to early central banks was rather flat, i.e. often every firm could have an account with the central bank if it would fulfil operational criteria. For example, the Bank of Amsterdam had around 2000 depositors in the late 17th century and the German Reichsbank 26,000 in 1912. Only during the 20th century, central banks gradually restricted access to their deposit accounts, allowing ultimately only banks and public authorities to keep access. Since the second half of the 20th century, non-bank firms and households could generally only access banknotes, and more junior layer account money, i.e. commercial bank money. Layering in the access to central bank money is also observed within the banking community as a voluntary phenomenon: there are for example groups of small mutual or savings banks which do access central bank accounts only *indirectly* through one umbrella or correspondent bank. For example, in the US, smaller community banks often hold their reserves with larger “correspondent banks” that themselves have master accounts at the Federal Reserve.

Ideally, the central bank could define access conditions to central bank deposits based on objective requirements which ensure the safety of the central bank and that the central bank can focus on its core function (and not on functions where it likely has comparative disadvantages to the private sector, like risk management towards heterogeneous and less transparent financial service providers). These requirements would naturally lead to a voluntary segregation into suitable and unsuitable participants, the latter deciding by themselves that fulfilling the operational requirements is not economically viable for them. In practice, central banks have translated this idea largely into institutional criteria to facilitate their task. Relying on institutional criteria is a form of outsourcing of the segregation work to supervisory authorities and to the private sector entities which must decide on the institutional format they choose for their endeavour, regulatory implications, and the benefits to fulfil the criteria for accessing the central bank. In the case of banks (“credit institutions”), this approach has worked well for a long time, but for example the perceived growing potential of e-money thanks to technological change (including through tokenisation, i.e. stablecoins) has led to a revision of this approach (see section 3.4).

2.5 The singleness of money and monetary sovereignty

Money may be defined as what is readily and immediately usable by the payer to discharge obligations, and what is generally accepted for payment and settlement by payees (sometimes subject to certain operational, practical constraints). Universal acceptability can be achieved through law (e.g. an effective mandatory legal tender status of central bank money) or by custom (if a certain payment instrument is accepted everywhere at the POI because merchants enjoy the convenience and low fee and the fact that so many clients use it). This definition starts from the use of money *for payments*, but this naturally brings along the store of value function: since payment needs are not deterministic, economic entities store monetary reserves for contingent payment needs.

The *singleness of money* means that all forms of money in one economy, independently of the form (paper, central ledger, tokenised) and issuer (central bank, bank, non-bank money issuer) are *denominated in the same unit of account and accepted universally at par since payees consider all these forms of money sufficiently similar and interchangeable in practice*⁷. Garrat and Shin (2023) define the singleness of money beyond reliance on a single numéraire also through the absence of “fluctuating exchange rates between different forms of money, whether they be privately issued money (eg deposits) or publicly issued money (eg cash). ... Ruling out exchange rates between different forms of money allows money to serve its role as a coordinating device for economic activity. In this context, ‘approximate singleness’ is an oxymoron. Small departures from par introduce frictions in trade and exchange that are amplified when they reverberate through economic transactions”. Hayek (1976) and other libertarians

⁷ Recent discussions of singleness and fungibility include Garrat and Shin (2023), Coste and Pantelopoulos (2025) and Bidder (2025).

have argued that heterogeneous moneys with different units of account can co-exist and that this would be efficient, or at least the implied inefficiencies would be far less than the inefficiencies created by *inflationary* money, which itself would be a consequence of the lack of competition. Most economists reject this and stress the inefficiencies of multiple moneys being co-used. In the words of Fischer (1986, 434), “Hayek’s tract is messianic, not analytic. ... The new approach is not adequately described. Hayek concedes to knowing little about how a competitive money system would work: he blames his ignorance on governments, whose monopolisation of the monetary system has prevented the needed accumulation of competitive experience. ... He is silent on the essential issues: the unit of account, the costs of having multiple currencies, the issue of convertibility of currency into a dominant money or good (for example gold), and the question of whether currency suppliers would be able to issue fiduciary money.” In some economies, experiments have been made with the co-existence of different denominations, like Peso-Dollar in Argentina, or Bitcoin-Dollar in El Salvador, etc. Sometimes the use of two different currencies seems to constitute an equilibrium for a while, but only rarely, and more generally economists would consider these cases as being due to a poor ability of domestic authorities to provide what is by far the first best, a single stable domestic currency.

For the question of layering and ledger-architectures, these conclusions support the case for monetary sovereignty through a single base ledger in (non-convertible) central bank money run by the public sector (through a central bank), reaping maximum network effects without abusing market power, and establishing a unit of account with minimum own noise in its scarcity, achieved by defining a price stability target in terms of a consumer good basket and rejecting convertibility into a commodity. All money would be directly or indirectly connected to the ultimate central bank money ledger through a hierarchical ledger architecture, which also ensures horizontal interoperability.

2.6 Convertibility of central bank money and its layering

Another form of layering can be found in the *convertibility (or redemption) promise that is at the basis of the singleness of money*. Money denominated in the same unit of account, except for the base layer, is typically defined by a convertibility promise, and not only through a market exchange mechanism that leads to sufficiently similar prices of different forms of money using the same denomination. The convertibility promise can be into money of the next highest layer, or directly into the ultimate money. *Commercial bank money (and non-bank money)* is in essence defined by the issuer’s promise to be readily converted into central bank money (ultimate money) at any time. This convertibility promise anchors the commercial bank moneys into being quasi-equivalents to central bank money and ensures the singleness of money. It also supports the interoperability of commercial bank moneys via a central bank settlement layer, which itself is the precondition of a convertibility promise of one issuer’s commercial bank money into the commercial bank money of another issuer. For example, Panetta (2022) insists that “Confidence that ‘one euro is one euro’ whatever form it takes rests on our ability to convert, at par, private money – such as funds held in bank deposits or digital wallets – into public money, which is the safest form of money available. This possibility of conversion reinforces confidence in the various forms of private money used for euro payments, ensuring the smooth functioning of the payment system.” Both MiCAR and the Genius act require convertibility of stablecoins at par, i.e. holders must be able to turn to the issuer and request payment of funds – at least in commercial bank money. Neither of the two legislations imposes a direct convertibility promise into central bank money. Commercial bank money is generally redeemable into central bank money – by withdrawing cash via an ATM. The lack of a direct convertibility obligation of stablecoins into central bank money could create risks for the singleness of money if stablecoins reach significant volumes. While for the time being, indirect, layered convertibility may suffice, a direct convertibility obligation into central bank money is ultimately the safer solution.

2.7 Layering in the access to central bank credit

Regular central bank credit is typically reserved for banks, whereby some central banks choose a broad set of banks (like the Eurosystem), while others traditionally preferred a narrower set (e.g. US Fed). On the side of collateralisation of such credit, differences also persist, with for example the Eurosystem being perceived as accepting a particularly broad collateral set compared to other central banks. So far, access to central bank *credit* was often linked to having access to central bank *deposits* and the RTGS system, also since the RTGS systems often relies on the provision of *intra-day credit* by the central bank (to ensure sufficient liquidity and avoid gridlocks). If indeed there are reasons to link the two, then this provides a further explanation for the preference of central banks to not provide access to their deposits to a too broad and non-standardised set of financial firms, but to stick e.g. to the well designed and regulated category of credit institutions. In the case of the newly eligible non-bank payment services providers, central banks normally opted for not granting them regular central bank credit.

Generally, from a macro-financial stability perspective, excluding a type of financial intermediaries that provide important risk-, maturity-, and liquidity transformation services to society from access to central bank credit in crisis situations might create vulnerabilities in case of negative macro-shocks. This might become relevant for stablecoins if these become very large and partially would hold somewhat less liquid assets. As an illustration, it may be noted that the Eurosystem has recently decided to grant access of CCPs to central bank credit in case of need (CCPs already had access to depositing with the Eurosystem). However, to mitigate possible risks of that change, the Eurosystem also introduced *additional safeguards* in relation to financial soundness and prudent liquidity risk management of CCPs. This illustrates further the challenges of central banks to define broader access criteria which support the safety and efficiency of the financial system, while avoiding being distracted by a multitude of risk management frameworks for heterogeneous clients on the asset and liability side of their balance sheet.

2.8 Layering in the money supply

Finally, although less relevant for payments, monetary economists have devoted, for more than 100 years, significant attention to the *creation* of money by banks, and how it can be that more junior ledgers (in our new meaning of the word) are able to create something anchored in a more senior ledger and thereby increase the total amount of issuance across the two hierarchical level, and how this can be reconciled with a well-determined quantity (and thus value) of money, i.e. monetary control by the central bank. Generations of monetary economics textbooks have tried to explain how central bank operations and private money creation interact, and how collateral requirements, reserve requirements, and economic forces may constrain the potential money creation by banks. The money multiplier was considered for many years the core formula which quantitatively linked the two layers of money. Today, central bank monetary policy is considered effective in controlling the money creation by banks without that formula, and in any case the role of monetary aggregates in the transmission mechanism has been downgraded.

3. Current innovations which impact layering

3.1 CBDC: *preserving* the anchor function vs. *extension* towards sovereign money

The decline in the use of cash raises questions about the future of the convertibility test, the anchor function of central bank money and the singleness of money (see above). CBDC can *preserve* the role of central bank money and thus the anchor function. Others, outside the central bank, from the progressist political spectrum, see CBDC as an occasion to introduce a *single layer* monetary system by associating it with the phasing out of the ability of banks to create and offer money in the form of sight deposits. In this vision, everyone would pay directly in CBDC, meaning that the base ledger becomes the universal

ledger for all payments. Sovereign money supporters believe that this would allow to improve the monetary system from a financial stability and fiscal perspective (less risk of banking crises, more direct seignorage income, less taxpayer money for rescuing banks). Central bankers distance themselves from this vision since they believe into the advantages of a layered monetary system in terms of decentralised credit provision process, and as they probably fear an even stronger push back of the financial industry if CBDC would aim at going beyond *defending* the current role of central bank money.

Interestingly, some central banks, like the ECB, also envisage a use of CBDC which would in some sense rely on commercial bank money as basis, reversing in this way the normal hierarchy of money: indeed, to address the argument vividly expressed by the banking industry that CBDC could disintermediate banks and endanger financial stability, the ECB has conceded to limit the possible holdings of digital euro and to allow payments beyond the warehoused level of digital euro through a sweep facility called the “reverse waterfall”. Commercial bank money would be converted for payment purposes instantaneously into CBDC to allow for the initiated payment in CBDC. Moreover, digital euro received by merchants would be converted automatically back into commercial bank money, suggesting at the limit (if the limit on holdings of digital euro will be very low) that central bank money would become a retail payment instrument *based on* commercial bank money, as if commercial bank money would be senior to central bank money. A similar reversal of hierarchy could occur if cross border payments in commercial bank money would rely on stablecoins as a settlement asset (see section 3.7)

3.2 Instant payment systems in central bank money

The Eurosystem’s TIPS was the first fast payment system settling directly in central bank money. Before this, instant payments were settled exclusively in a private ACH, often also with elements of deferred net settlement, and only occasionally (e.g. daily) cleared in central bank money. In this sense, the technological ability of central banks to offer 24/7 fast payments allowed for reducing the number of layers in instant payments from three to two, making the ledger architecture simpler and thereby presumably more efficient. The delayering was not associated with a broadening of the set of direct participants to ECB payment systems since a requirement for banks to rely on TIPS is that they are connected to the Eurosystem’s RTGS system T2. Moreover, private ACHs supporting instant payments have the same set of participants as the ones in T2, which is also enshrined as a principle in the ECB’s prefunding policy. Because of this equivalence of participants, the additional layer introduced by a private ACH cannot be justified as a specialisation to run relationships with a broader and more heterogeneous set of clients. In a world in which fast payments become the new normal, it could however be argued that the co-existence of a private ACH (in a three-layer structure) and a fast payment system in central bank money (a two-layer structure) are justifiable in view of the additional resilience achieved.

3.3 The return of non-financial money?

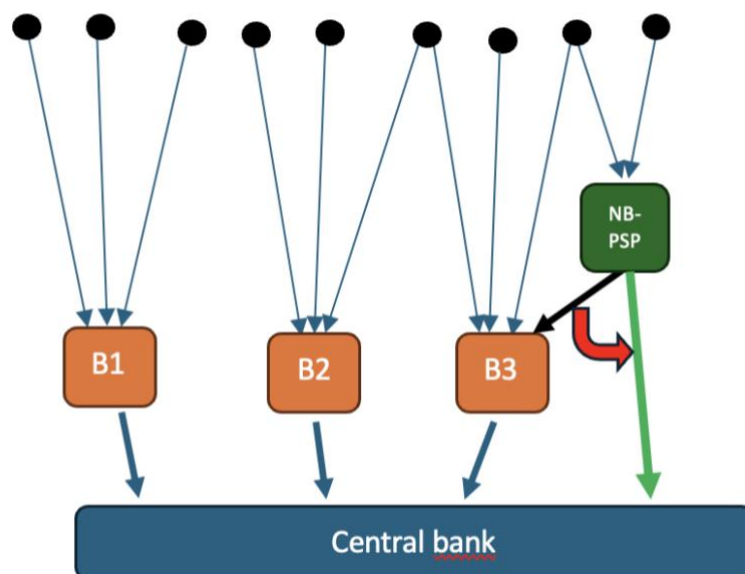
Bitcoin promoters try to popularise the perception that bitcoin is commodity money, a sort of gold of the 21st century. While bitcoin seems to be better described as a ledger system with virtual entries, it is true that in terms of settlement logic, a parallelism to commodity money can be constructed in the sense that bitcoin is not a *financial* item (i.e. it is neither a claim, nor a liability). Reliance on bitcoin as universal money would represent an extreme delayering. Beyond its limited efficiency as means of payment, bitcoin suffers from its inherent price volatility, which is also a result of the lack of a convincing valuation method for bitcoin (except to argue that it has no utility and that the fair price should therefore be zero).

3.4 Granting non-bank payment services providers access to central bank accounts

Non-bank payment services providers typically run ledgers and/or payment instruments with a narrow focus, with some types having a very lean and normally transitory balance sheet associated with the payments they facilitate, while others - “e-money institutions” in the EU terminology - allow clients to hold permanent money-like positions (i.e. offering also store of value functions) and are of ledger types II or III in the classification of section 2.2. Continuing with the example of the EU, the 1998 settlement finality directive (SFD) was mostly interpreted in a way to exclude access of any non-banks to payment systems, and therefore also to the Eurosystem’s RTGS system. This element of the SFD was only changed in 2023 and the Eurosystem is currently in the process of granting selected non-banks access to T2. The CPMI’s cross border work and the G20 also concluded that central banks should grant direct access to non-bank payment services providers, which is now a general trend, illustrated in Figure 5. The granting of central bank access to non-bank payment services providers also constitutes a reputational improvement for the beneficiary non-bank payment services providers, as users may consider this as a validation of their business model by the official sector. Central banks who grant accounts to non-bank payment services providers have done so generally in a selective way, checking carefully that those fulfil operational and soundness criteria. In the case of banks, the checking of soundness criteria is left to supervisory authorities, since banking regulation and supervision is considered to provide a strong set of rules and assurances, while regulation of non-bank payment services providers is much lighter and heterogeneous depending on the type, location, and responsible authority. Therefore, some layering persists in the sense that even after lifting strict legal constraints, by far not all non-bank payment firms will ultimately gain access to central banks.

The potential of non-bank payment firms seems to have significantly increased due to technological progress, including quasi cost-free communication via the internet, universal penetration of society with smart phones, biometric recognition, fast payment technology, and APIs allowing for open banking. Stablecoins, which is in essence narrow vehicle money distributed via a decentralised blockchain platform, will be dealt with separately in section 3.7. The increased potential of non-bank payment service providers due to technological progress seems to have convinced legislators and central bankers (including the G20) that it is preferable from an efficiency perspective to grant base ledger access to non-bank payment service providers (instead of forcing them to connect with the payment system via the next layer of ledgers – banks). The main practical cost of this trend is that central banks (and other operators or payment systems) can no longer rely on simple institutional criteria (i.e. having a banking license, and the associated strong regulatory and supervisory frameworks) to determine eligibility for direct participation, but need to design and run a more work-intensive, objective and effective eligibility framework for a quite heterogeneous set of new applicants.

Figure 5: Granting direct access to non-bank payment services providers (NB-PSPs). Black dots are non-financial firms and households, B1, B2, B3 are banks



3.5 Public blockchains

Public blockchains aim at flattening payment and settlement infrastructure, including retail and wholesale transactions, with smart contracts taking over the role of financial instruments and settlement processes offered in the traditional world by intermediaries (BCBS 2024, Bindseil and Malekan, 2025), including possible customised access constraints at the instrument level (instead of at the ledger level). Decentralised finance applications running on public blockchains would offer several advantages, including continuity of operations, elimination of traditional intermediaries, the universality and flexibility of the base ledger, the ability to handle a multitude of tokenised assets at no extra cost, the elimination of expensive and potentially error-prone human decision making, and public access. These features could allow public blockchains to provide not only a universal payment ledger for all, but also financial market infrastructure with unprecedented efficiency. The fact that DeFi *allows* flattening radically the financial architecture does not imply that market participants will opt for it: Smart contracts could organise trading in batches and foresee netting and settlement cycles. While it is plausible that public blockchains have potential, various challenges remain, relating to governance, legal certainty, settlement finality, accountability and anonymity (see e.g. Basel Committee on Banking Supervision, 2024, and Committee on Payments and Market Infrastructure, 2024, section 4). Another question is whether tokenisation of assets into public blockchain (where they co-exist with blockchain-native assets) really flattens the ledger architecture. Alternatively, one could interpret the tokenisation platform as adding a control system over certain positions in the initial ledgers such as to enable smart contracts and atomic settlement with these controlled positions. This question will be taken up further below in the context of permissioned programmable platforms.

3.6 Tokenisation on (permissioned) multi-asset platforms, including cross-layer

According to Committee on Payments and Market Infrastructure (2024), Token arrangements are designed “to enable multi-asset, multi-function and multi-party financial transactions and services. A token arrangement might record both money and other assets. This differentiates it from existing payment, clearing and settlement arrangements, which typically hold money on separate ledgers. The standardisation of certain digital token features may facilitate the coexistence of different asset types

on a single programmable platform. Tokenised assets can then be traded and settled using applications built on the platform. These applications may allow for bundling different functions and creating new ones. For instance, an application could combine pre- and post-trade services - financial market functions that are typically separated in existing arrangements. Token arrangements may also employ automation and conditionality of transactions across a range of functions and/or asset types, potentially affecting the execution of financial market functions if allowed by legal and regulatory frameworks. Overall, this could expand the set of operationally feasible options for carrying out financial transactions". In permissioned wholesale multi-asset platforms, central bank moneys (in different currencies), and commercial bank deposits (again in different currencies), would co-exist in tokenised form on one platform. Is this a single layer or still a double layer monetary architecture? What exactly changes when such a programmable platform is launched? Such a system could fall under type I of the ledger typology introduced in section 2.2., i.e. we might interpret it as a control system which does not take principal positions. Such a platform delivers atomic 24/7 settlement in RTGS mode so that it should not create any other risks than (possibly) operational risks.

In any permissioned multi-asset platform, the question arises (like in the layering of the access to payment systems and FMI): *Who can hold which tokens and who cannot because of constraints set by law, by the platform, or be the token issuer?* The following assumptions would preserve the current general access logic:

- *Banks are allowed to hold tokens issued by THEIR central bank* (i.e. the central bank where they also have RTGS deposit account access) but not issued by other central banks.
- *Banks can in principle hold tokens issued by any commercial bank from the world* in any currency of the world, if they bilaterally agree to this, in the same way as any bank can open a vostro account for another bank if there is demand for it. However, domestic correspondent banking is (most of the time) voluntarily avoided, and a bank prefers using its central bank account for its domestic currency and settles there its transactions with other banks. Therefore, all commercial bank money tokens will presumably be correspondent-banking foreign currency positions. In an instantaneous STP world, in which all banks always want to concentrate their commercial bank money in ONE correspondent account (per foreign currency), and if the main account is still outside the platform, then banks will typically not hold significant amounts of commercial bank issued tokens but only as pass-throughs in (smart contract based) transactions.
- *Central banks do not hold commercial bank money-tokens*: they never hold uncollateralised deposits with banks but only provide collateralised credit. Only once also securities are tokenised into the programmable platform, then also central bank credit to banks can be provided within the platform.
- *Central banks can hold tokens issued by other central banks* In the same way as central banks offer to each other a sort of correspondent accounts.
- *What about non-bank financial entities* which have no central bank account at all, say a global asset management group with operations in various currencies and significant FX operations which relied so far only on commercial bank money accounts in the various currencies? Such entities have access to commercial bank money and therefore, if we assume that the programmable platform should replicate existing relationships, could also be permitted into the programmable platform with access only to commercial bank deposit tokens (and if available securities).

We illustrate the working of the platform through flow of funds examples in annex 1. *Figure A-1* (in the annex) chooses a presentation in which the programmable platform is *not* a separated ledger, but a control function over specific positions in existing ledgers. The platform positions are established for undertaking specific transactions for which the platform provides unique advantages. Figure A-1 illustrates the basic functioning of the platform in three steps: Uploading of funds on the accounts controlled by the platform, i.e. act of tokenisation into the platform. Second, we show the flows related to a client FX transaction using tokens for an amount Y (expressed in currency B, with β being the FX rate), all processed STP at once (assuming that the respective bank client systems are equally STP and

that Bank C had provided immediately executable FX quotation). Third, an interbank FX transaction in which Bank A replenishes its FX reserves on a correspondent banking account of another bank held outside the platform. The platform, by having commercial bank and central bank money tokens from several countries and currencies under its control, offers several alternative ways to implement one specific transaction. As *chains* of atomic transactions can be implemented, credit and settlement risks should be low (or negligible) and therefore also using commercial bank money tokens as temporary (instantaneous) conduits might not be perceived to be significantly riskier than reliance on central bank money. This also depends on the speed of onramp and offramp transfers into the platform (we should assume that these are also instantaneous) and on whether all smart contracts in commercial bank money are also doable in central bank money (it is not unlikely that the central bank opts for a narrower set). There is no reason to consider that the fact that the (pass-through-type ledger) platform has both layers of money (commercial and central bank) changes any fundamental element of the monetary architecture, except improving the efficiency and safety of payment and settlement. Speed and 24/7 continuity accelerate financial flows, but that is a universal phenomenon not linked to tokenisation.

Figure A-2 illustrates the case in which the programmable platform would have “taken over” the traditional accounts. Indeed, in the long term the duplication of accounts between the ones controlled by the platform and the traditional could be considered inefficient. First, the tokens in foreign commercial bank money could become THE nostro accounts of banks. That would simplify processes further. Ultimately, the platform could replace the domestic RTGS systems – as assumed in Figure A-2. Liquidity would no longer be split between two pools. All banks would participate in this scenario to the programmable platform. The intra-system claims and liabilities within banking group C would also be transferred into the platform. Again, while this would be highly efficient, there is no reason to believe that it would fundamentally change the architecture of money and layering, and the distinction between bank and central bank money.

Finally, Figure A-3 provides a representation of the platform as the ledger itself). This would mean that on the liability side of financial institutions, we would no longer have the sub-positions to different obligors, but only a single obligor position towards the platform. This presentational change however does not change the assessment of the implications of the platform: the platform per se does not change the fundamental architecture of money and finance, nor the layering between commercial bank and central bank money. It facilitates speed, continuity, and competition.

3.7 Stablecoins: combining narrow banking and tokenisation

How to interpret payments in a stablecoin in the context of layering? In annex 2, we illustrate in a simple system of financial accounts the layered flows of funds occurring when SCs are created and used. Like in the discussion of permissioned programmable platforms, we could consider treating either the SC as the ledger and the blockchain simply as a medium to access this ledger, or we interpret the SC as the issuer of a sort of *bearer instrument*, and the blockchain platform as the ledger, which is what we opt for in annex 2⁸. We can consider the payment in the SC as a single layer payment in the sense that the payment does not affect other ledgers, i.e. it is not automatically mirrored in a more senior ledger. At the same time, the on-ramping would seem to have affected “2.5” layers: the accounts of the households with banks, the banks’ accounts with the central bank, but also the SC/blockchain joint ledger system which itself (the SC to be precise) holds its assets in the form of deposits with bank 2.

A key topic of attention so far relating to SCs has been the impact of SCs on funding stability of banks. Introducing SCs tends to drain bank deposits since deposits held by the SC issuer are concentrated with

⁸ Although this ledger is only an agent and not a principal; type I ledger in section 2.2.

certain banks and therefore some banks will lose previously stable, cheap and granular deposits, while others will gain deposits which will be more concentrated, expensive and unstable. Therefore, the creation of stablecoins could structurally tighten lending conditions. In addition, as any new deposit fund destination that can be accessed quickly and easily, SCs will be destabilising for bank deposits in a banking crisis. SCs also create financial stability issues in case they are themselves subject to a run and need to do fire sales. Here, the layering of access to central bank *credit* becomes relevant. No access to the LOLR creates additional risks (everything else unchanged). Public authorities have tools to reduce, probably even to acceptable levels, the negative externalities of SC on financial stability (demanding liquidity and capital requirements, redemption and disclosure rules, etc.).

The central bank could also grant to the SC issuer access to central bank deposits and thereby disintermediate the banks as layer between SCs and the central bank. A third asset class that SC issuers can hold as reserves are short-term highly liquid securities, such as short-term government debt. If the SC diversifies into this type of reserves, it becomes a ledger of type III in the logic of section 2.2, while if it is fully invested either in bank deposits or in central bank money, it is of type II (with however holding its funds in senior level ledgers, one “+2” ledger – the central bank, and several “+1” ledgers – commercial banks). How to interpret SC securities holdings from a layering perspective? The creation of a SC will still involve payment by the entity desiring to hold SC to the SC issuer which then will purchase securities in a second step using these bank deposits. Therefore, the layering does not seem to change. On aggregate, holding securities does not drain bank deposits.

Finally, SCs are considered by some to be particularly promising in *cross border payments* and several platforms were recently announced which would allow (USD denominated) stablecoins to act as settlement asset for cross border payments (“cross border stablecoin sandwich” or variants of it – announcements for example by Bridge/Stripe, UBIX, Circle/Finastra and Swift). This could disintermediate conventional correspondent banking and lead to faster and more direct settlement chains, including atomicity. If we consider a correspondent banking network as one layer, then its substitution by a stablecoin solution would change the nature of the ledger involved in the transfers, but not really the number of layers. In any case, the effects on the relative roles of institutions and thereby on the “horizontal” architecture could be considerable. Moreover, we might observe (like in the case of CBDC with a low holding limit and a two-directional waterfall into commercial bank money), *a reversal of seniority between ledgers*. Until recently, stablecoins relied on bank deposits as settlement asset, but under the cross-border stablecoin sandwich, it would be the other way round, stablecoins will have become the settlement asset of commercial bank money and in this sense senior to commercial bank money – at least in this specific usage.

4. Conclusions: benefits and risks of innovation-induced changes to the layering of money and payments

Layering in money and payments is shaped by economic and regulatory factors. Recent innovations are altering the economics of layering, and regulations adapt to these changes, further influencing layering. Technological progress should per se extend the efficient frontier of opportunities, but changes to the financial system also bear risks: First, new structures are less understood than old ones, regulation gets outdated, and there is no experience about what systemic weaknesses new structures may have and how to react when risks materialise. Second, new technology which moves the financial system towards continuity and immediacy also facilitates quick outflows of short-term liabilities which can be destabilising relative to the previous slower financial world with settlement lags and pauses which provided time to sort out problems. Continuity and immediacy also mean less clearing and settlement cycles, and related changes in the supply and demand of liquidity.

Beyond these general considerations, a few specific changes of layering caused by innovations seem to have significant effects and have policy implications. First, the *disappearance of retail central bank money* (due to the declining relative attractiveness to pay in cash) could raise the question of its anchor function (ensuring the singleness of money through the permanent and universal test of the convertibility promise). Some, outside the central banking community, believe that CBDC provides an occasion to achieve a “sovereign money” system, i.e. a single layer payment / monetary system in which central money prevails, and commercial bank money would disappear. Second, the discussions around *granting or not access of non-bank money issuers to central bank deposits* and thereby elevating them from being “layer three”- to “layer two” junior ledgers have been concluded with the G20 expressing a clear preference for granting them access. This decision however requires central banks to develop their capacity to select and monitor counterparties of a more heterogenous and less regulated nature and to manage the risks from dealing with those. Remarkably, in the specific case of stablecoins, the US, EU and UK authorities seem to still take different directions (preference for a reserve in treasuries, in bank deposits, in central bank deposits, respectively). Third, *Public blockchains and DeFi* promise to disintermediate and substitute various payment and settlement systems by one flat programmable omni-asset platform but potentially raise governance and security challenges. Fourth, *permissioned programmable platforms* which include two layers of money (central bank and commercial bank moneys) do not seem per se to fundamentally change the monetary architecture, but they allow for efficiency gains and ultimately create a new environment with likely new competitive forces unleashed that will also affect indirectly monetary and payment architectures (and create new risks in transition). Fifth, *stablecoins* as tokenised money issued by narrow vehicles (ledgers of types II or III), combining blockchain and non-bank money issuance, if becoming as successful as envisaged by some, could change the relative role of bank money and the architecture of cross border payments.

Rapid technological change affects layering and demands ongoing attention. Analysing these developments can help society benefit from innovation but often requires updating regulations and adjusting central bank policies and operations. Without such changes, technology may negatively impact society.

Literature

Bank of England (2023), “Regulatory regime for systemic payment systems using stablecoins and related service providers”, Discussion paper.

BCBS (2024), Novel risks, mitigants and uncertainties with permissionless distributed ledger technologies, Working Paper 44.

Bidder, Rhys (2025), “Singleness of money: Towards a nuanced debate”, forthcoming in a CEPR volume edited by Dirk Niepelt.

Bindseil, Ulrich and O. Malekan (2025), “Public crypto networks as financial market infrastructures,” Journal of Payments Strategy & Systems, Henry Stewart Publications, vol. 19(4), pages 410-426, December.

BIS (2025), “The next-generation monetary and financial system”, Chapter III of the BIS Annual Economic Report 2025.

Bolt, Wilko, Vera Lubbersen and Peter Wierts (2022), Getting the balance right: Crypto, stablecoin and CBDC, DNB Working Paper 736.

Committee on Payments and Market Infrastructure (2024), “Tokenisation in the context of money and other assets: concepts and implications for central banks – Report to the G20”, BIS.

Coste, Charles and George Pantelopoulos (2025), "Central bank money as a catalyst for fungibility: the case of stablecoins", ECB WPS 3111.

ECB (2020), "Change request form - TIPS adaptation to migrate ACH technical accounts in TIPS", TIPS Change Request Nr. 0033.URD, 22 February 2020.

ECB (2023), Policy on the use of prefunding by ancillary systems, October 2023.

Fischer, Stanley (1986), "Friedman versus Hayek on private money", Journal of Monetary Economics, 17, 433-439.

Frost, Jon, Hyun Song Shin and Peter Wierts (2020), "An early stablecoin? The Bank of Amsterdam and the governance of money," BIS Working Papers 902, Bank for International Settlements.

Garratt Rodney and Hyun Song Shin (2023), Stablecoins versus tokenised deposits: implications for the singleness of money, BIS Bulletin No 73.

Hee, Kees van, Anneke Kosse, Peter Wierts and Jacob Wijngaard (2025), "Let's speak the same language: a formally defined model to describe and compare payment system architectures", BIS Working Papers No 1259.

Joskow, Paul L. (2012). "Vertical Integration", The Antitrust Bulletin, 57(3), 545-586.

Panetta, Fabio (2022), "Public money for the digital era: towards a digital euro", Keynote speech by, Member of the Executive Board of the ECB, at the National College of Ireland, Dublin, 16 May 2022.

Rosenbaum, Aaron, Garth Baughman, Mark Manuszak, Kylie Stewart, Fumiko Hayashi, and Joanna Stavins (2017), "Faster Payments: Market Structure and Policy Considerations", Finance and Economics Discussion Series 2017-100. Washington: Board of Governors of the Federal Reserve System.

Annex 1: Programmable platforms: central bank and commercial bank money tokens being on the same ledger

In the system of financial accounts A-1, we assume three banks: Bank A has access to central bank A ("CeB-A") only, Bank B to CeB-B only, and Bank C has subsidiary in both countries/currencies (C-A, C-B) and therefore access to both CeBs. We assume that the banking group C has no significant non-bank client relationships. In the accounts below, we display explicitly on the liability side all possible parties holding potentially these liabilities, such as to be most explicit and pedagogic on the flows of funds. We present the following transactions:

- Uploading of funds on the "DCAs" controlled by the platform (i.e. tokenisation). Banks upload X_A, X_B, X_{CA}, X_{CB} , expressed in the respective local currencies.
- A client FX transaction using for an amount Y (expressed in currency B, with β being the FX rate), all processed STP in one (assuming that the respective bank client systems are equally STP and that Bank C had provided immediately executable FX quotation). The transfer of the real good is not STP nor DvP, although we show it in the financial accounts to be executed and settled at the same moment in time as the payment leg.
- An interbank FX transaction in which Bank A replenishes its FX reserves on a correspondent banking account of another bank held outside of the platform. We add Bank D for that, which we now assume to be the B-country correspondent bank in country B which for whatever reason has not joined the platform. The FX reserves are provided once more by Bank C which is specialised in this business. The amount of fresh reserves is Z (in B-currency).

Figure A-1: Basic transactions in the programmable platform

Country A (in A currency)			
Firm A			
Real goods	X + β Y	Equity	X
Account Bank A	X - β Y		
Bank A			
Dep. at central bank A	X - X_A	Deposits	X - β Y
Tokens CeB A	+ X_A - β Y - β Z	Tokenised deposits	
Nostro account Bank D	+ β Z	Held by Bank B	
Other assets		Held by Bank C-B	
		Credit central bank A	X
Central Bank A			
Credit to banks	X	Deposits	
Tokens CeB B		Held by Bank A	X - X_A
		Held by Bank C-A	X - X_{CA}
		Tokenised deposits	
		Held by CeB B	
		Held by Bank A	+ X_A - β Y - β Z
		Held by Bank C-A	+ X_{CA} + β Y + β Z
Bank C-A: FX Bank, A-country subsidiary			
Dep. at central bank A	X - X_{C-A}	Cred. central bank A	X
Tokens CeB A	+ X_{C-A} + β Y + β Z	Tokenised deposits	
Other assets		Held by Bank A	
		Held by Bank B	
		Intra-Group liability	+ β Y + β Z
Bank C-B: – B-country subsidiary (belongs to B-country)			
Dep. at central bank B	X - X_{C-B} -Z	Cred. central bank B	X
Token CeB B	+ X_{C-B} - β Y	Tokenised deposits	
Intra-Group claims	+ β Y +Z	Held by Bank A	
		Held by Bank B	
Country B (in B currency)			
Firm B			
Real goods	X -Y	Equity	X
Account Bank B	X +Y		
Bank B			
Dep. at central bank	X +a	Deposits	X +Y
Token CeB B	+Y	Credit central bank B	
Other assets	X	Tokenised deposits	X
		Held by Bank A	
		Held by Bank C-A	
Bank D			
Dep. at central bank	X +Z	Deposits	X
Other assets	X	Vostro account Bank A	X +Z
		Credit central bank B	
Central Bank B			
Credit to banks	X	Deposits Bank B	X - X_B
Token CeB A		Deposits Bank C-B	X - X_{C-B} -Z
		Deposit Bank D	X +Z
		Banknotes issued	
		Tokenised deposits	
		Held by CeB A	
		Held by Bank B	+ X_B +Y
		Held by Bank C-B	+ X_{C-B} -Y

Figure A-2 illustrates the case that the programmable platform would take over the central liquidity accounts of banks, including the domestic RTGS system.

Figure A-2: When programmable platform would have allowed to discontinue the traditional accounts

Country A (in A currency)			
Firm A			
Real goods	X	Equity	X
Account Bank A	X		
Bank A			
Tokenised CeB deposits	X	Deposits (of non-bank)	X
Tokenised Bank D deposits	X	Tokenised depts	
Other assets		Held by Bank B	X
		Held by Bank C-B	
		Credit central bank A	
Central Bank A			
Credit to banks	X	Tokenised dep	
		Held by CeB B	X
Tokenised dep CeB B		Held by Bank A	X
		Held by Bank C-A	X
		Retail CeBM and other Liabs.	X
Bank C-A: FX Bank, A-country subsidiary			
Tokenised CeB deposits	X	Cred. central bank A	X
Other assets	X	Tokenised deposit	X
		Held by Bank A	X
		Held by Bank B	X
		Held by bank C-B	
Bank C-B: – B-country subsidiary (belongs to B-country)			
Tokenised CeB deposits	X	Cred. central bank B	X
Tokenised Band C-A deposits	X	Tokenised deposits	
Other assets	X	Held by bank A	
		Held by bank B	
Country B (in B currency)			
Firm B			
Real goods	X	Equity	X
Account Bank B	X		
Bank B			
Tokenised CeB deposits	X	Deposits clients	X +Y
Other assets		Credit central bank B	
		Tokenised depts	X
		Held by Bank A	X
		Held by Bank C-A	X
Bank D			
Tokenised CeB deposits	X	Deposits	X
Other assets	X	Token deposits of Bank A	X
Central Bank B			
Credit to banks	X	Banknotes issued	X
Tokenised dep CeB B		Tokenized dep	
		Held by CeB A	X
		Held by Bank B	X
		Held by Bank C-B	X
		Held by Bank D	X

The programmable platform could also be extended to cover credit operations between central banks and the banks and include the securities leg. How could we represent this system if we instead **imagine the programmable platform as being actually the ledger**? This would mean that on the liability side, we

would no longer have the sub-positions to different obligors, but only a single obligor position towards the programmable platform. We now omit bank D for simplicity.

Figure A-3: If the programmable platform is represented as an actual ledger

Programmable platform			
Bank A	X	Token Bank A Held by Bank B	
	X	Token Bank A Held by Bank C-B	
Bank C-A		Token Bank C-A Held by Bank B	
		Token Bank C-A Held by Bank C-B	
Central Bank A		Token CeB A Held by CeB B	
		Token CeB A Held by Bank A	
		Token CeB A Held by Bank C-A	
Bank B		Token Bank B Held by Bank A	
		Token Bank B Held by Bank C-A	
Bank C-B		Token Bank C-B Held by Bank A	
		Token Bank C-B Held by Bank C-A	
Central Bank B		Token CeB B Held by CeB A	
		Token CeB B Held by Bank B	
		Token CeB B Held by Bank C-B	
Country A (in A currency)			
Firm A			
Real goods	X	Equity	X
Account Bank A	X		
Bank A			
Token CeB A	X	Deposits (of non-bank)	X
Token Bank D	X	Token	X
Other assets		Credit central bank A	X
Central Bank A			
Credit to banks	X	Token	X
Token CeB B		Retail CeBM and other Liabs.	X
Bank C-A: FX Bank, A-country subsidiary			
Token CeB A	X	Cred. central bank A	X
Other assets	X	Token	X
		Intra-Group liability	X
Bank C-B: – B-country subsidiary (belongs to B-country)			
Token CeB B	X	Cred. central bank B	X
Intra-Group claims	X	Token	
Country B (in B currency)			
Firm B			
Real goods	X	Equity	X
Account Bank B	X		
Bank B			
Token CeB B	X	Deposits clients	X +Y
Other assets		Credit central bank B	
		Token	X
Bank D			
Token CeB B	X	Deposits	X
Other assets	X	Token	X
		Credit central bank B	
Central Bank B			
Credit to banks	X	Banknotes issued	X
Token CeB B		Token	
		Equity	X

Annex 2: Flow of funds of creation and use of stablecoins

Below, users first need to create SCs and we assume both users hold the stablecoins via one public blockchain. We choose a presentation which interprets the SC as the issuer of a bearer instrument, and the DeFi platform as the ledger. The SC holds its funds with the banking system – to be precise with bank 2. **The two households onramp a_1 and a_2 , respectively, to the stablecoin issuer.** Subsequently, **a payment b** is made between the two parties SC holders. We assume there is no subsequent defunding ($a_1 > 0, a_2 > 0, |b| \in [0, \min(a_1, a_2)]$). For the sake of completeness, we also show how a **payment c** (with the same purpose as y) would have been done in commercial bank money.

Figure A-4: On-ramp of funds into an SC, and use of the SC for payments

Person 1 (P1)			
SC		+a1	+b
Deposits at Bank 1	X	-a1	+c
Real asset	X		-b -c
Bank 1			
Other assets	X		
Deposits at central bank	X	-a1	+c
Deposits P1	X	-a1	+c
Equity	X		
SC issuer			
Deposits with Bank 2		+a1 + a2	
SC issued			+a1 + a2
Ethereum blockchain (ledger)			
SC		+a1 + a2	
SC P1		+a1	+b
SC P2		+a2	-b
Bank 2			
Other assets	X		
Deposits at central bank	X	+a1	-c
Deposits P2	X	-a2	-c
SC deposits		+a1 + a2	
Person 2 (P2)			
SC		+a2	-b
Deposits at Bank 2	X	-a2	-c
Real asset	X		+b +c
Central Bank			
Other assets	X		
Deposits Bank 1	X	-a1	
Deposits Bank 2	X	+a1	

The payment b is a single layer payment in the sense that it is not mirrored in any other ledger, i.e. it is internal to the SC/Ethereum ledger. At the same time, the on-ramping would seem to have affected “2.5” layers: the accounts of the households with banks, the banks’ accounts with the central bank, but also the SC/Ethereum ledger system, whereby the SC itself holds its assets in the form of deposits with bank 2.

Recent Issues

No. 472	Tobias Tröger	Systematic Stewardship on the Waterbed
No. 471	Yue Wang	Consumer Credit and the Rise of Electric Vehicles
No. 470	Ulrich Bindseil	Regulatory Responses to the Financial Stability Implications of Stablecoins
No. 469	Andreas Fuster, Virginia Gianinazzi, Andreas Hackethal, Philip Schnorpfeil, Michael Weber	The Response of Debtors to Rate Changes
No. 468	Marina Traversa	Weaker Today, Stronger Tomorrow: Peer Learning and Firm Innovation after the Great Recession
No. 467	Claes Bäckman, Walter D'Lima, Natalia Khorunzhina	Housing Capital Gains across the Income Distribution
No. 466	Niclas Griesshaber, Jochen Streb	Multimodal LLMs for Historical Dataset Construction from Archival Image Scans: German Patents (1877–1918)
No. 465	Winta Beyene, Matteo Falagiarda, Steven Ongena, Alessandro Scopelliti	Do Lenders Price Diesel Risk? Evidence from Dieselgate and Low-Emission Zones in Captive vs. Independent Banks
No. 464	Kevin Bauer, Oliver Hinz, Ekaterina Jussupow, Lena Liebich, Moritz von Zahn	Knowing (Not) to Know: Explainable Artificial Intelligence and Human Metacognition
No. 463	Florian Heeb, Julian F. Kölbl, Camilla Weder	Beliefs About the Climate Impact of Green Investing
No. 462	Florian Berg, Marco Ceccarelli, Florian Heeb, Alexey Ivashchenko, Roberto Rigobon, Camilla Weder, Remco C. J. Zwinkels	The Market for Voluntary Carbon Offsets
No. 461	Marina Traversa, Guillaume Vuillemeys	Entry in Banking Markets
No. 460	Pasquale Della Corte, Can Gao, Daniel P. A. Preve, Giorgio Valente	What 200 Years of Data Tell Us About the Predictive Variance of Long-Term Bonds