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What is New about Cryptocurrencies? A Visual Analysis

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In the context of recent developments with cryptocurrencies, as well as the potential rise of central bank digital currencies, we present a new visualisation of money. Using three novel figures, we distinguish between the relevant mechanisms, technologies, record-keeping, and transactions of various forms of money, as well as the classifications of different types of money; this enables the resolution of omissions and ambiguities in other recent such visualisations (CPMI 2018; Bech and Garratt 2017; Bech and Garratt 2017; CPMI 2015; Wadsworth 2018a; Wadsworth 2018b). This reveals the novelty of cryptocurrencies, which use the software-based cryptographically secured record-keeping, that support the issue of money with a credible commitment to a limited quantity of issue. We conclude with a discussion of policy implications stemming from our analysis.

Keywords

Money, Cryptocurrencies, Central bank digital currencies, Bitcoin

JEL Classification

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1 Introduction

Technology is fundamentally altering both the forms in which money is held and the mechanisms of monetary transfer. The emergence of cryptocurrencies such as Bitcoin has sparked extensive discussions: of whether their supporting blockchain technologies are fundamentally new developments that could disrupt existing monetary arrangements; and, also, on how policy makers should respond to these new technologies.

A recent strand of literature offers several visualisations of the characteristics of money and how they are affected by these technological changes (for example the 'money flower' of Bech and Garratt (2017)). Visualisations such as these are powerful and valuable organising devices. They are though also necessarily simplifying and, if not adequately thought through, potentially distorting summaries of the key issues.

These visualisations have been primarily developed as contributions to one part of this broader discussion: whether central banks should issue of digital currencies (CBDC), electronic versions of cash either widely accessible (retail CBDC) or limited to non-bank and bank financial institutions (wholesale CBDC). One technical issue is whether such issuance should employ blockchain technologies. Central banks in many countries have been weighing the benefits of widening access to their balance sheets in these different ways.[1]

All these variations of CBDC would be a marked change from the current status quo where only banks can hold accounts at central banks non-bank holdings of central bank liabilities must take the form of physical cash. Potential positive implications of CBDC and other technology based monetary innovations include: lower cost of issuance; convenience for users; increased competition in financial services; ability to pay interest; flexibility in the transmission of monetary policy particularly allowing policy makers to avoid the zero-lower bound; and the promotion of financial inclusion. [2]

The purpose of this paper is to develop and present an alternative, richer visualisation incorporating other visualisations and providing a more accu-

1. The first mention seems to be Raskin and Yermack (2016). There are many policy and research papers, e.g. Bordo and Levin (2017); Pfister (2017); Mancini-Griffoli et al. (2018); Meaning et al. (2018); CPMI (2018); Niepelt (2018);Bordo and Levin (2019). A conference proceedings summarising these debates is Gnan and Masciandaro (2018)

2. M-Pesa in Kenya and PayTM in India are prominent examples of technologies promoting financial inclusion.

rate representation of how the newly envisaged forms of money - cryptocurrencies, stable coins and CBDCs - differ from each other and from established fiat and and bank money. Hence, we provide a preliminary assessment both of what is really new about these new monetary technologies and of how financial regulators and central banks might respond to these developments.

We argue that greater insight is provided by distinguishing and separately visualising two, distinct aspects of money:

1. The different technologies of recording ownership and transfer, whether this is through bearer money (a physical object) or an account-based money. In the case of bearer money, value is either embodied in the object or the object itself is of relatively low value but representative of a larger value. Account-based money is necessarily representative whether based on paper or electronic records the records themselves are only indicative of value. Amongst the variety of electronically recorded money, we can distinguish a range of technologies used for transfer, specific to individual providers or through shared, common processes.

2. The different arrangements for supporting the value of representative money (either physical tokens or nominal account-based money) depending on (i) the issuer of the money (whether state or private); (ii) amongst private money whether this is fully reserved narrow money or fractionally reserved broad money; (iii) whether the issuer maintains a fixed parity against some other form of money, financial or real asset; or instead a floating parity; and (iv) whether the holding of the money is relatively restricted or available to and adopted by a broad range of users.

Distinguishing these two separate aspects of the new monetary technologies we propose here a new visualisation of three complementary diagrams that more fully capture the large existing literature on institutional monetary arrangements. We believe these visualisations provide greater useful insight into current debates on the new technologically enabled forms of money.

Specifically, our visualisation offers the following answer to the question posed in our title. Cryptocurrencies are new in two quite different ways:

1. Unlike earlier forms of money, they utilise cryptographic security for instructing transfer of ownership (much as WhatsApp uses cryptographically secured messaging). This is a major innovation that we expect

will be widely adopted, not restricted to cryptocurrencies. The same techniques of secure transfer can also be used with either conventional commercial bank and or central bank issued money.

2. They are also privately issued records of value with no fixed parity against financial or real assets. The innovation here is the private issue. The cryptographic security allows credible limits on issue that prevent unlimited duplication.[3] This is also a major innovation but in our assessment unlikely to become a major part of or displace existing established monetary arrangements.

The remainder of the paper is organised as follows: we consider the existing money diagrams in the next section, followed by a review of the broader literature. We then present and justify our own visualisation. The final section concludes with a brief discussion of the implications of these new technologies for central banking and financial regulation.

2 Some Recent Money Diagrams

With CBDC and cryptocurrencys growing importance, many recent papers have introduced visualisations that classify different forms of money according to various criteria. The diagrams are all produced by researchers associated with central banks, a reflection of the interest policy makers have in intuitive representation of the new monetary technologies. A particular focus is on understanding how a CBDC conventional digital currency (using conventional payment technology) or CBDC cryptocurrency (using distributed ledger technology) relates to existing forms of money.

The most widely cited of these visualisations is the money flower, first presented in Bech and Garratt (2017) and then with some re-labelling by the Committee on Payments and Market Infrastructures (CPMI 2018). In Figure 1 we reproduce the 2018 version of this figure. This visualisation combines together four independent criteria for the classification of money: (i) issuer (central bank or other); (ii) form (digital i.e. electronic or physical);

3. State issued fiat money with no fixed parity, protected instead against unlimited duplication by penalties against forgery and not always reliable self-discipline limiting issue, date back centuries. Unbacked paper money issued by the Chinese Yuan dynasty and by its predecessor the Chin rulers of Northern China from the mid-12th century is an early example (see Peng (1994); Davies (2002)).

(iii) accessibility (widely accessible or limited); and (iv) transfer mechanism (decentralised tokens that are transferred peer-to-peer or centralised account transfer).

While eye-catching, there are some problems with this visualisation. The choice of classification criteria appears somewhat arbitrary, with little justification for why these might be important to understanding technological developments in money. The version of Bech and Garratt (2017) refers to two closely related recent taxonomies, also presented visually, which each classify money according to three rather than four independent criteria. One of these is Bjerg (2017) which employs three of the four classifications subsequently used in Bech and Garratt (2017): central bank issue v. other issue; electronic v. physical; and wide accessibility versus limited accessibility. Bech and Garratt (2017) extend this classification by adding also a distinction between decentralised peer-to-peer transfer v. centralised account transfer. The other is CPMI (2015) which employs only two of the four classifications used by Bech and Garratt (2017): decentralised peer-to-peer transfer; and electronic v. physical recording keeping; together with a third classification: the liability of no-one v. balance-sheet liability. This last classification is not included in the Bech and Garratt (2017) money flower.

Figures 2 and Figure 3 are further recent visualisations. Figure 2 is reproduced from the money tree, Figure 1 of Wadsworth (2018a) and Wadsworth (2018b). This presents a hierarchy of money, distinguishing at the highest level physical money or cash (what we prefer to describe as bearer money) from digital or electronic money; and within digital money distinguishing conventional bank or central bank money (using a conventional payment technology); and cryptocurrency (using distributed ledger technology). These two categories are then further identified by either fixed value i.e. maintained in a fixed rate of exchange against other forms of money; or variable meaning that there is no fixed external valuation.

Figure 3, yet another recent visualisation, is the control structure of currencies cube reproduced from Berentsen and Schar (2018b). This cube distinguishes three different aspects of money along three dimension. One dimensions, that corresponding to the highest level hierarchy in the money tree of Wadsworth, is the distinction between physical and virtual money. The two other dimension that of monopoly central bank issue v. competitive private issue decentralised peer-to-peer transfer v. centralised transaction, are two of the distinctions captured in the 'money flower' diagram of Bech and Garratt (2017); CPMI (2018).

While promising ways of summarizing the issues concerning new monetary technologies and central bank issue of digital currencies, there are potential problems with all these diagrams. First, the decision to treat the dimensions of classification as independent and hence allowing all possible combinations of classification, as in Bech and Garratt (2017) Berentsen and Schar (2018b), throws away information about monetary arrangements that could be important and useful to policy makers. Only Wadsworth attempts to capture any element of hierarchy amongst different forms of money. Second, these diagrams can capture at most only four dimensions (four two-way classifications), with as a result some possibly important aspects being ignored, for example the question of whether a money is a liability as raised in CPMI (2015).

To address these limitations, we have set ourselves the goal of developing a visualisation more fully justified by review of the historical and current literature identifying relationships amongst classifications and offering a more transparent discussion of what classifications are included and what excluded.

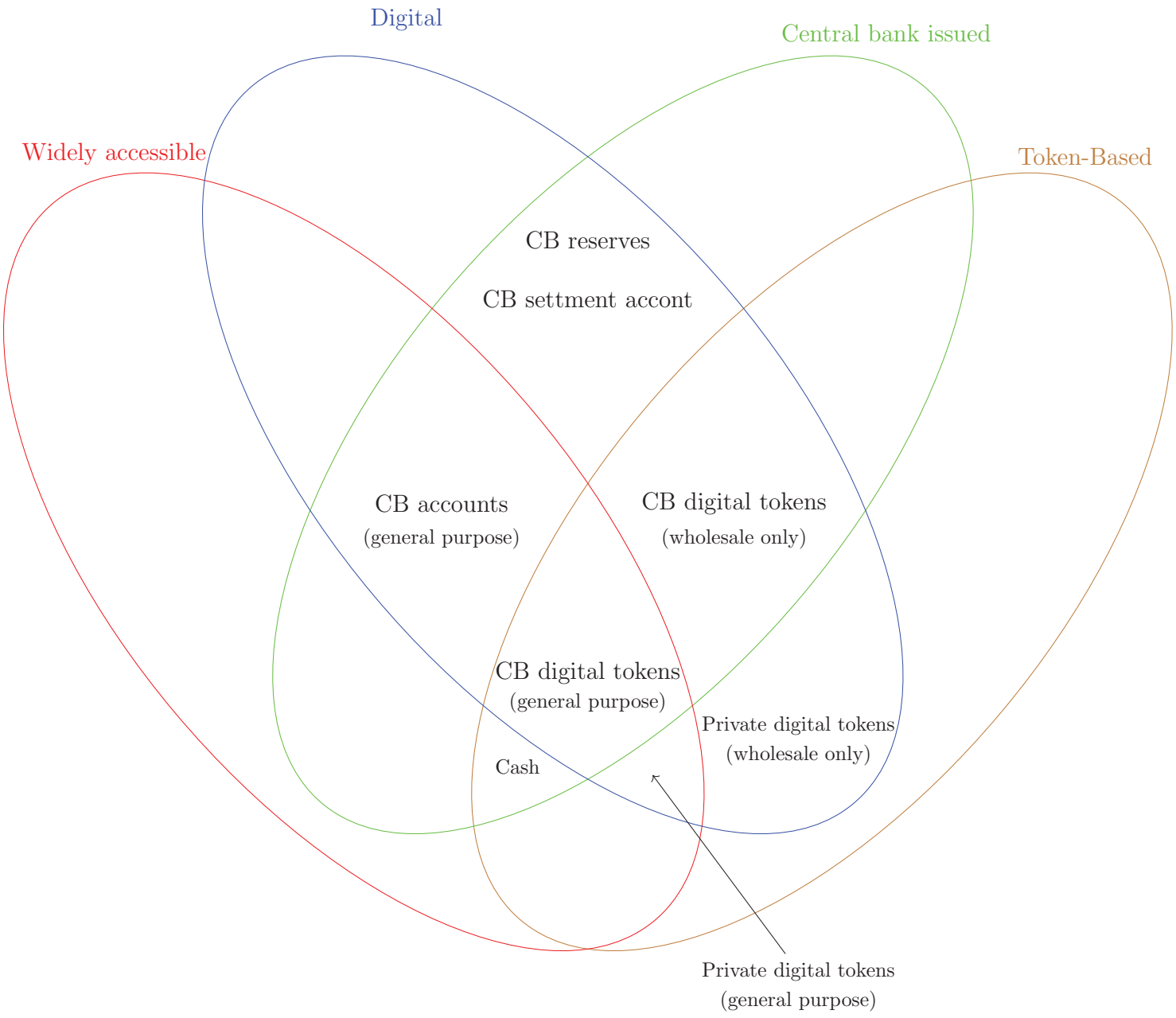

Figure 1: Money Flower: Adapted from Coeure and Loh (2018)

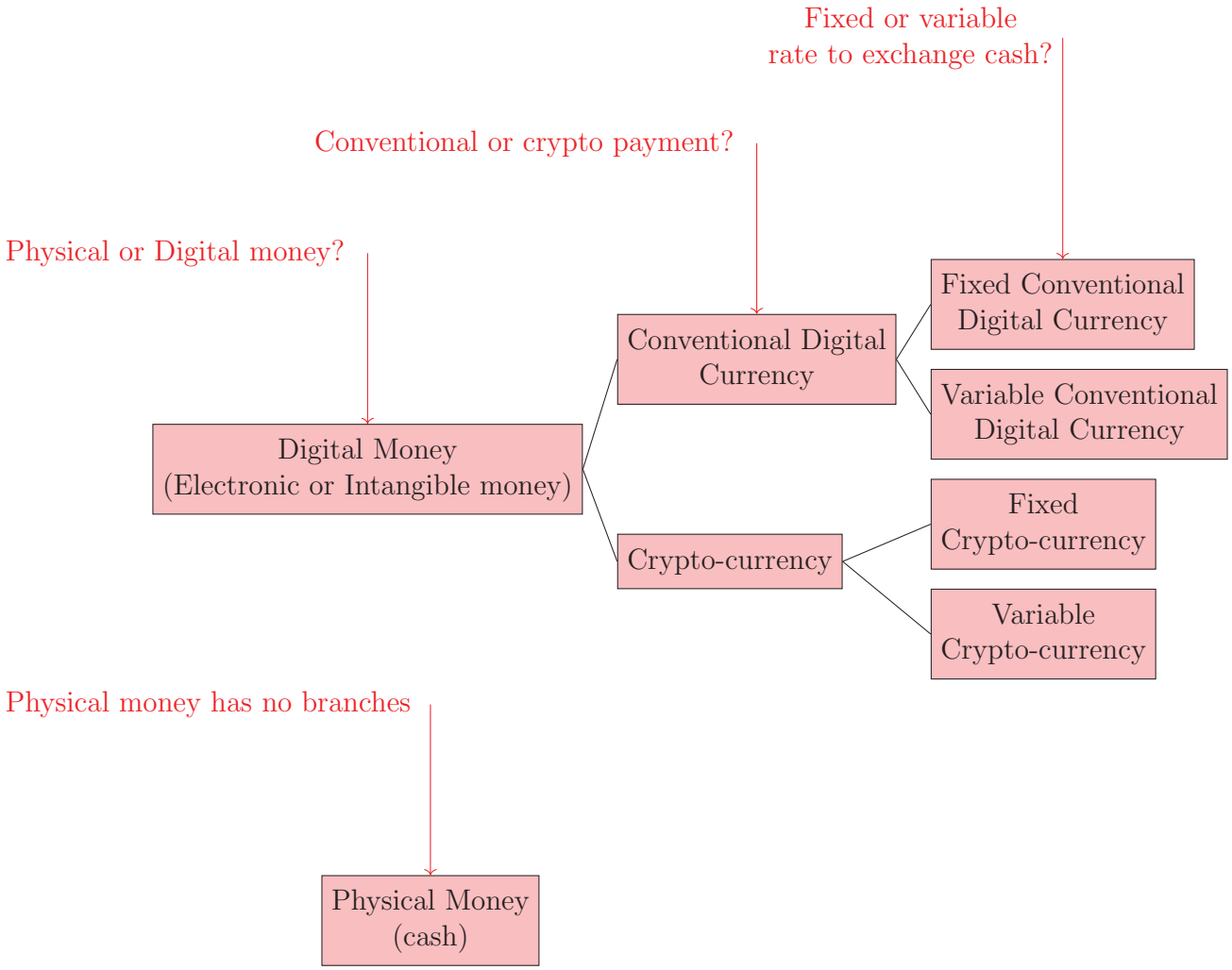

Figure 2: Money Tree: Adapted from Wadsworth (2018c)

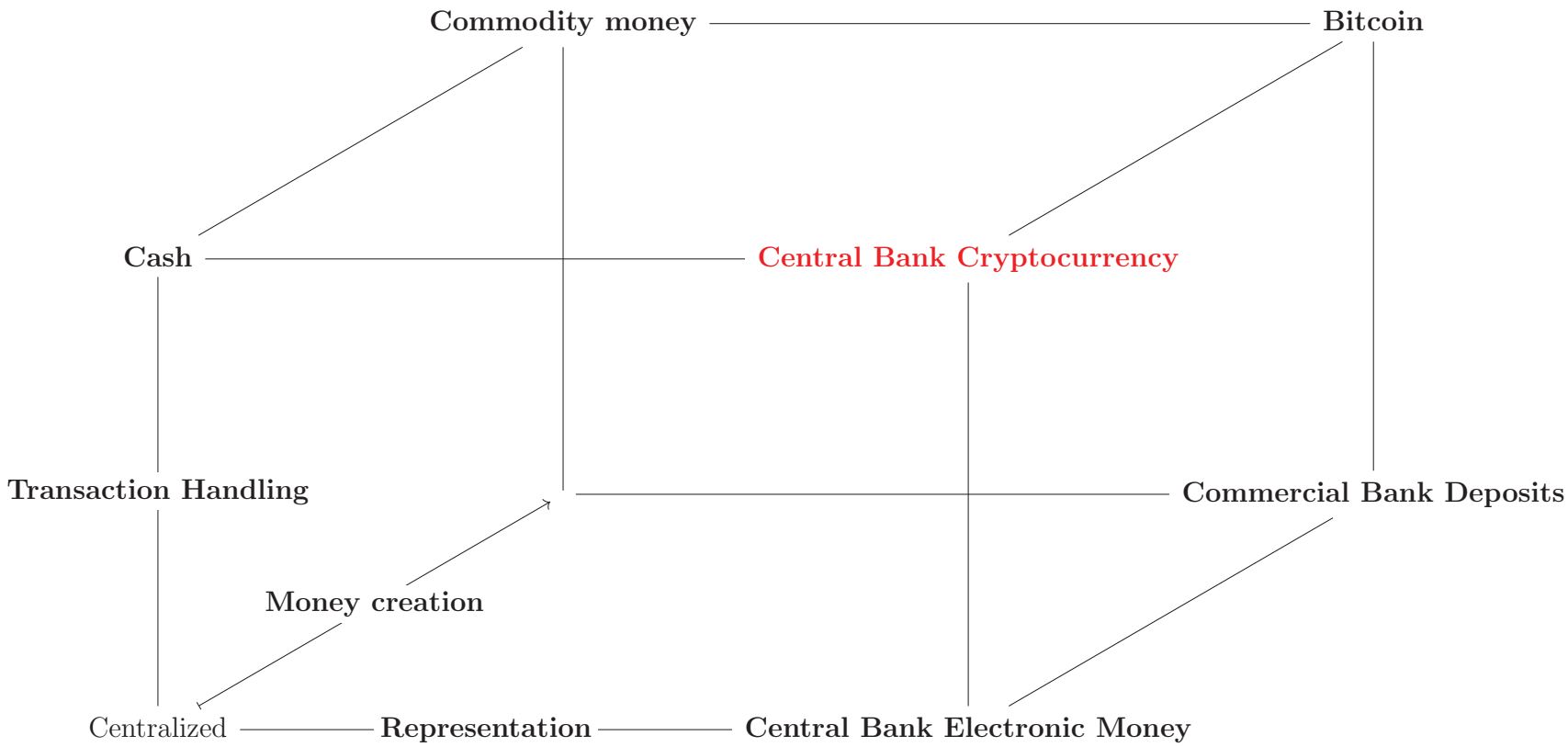

Figure 3: Source: Adpated from Berentsen and Schar (2018a)

3 A Brief Review of Relevant Literature

We also seek to clearly locate our visualisation in relation to the vast literature on the role of money and banking in economic exchange and how this is affected by social, economic, institutional and technological change. [4] For visualisations of money to inform current policy debate, their construction needs to pay close attention to the key issues in this large body of relevant scholarship. [5]

From this extensive literature we identify three prominent aspects of monetary arrangements that we believe should be captured in visualisations of monetary arrangements.[6]. The first, in a distinction that can be traced back to Aristotle, is whether money is an object formed from a commodity such as precious metal ('metallism') or whether it is an abstract concept, a nominal value or ticket whose use is rooted in custom and law ('nominalism').[7]The second is the role of the state versus that of the market in developing and supporting the institutions of monetary exchange.[8] The third is whether private credit or claims backed by private credit (i.e. fractionally reserved

4. One indicator: of the 1039 pages of Schumpeters History of Economic Analysis Schumpeter (1954), around one-sixth are devoted to monetary issues and the institutional arrangements of money and credit.

5. Less relevant are many issues that have dominated the monetary literature since the mid-20th century: e.g. understanding and modelling money demand and the transmission of monetary policy. While the new technologies of money are also relevant here, visualisation of the kind we explore is more suited to contrasting different monetary arrangements than to analysing the relationships between money, interest rates and other economic variables.

6. **KB** present a more detailed review of this literature, distinguishing these three aspects of monetary debate and relating them to monetary history. Supporting references include Schumpeter (1954); Cowen and Kroszner (1994); Smithin (2000); Wray (2004); Latzer and Schmitz (2002)

7. The view that money is based on a commodity, most often a precious metal, rather than being an arbitrary nominal unit is associated with some of the earliest scholastic writings on economics, who built on Aristotelian thought, with most economists in the British classical tradition from Adam Smith to John Stewart Mill and with many German language monetary economists including Menger and Von Mises.

8. These metallist ideas are rooted in historical periods when most national monetary arrangements were based on either a gold or a bimetallic gold/silver standard with coin and bank notes exchangeable against specie. The rise of the nation-state and its adoption of wide-ranging fiscal, financial and monetary responsibilities has led to European monetary thinking putting much more stress on 'chartalist' views in which monetary arrangements are largely shaped by law and government policy.

private money including bank transaction deposits) can substitute effectively for state issued or commodity based money in monetary exchange. [9]

The literature offers extensive discussion of all three of these aspects of monetary arrangements: object v. nominal unit; state v. private provision; and narrow, fully reserved, outside money v. broad, fractionally reserved inside money. This suggests that all three need to be included in visualisations created to help policy makers understand the implications of technological change for monetary arrangements. However, of the three recent visualisations presented in Section 2, only Wadsworth draws a distinction between physical objects and nominal accounting units and none of the three incorporate the distinction between narrow and broad money. Our proposed visualisation includes all three of these central aspects of money.

For our purpose of creating insightful visualisations, we do not need to take a position on the further associated fierce accompanying debates, about what forms monetary arrangements should be.[10] What matters in the context this paper are the descriptive content of these different views of money,- understanding what arrangements are today, have been in earlier historical periods, may be in the future, and ensuring all are captured in our proposed visualisations.

We must though recognise that these three aspects of money are interdependent. Money backed by credit, i.e. broad or inside money, has been almost always been offered through private initiative. The widespread view that the state should have primary responsiblity for the creation of money and monetary arrangements is inconsistent with the metallist viewpoint (though

9. Similarly the growing importance of bank credit and deposits together with the decline and eventual abandonment of these metallic monetary standards in the 20th century clearly shifted the balance of debate to nominalist interpretations of money and to broad acceptance that both private credit and bank transaction deposits (to use the terminology of Gurley and Shaw (1960) 'inside money') are used equivalently in monetary transactions as state provided outside money such as central bank notes or other central bank liabilities ('outside money').

10. As an example see Schumpeter (1954) who points out that it is possible to reject 'theoretical metallism', while at the same time favouring 'practical metallism'. An example is Von Mises who accepts the possibility of fiat or credit money but argues that nominal money should be tied to those of a commodity such as gold in order to limit the ability of the state to engage in inflationary monetary finance. Another example, it is possible to accept the importance of credit as a form of money without endorsing the associated view that state intervention is required in monetary arrangements to counter the instability and potential economic slump associated with private credit, an argument frequently made in 'post-Keynesian' monetary analysis e.g. of Minsky, Davidson or Wray.

metallist thinking allows some role for the state e.g. in defining monetary units and providing high quality coin).These relationships indicate that any visualisation should, like that of Wadsworth (2018b), include such hierarchical relationships amongst these different aspects of money.

Turning the recent literature on cryptocurrencies, we note two common views that we suggest are misconceived and need to be corrected in order to accurately visualise cryptocurrency and other forms of money. It is commonly stated that cryptocurrencies are decentralised with no central issuer while conventional fiat money is centralised, i.e. managed and issued by national institutions. [11] It is also often stated that cryptocurrencies are tokens that exchange directly peer-to-peer as opposed to bank money which passes indirectly through central bank settlement. [12] Both of these statements are inaccurate. There is a danger, that if not constructed with sufficient care, these inaccuracies are inherited in visualisation of money and hence mislead rather than inform policy debate.

It is an oversimplification to describe cryptocurrencies or their underlying 'blockchains' as decentralised and established monetary systems as centralised. Several distinct operations are involved in monetary transfer confirmation of payments instructions, updating of records, final validation as well as control of overall monetary issue, with a range of possible degrees of centralisation for each.[13] It is true that the updating of the records of cryptocurrency holdings is decentralised. But this is also true of conventional commercial bank money where there is no single national monetary ledger (record keeping is decentralised to the level of individual commercial banks, although each bank has its own centralised ledger). Confirmation of payments (i.e. checking that the payment instruction is valid) is a distinct process that precedes the updating of the records of monetary holdings.[14] In both cryptocurrency and conventional commercial bank payments, oper-

11. Versions of this characterisation are found in Bech and Garratt (2017); Soderberg (2018) and others.

12. See Milne (2018) for a critique of the characterisation of cryptocurrencies as tokens.

13. See Rauchs et al. (2018); Kavuri and Milne (2019) who distinguish the range of different functions carried out by blockchains or distributed ledgers and the different degrees of decentralisation possible for each function.

14. More precisely, settlement usually proceeds the updating of records of monetary holdings. In the case of commercial bank money payment, payee balances may be updated through a crediting of the account balance before settlement but these credits are not final and irrevocable. Payer balances are usually but not always debited immediately on payment instruction.

ations for validating payments are partially, not fully, decentralised through proof or work or mining in the case of Bitcoin and through final settlement using central bank money for conventional payments.[15] A fourth key operation is overall control of issue. Here the situation is entirely the other way around: issue is centralised in the case of cryptocurrencies (the overall amount is limited by their software) but decentralised for conventional commercial bank money (each bank can create transaction deposits through extending loans).

It is also misleading to describe cryptocurrencies as tokens that pass peer-to-peer. They are not physical objects. Somehow though widespread, but we believe mistaken, belief has taken hold that they are some form of 'virtual object' passed from one user to the other over the internet and not (as they in fact are) accounting entries.[16]. A more accurate understanding of the transfer of cryptocurrencies comes from recognising that the cryptocurrency ledger is akin in structure (although not in terms of institutional control) to a ledger operated by a single monopoly commercial bank, with all transfers between holders taking place through a combination of debit and credit on this ledger. They are transfers of records of ownership in an accounting system, not transfers of an object that exist independently of the supporting records of ownership. This also means that cryptocurrencies are thus a narrow money with no fractional reserving (a key point omitted from the visual diagrams we have discussed above in Section 2) and therefore do not require central bank settlement (there is no transfer between ledgers with matching transfer of central bank reserves).

The visualisation we set out in the next section, distinguishing separately innovation in transfer and records of ownership and innovation in the arrange-

15. There is a lot of detail here, of primary interest only to payments specialists. Milne (2017) Appendix B provides a non-technical discussion of Bitcoin confirmation. Many practitioner and policy publications describe the mechanisms for validating commercial bank transfers. Confirmation of Bitcoin transactions is undertaken by miners engaged in proof of work, with only five mining groups undertaking the large majority of confirmations. The use of netting means that confirmation of commercial bank payments combines a mixture of both decentralised and centralised mechanisms: for smaller payments confirmation can be near immediate on receipt and checking of the payment instruction between two banks i.e. highly decentralized; for large payments routed through real time gross settlement systems, confirmation depends on the paying bank having sufficient liquidity to direct the payment through the central settlement system, so instructions are decentralised by execution depends to a degree on central arrangements to provide intra-day liquidity.

16. This point is discussed in more detail in Milne (2018)

ment for establishing value for representative money, avoids these inaccurate conceptions about the decentralisation and token status of cryptocurrencies.

One further point, before we present our own visualisation. When considering account-based money it is necessary to take account of evolution in their supporting payment arrangements. This is a challenge because there is today considerable variety of payment schemes for transfer of modern electronically recorded money.[17] These arrangements include (i) national payment schemes including large value real time payments, cheque clearing, ATM withdrawals, batch payments, direct debit and push credit transfers; (ii) card payment schemes mostly now organised through global card associations such as Visa and Mastercard; (iii) non-bank schemes for transfer of fiat value such as Paypal or (in China) Alipay and WePay and (in East Africa) MPesa; and (iv) a large number of payment processing solutions, tailored to handle payments approval in different transaction contexts (Paypal again, Stripe, Square, WorldPay and many others); and now the recent emergence of cryptocurrency technologies (based on so called 'blockchains' or 'distributed ledgers') where the entire process of recording ownership and making transactions is carried out within a single secure software environment.

To capture this complexity, we think of all ownership and payments arrangements for electronic account-based money as all lying somewhere between two polar extremes:

1. Purely institutionally-mediated processing, based on verification of the identity of the account holder before processing their payment instruction using independent, internal processes (which for fractionally reserved banks are ultimately settled through the delivery of a matching reserve asset);

2. institutionally independent cryptographically-secured processing where all ownership transfers take place using a single common software en-

17. There is relatively little literature studying the economic and monetary implications of payment arrangements. There has been quite a lot of attention to credit card payments in the literature on two-sided platforms (e.g. Evans and Schmalensee (2005); Rochet and Tirole (2002). Beyond this Green (2008); Kahn and Roberds (2009) offer insightful discussion, drawing a distinction between payments validation based on identification of an object (i.e. bearer money) and on identification of the owner (account-based money). This though is, asKahn and Roberds (2009) already recognised even at the time they were writing rather too simple a classification. We are aware of little else until the recent interest in cryptocurrencies.

abled process requiring only access to cryptographic keys to initiate payments.

At the first extreme are the earliest historical banking arrangements, where transfers took place either by withdrawal of physical money e.g. gold or acceptance of an instruction (a bill or an account transfer) by another bank. Cryptocurrencies are the other extreme case with no institutional involvement in transaction processing which is instead all handled automatically by the supporting software.[18]There is an evident historical trend between these two extremes. From the 19th century onwards, with the advance of communication technologies, it became possible to also instruct transfers of account-based money between institutions through agreed national multilateral transaction schemes. These employed standardised written instructions (a cheque or giro) together with industry wide co-operation on the matching settlement of payments between banks using transfers of a reserve assets (which took various forms, commodity money, government issued notes, claims on a clearing house or reserves held at a central bank).

The other and most recent form of account-based money is that recorded electronically from the 1960s onwards. Electronic recording of monetary accounts has been widely used for only half a century and the technologies of transfer of electronically recorded money have evolved substantially over this time. The processes for transfers of electronic money debit cards, ATM withdrawals etc., have until recently paralleled those for written records of money, with the payment also institutionally mediated after receipt of an instruction for withdrawal or transfers. These required checks on identity (corresponding on the checks of signatures required for paper based payment instructions, for example correct response to security questions or the provision of an online password). After this and following checks on the sufficiency of funds, instructions for withdrawal or transfer of ownership can be accepted.

The new cryptography based technologies can support a further shift towards shared arrangements, with new technologies allowing banks to shift increasingly to shared processing arrangements, to reduce the need for costly manual interventions and to meet customer demands for making payments

18. A consequence of the absence of institutional mediation is that cryptocurrencies are pseudonymous, instructing a payment requires only possession of the private cryptographic key corresponding the public key associated with a cryptocurrency balance; no link to or verification of a real-world identity is necessary.

in a variety of online and face-to-face contexts with improved transaction speed and real time information. Regulatory mandate is also now requiring banks to use related technologies (cryptographically secured Application Programming Interfaces or APIs) to support greater competition in banking services. The leading example is open banking in the UK. This is encouraging a parallel development where institutional responsibilities are standardised and hence unbundled so that they may be handled by different institutions or on occasion sufficiently automated that they require no institutional involvement at all. [19]

At the same time, institutional responsibilities for payment records and transactions will not be entirely removed. Shifting core payments processing onto a common shared basis is a costly and risky undertaking, and may weaken a banks' competitive position, making such change difficult to justify from a business perspective. Even when market and regulatory pressures force banks to move substantially towards shared business processing, they will still need to retain substantial institutional responsibilities, for applying know-your-customer (KYC) and anti-money laundering (AML) regulations and because many customers will still want institutional help in managing their ownership and transactions of financial assets (even where software solutions exist that allow them to do this without any institutional involvement).

4 Three Visualisations of Monetary Innovation

This section presents our three visualisations of monetary innovation. These figures we argue together provide a more complete analysis of the impact of technological change on forms of money than other recent visualisations. Figure 4[20] is similar to the money tree of Wadsworth (2018b) illustrating the hierarchy of technologies for recording and transferring ownership of money. Figure 6 is similar to the money flower of Bech and Garratt (2017) but restricted to the arrangements supporting the underlying value of money, keeping these separate from the Figure 4 hierarchy of technologies used for

19. On Open Banking see (The Open Data Institute and Fingleton 2019).

20. To draw the diagrams, we used a combination of manuels, material including Chiang 2012, Tantau 2007, tikzcd 2018 and Zivanovic 2017 and website material such as tex.stackexchange 2013, tex.stackexchange 2015).

recording and transferring of ownership. We incorporate the distinction between narrow and broad money, omitted from other visualisations, and avoid the misleading characterisations of cryptocurrency as decentralised or their transfers as the peer-to-peer transfer of a virtual object.

4.1 Ownership and transfer

In Figure 4, which represents the different arrangements for ownership and transfer, entries towards the left-hand side are older technologies while those the right represent newer technologies. One main branch, to the left of Figure 4, contains all bearer forms of money with a change of ownership taking place through the physical transfer of an object. Furthest to the left is physical commodity money. This form of bearer money is used either in its natural form, or manufactured in a standard form such as coinage. The common feature is that the material of which it is made is worth full or near to full face value. Bearer money, while still being a manufactured object such as a coin, may instead be a representative token instead of a physical commodity with the value of the material of which it is made much less than its full face-value.

The other main branch, to the right of Figure 4, contains all account-based money. This divides into two sub-branches. Much the older sub-branch are account monies recorded using written records, for which the oldest historical examples are those written in clay dating from third millennia BC Mesopotamia and on papyrus from second millennia BC Egypt. Ownership and transfer of account-based money recorded using paper records appears in both China and Europe from the first millennia BC onwards.

Figure 4 highlights one of the central cryptocurrency ownership and transfer innovations: employing cryptographic security to minimise institutional mediation in the recording and transfer of the ownership of money. As we have already discussed, what this is creating is a range of possibilities lying between two polar extremes, so this is represented by as represented by the double headed arrow in Figure 4. To the left purely institutionally intermediated exchange. To the right cryptographically secured software based exchange without institutional mediation. In practice current and prospective future payment arrangements will lie somewhere between these extremes, utilising modern cryptographic security and employing a mixture of institutional and shared processing.

Still, while it will often still be institutionally mediated, the employment

of cryptographic security reflects a fundamental change in the underlying technologies for recording ownership and executing transfers of money. Employing cryptocurrency technologies, these technologies can now be implemented using a common software employed across institutions. This can be contrasted with conventional arrangements, which employ institutional specific arrangements for electronic recording of money holdings and conducting internal transfers, accompanied by shared arrangements between institutions for payments messaging and for subsequent settlement of transfers between institutions.

4.2 Issue and valuation of representative money

Figure 6, our second complementary visualisation, explore the different ways in which value is established for different possible forms of representative money.

Figure 5 and 6 distinguishes four aspects of the issue of representative money:

1. The first is whether money is state or privately issued. This is captured by the circle at the centre of Figure 6.

2. The second is whether value is floating or a maintained parity against the value of some other underlying monetary, financial or physical asset. This is captured by the horizontal straight line.(Above the line are monies with floating valuations, below with maintained parities). This is represented in Figure 5.

3. The third is whether the holding of money is fully reserved (narrow) money or fractionally reserved (broad) money. Fractional reserving is typically only offered by private institutions, making loans of monetary deposits in order to earn an interest margin but resulting in deposits exceeding their reserves.[21] Such lending requires money that is valued at a fixed parity against some other financial or real asset. The division between narrow, and broad money is thus represented by a semi-circle

21. In practice this division between state provided narrow or fully reserved money and privately provided broad or fractionally reserved money is not always a clearcut as suggested by our Figure 5. There are state-owned fractionally reserved banks in many countries, operating on commercial or quasi-commercial basis and also privately-owned fractionally reserved banks that often follow government or central bank directions.

in the lower maintained parity half of the diagram. Forms of money above the semi-circle are narrow fully-reserved money either with a parity maintained by buying and selling of reserves or a floating value. Forms of money below the semi-circle are broad fractionally reserved money which necessarily have a maintained parity.

4. The fourth is whether the money is widely accessed and accepted by any natural or legal person, or instead access and acceptance is limited to only a few institutions or individuals distinguished by locality, residence or nationality.This is represented by the arrows at the top of Figure 6. The extent of acceptance is a matter of degree, there is no sharp distinction between monies with wide acceptance and those with only local acceptance. Any particular money lies on a spectrum, with internationally accepted reserve currencies such as the dollar at one extreme and local community currencies at the other.

Figures 5 and 6 highlight the central cryptocurrency innovation in issue and valuation: the possibility of a privately issued narrow money with a floating value that is not referenced to any other financial or real asset. This possibility rests the technological innovation of shared secure operational arrangements for ownership, creation and transfer of account-based money.

Historically narrow representative money with floating values have always been state issued fiat currencies, deriving their value from the legal and economic powers of the state, including the collection of taxes, payment of government salaries and other expenditures and the creating and enforcement of the law of monetary exchange. The large-scale interest and substantial investments in Bitcoin and other cryptocurrencies demonstrates that, using cryptographic security, it is possible to instead have a privately issued floating currency, one that does not require institutional mediation for recording and transfer of value and whose fundamental value is based not on the power of the state but on demand for use in anonymous exchange and from libertarian sentiment and philosophy opposing state involvement in economic exchange.

The substantial fluctuations in cryptocurrency prices and the consequent limited application in day-to-day exchange has led to the launch of a number of so called 'stable coins' employing cryptocurrency technologies for transfer and recording ownership for account-based money with maintained parities

either against established fiat currencies or other assets.[22]

Our figures indicate that stable coins are less innovative than cryptocurrencies. From the perspective of monetary issue and valuation they are not new. They are simply the latest examples of privately provided monetary stores of value linked to real or financial assets, forms of money that have long history, examples including bills of exchange, letters of credit, shares in money market mutual funds and also commodity and equity mutual funds and more recently exchange traded funds. They may be either fully reserved narrow money or fractionally reserved.[23]

This though does not mean that stable coins of some kind will not at some point in the future establish themselves as widely accepted forms of money. The issue is not primarily technological. Widespread adoption does not require stable coins to use the same transaction technologies as cryp-

22. The June 2019 announcement of plans for Facebooks Libra currency, tied to a basket of fiat currencies, is the most widely discussed example.

23. Current experiments with stable coins utilise other experimental mechanics for supporting stable coins, apparently inconsistent with our Figure 5. These are described and analysed in Pauw (2018); Weber (2019). The reason we do not attempt to distinguish them in Figure 5 is that they can all be viewed as versions of fractionally reserved issue of broad money already incorporated in Figure 5. Weber (2019) describes one such mechanism for issuing stable coins which he labels as 'crypto central banking'. The examples he provides are Basecoin, Carbon and USD Fragments. The issuers of these stable coins claim to be able to maintain a stable market value against fiat currency by buying and selling their stable coin using a cryptocurrency (or other cryptoasset) that they themselves also issue. Whenever the price exceeds a narrow band around their target valuation they sell their stable coin using their crypto currency; whenever it falls below the band they do the reverse, purchase their stable coin using their cryptocurrency. Pauw (2018) describes essentially the same mechanism describing it as 'uncollateralized issue', mentioning the further examples of Basis and Saga. Pauw (2018) also describes a fourth mechanism that he labels 'crypto collateralised' in which there is a reserve, typically larger than the value of the issued stable coin ('overcollaterization') but consisting of cryptocurrencies or cryptoassets acquired or issued by the issuer of the stable coin. Examples are Bitshares, MakerDao and Havven. Both mechanisms can be classified as fractionally reserved issue of stable coins, i.e. they fit in our Figure 5, but represent the extreme where no fiat reserve is held at all. In our view they are all also inherently unstable, able to maintain the stable value of their coins against any loss of investor confidence only so long as there is a liquid market for and sufficient holdings the underlying assets to maintain their stable value (or backin by a sponsor wit sufficiently deep pockets to maintain their value). Eichengreen (2019) similarly criticises these various of stable coin, doubting their stability, suggesting that only fully-reserved crypto-issue of stable coins backed by fiat currency is viable. We believe that fractionally reserved issue is also possible provided it follows well-established practices of commercial bank risk management and regulation.

tocurrencies. If we define stable coin as any fully reserved fiat denominated private money (as identified in Figure 5 and 6) then stable coins have already established themselves as preferred media of exchange in East Africa (MPesa) and in China (WeChat Pay, Ali Pay).[24] This recent experience shows that stable coins can be a viable alternative to bank payments where conventional banks fail to meet customer demand for convenient rapid payment transfers and regulators are supportive.

This is not to say that the advances in transaction technologies captured in Figure 4 are unimportant. They make it possible to provide low cost and convenient direct transfer of mutual fund participations in an underlying set of assets, offering the possibility of both transactions services and income in privately issues stores of value that are relatively stable (valued in terms of underlying assets such as bonds) and do not rely as commercial bank deposits doon state regulation and state-backed deposit insurance. This possibility has long been envisaged in the monetary literature but is now more feasible from the technological perspective than ever before.[25] We envisage such forms of mutual fund based stable coin being most attractive as a transactions medium in financial market exchange between professional investors who are not protected by deposit insurance.[26] We cannot rule out the possibility of more widespread commercial and retail use.

24. Some readers may object that Mpesa and WeChat Pay are not stable coins. This a semantic issue. In terms of our Figure 5 they are stable coins. In terms of Figure 4 they are not as far to the right of the 'institutionally mediated/ crypt-mediated' continuum as the stable coins recently issued by cryptotechnology based start-ups. But economically what matters is adoption and meeting a user need not what whether they use the most advanced possible transaction technologies or avoid institutional responsibilities for processing of transfers.

25. The possibility of such privately issued money backed by real assets has a long history in the monetary literature and technological advances since the 1970s have revived interest reflected in the widely discussed proposals of Hayek for competing currencies backed by real assets F A Hayek (1978); Friedrich August Hayek (1979) and in related proposals of the 'new monetary economics' discussed in detail by Cowen and Kroszner (1994).

26. A further barrier to retail adoption of mutual fund based competing monies (apart from the protection provided by state back deposit insurance) is the willingness of households and small businesses to take the trouble to compare different forms of money and decide which to use in any particular transaction, especially when costs are unclear. Further technological developments though could make costs transparent and automate decisions about which of several competing payments media to use.

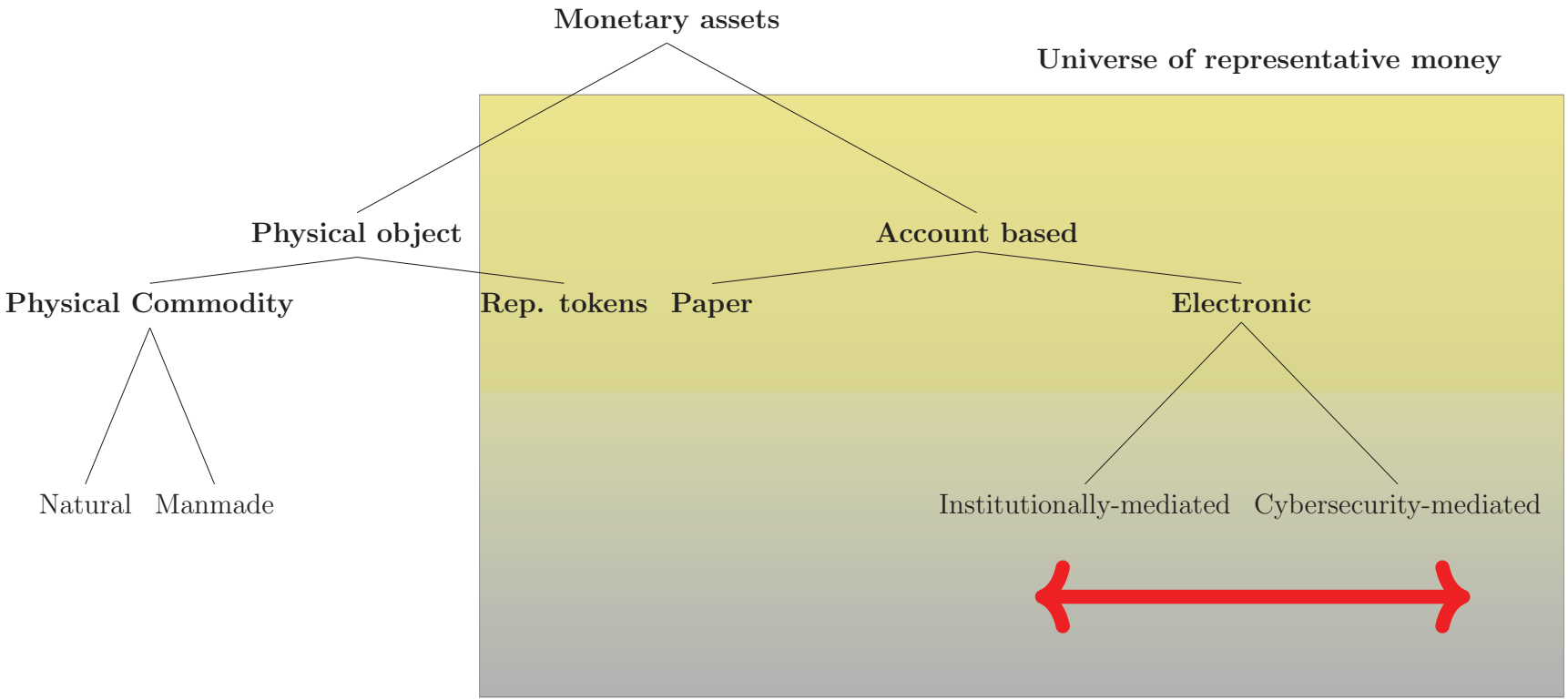

Figure 4: Mechanism, Transfer and Ownership

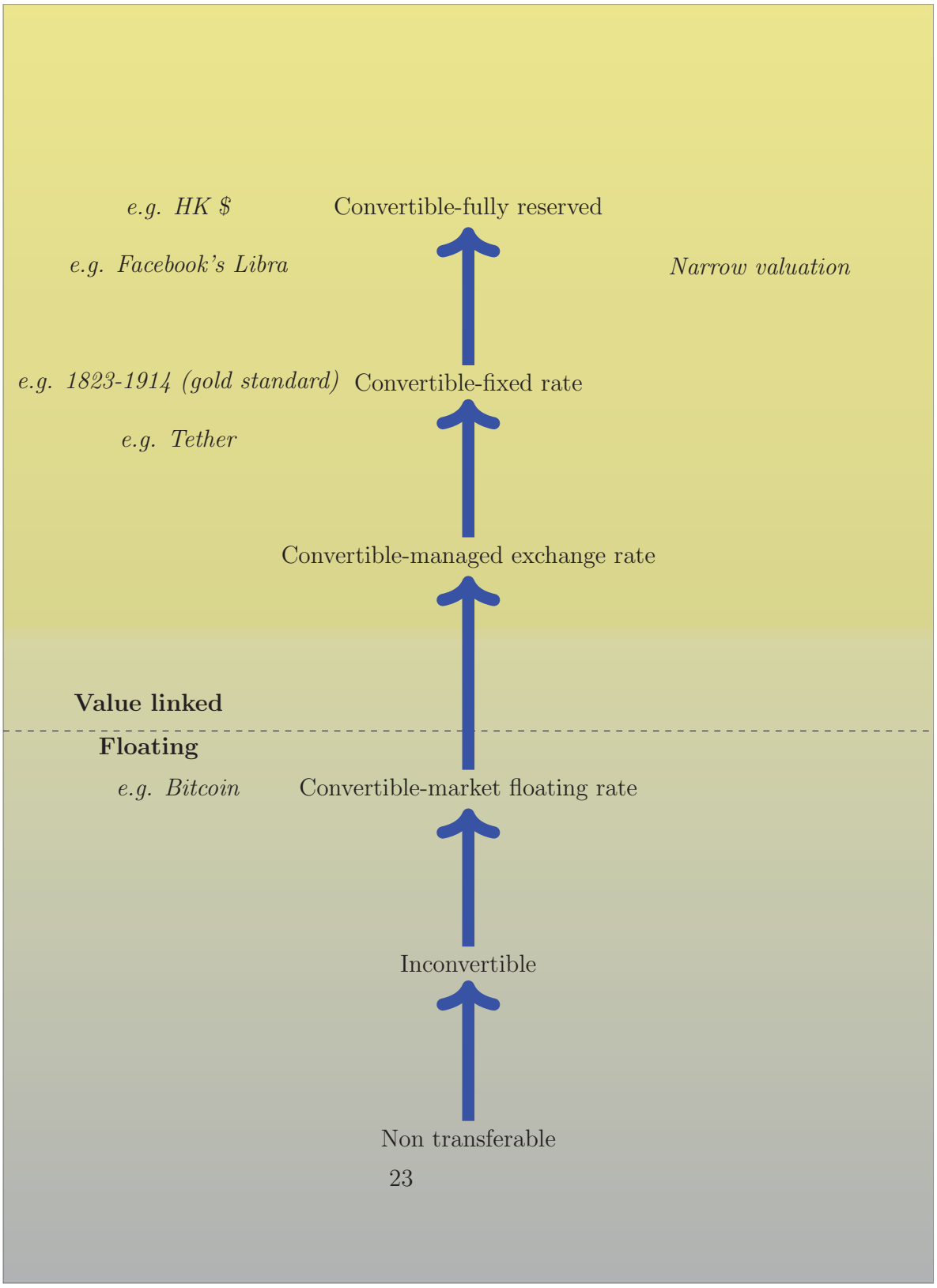

Figure 5: Valuation

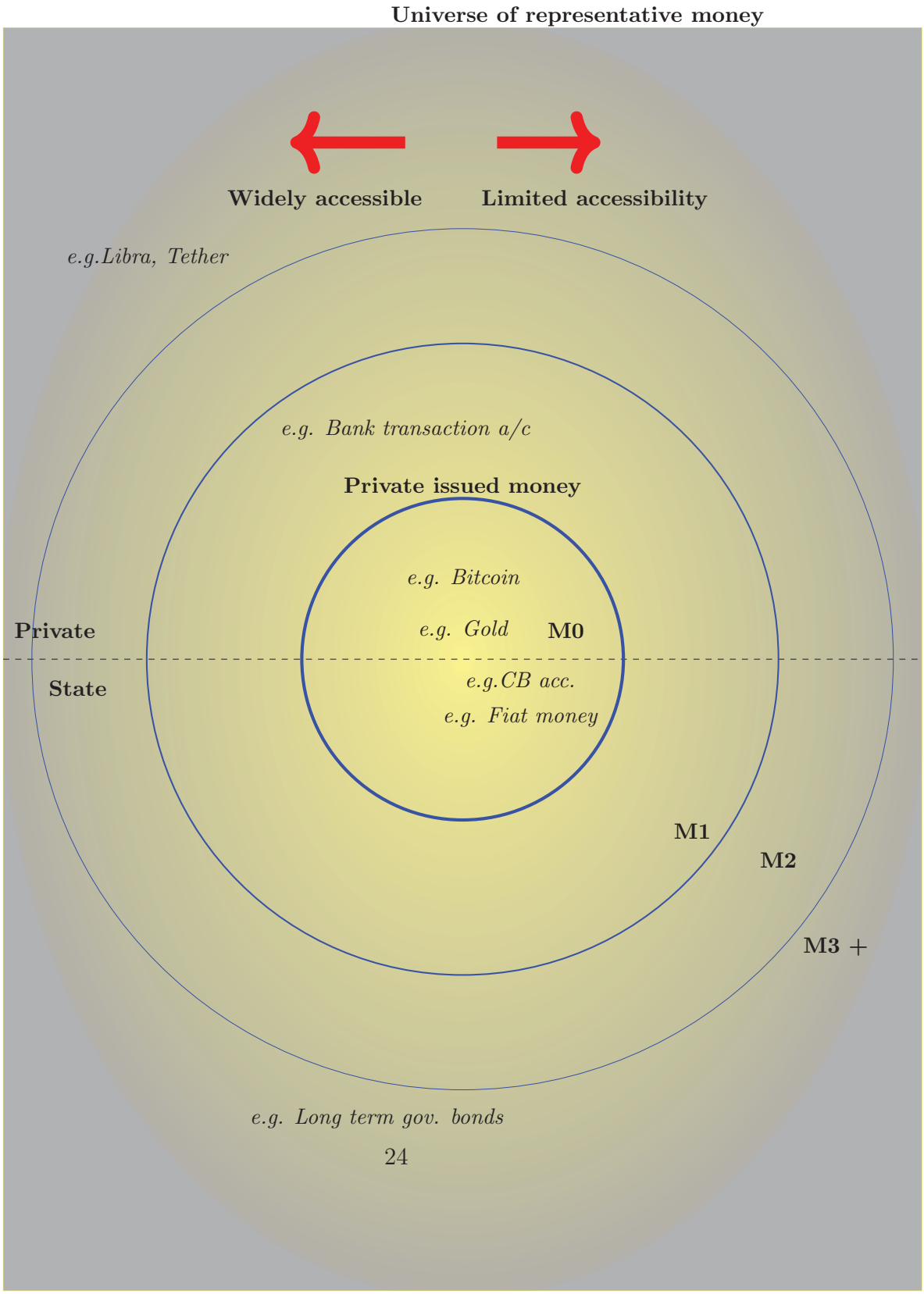

Figure 6: Issue

5 Summary and concluding discussion.

This paper builds on and extends recent efforts at visualisation of the key characteristics of new monetary technologies (CPMI (2015); Bjerg (2017); Bech and Garratt (2017); Wadsworth (2018b); Berentsen and Schar (2018b); CPMI (2018)). Our contribution is to distinguish and separately visualise two fundamental aspects of monetary assets: the supporting technologies for holding money and making transactions (in our Figure 4); and the arrangements that support the value and issue of money (in Figure 5 and 6). Like Wadsworth (2018b) but unlike other contributions, our visualisations also take account of hierarchical relationships amongst different categories of money. This concluding section summarises our findings and briefly discusses their implications, both for the future adoption of cryptocurrencies and stable coins and the adoption of their supporting technologies by commercial and central banks.

Addressing the question set in the title of our paper, our visualisations distinguish two corresponding cryptocurrency innovations. One novelty is transfers from one account to another, employing cryptographic security (a combination of public and private security keys) with minimal institutional mediation using shared software (Figure 4). Crypto currencies are located furthest to the right on a continuum represented by the two arrows (institutional-mediation/cryptographic-mediation) in this figure. This differs from the other extreme of purely institutionally-mediated intermediation, furthest to the left of these two arrows, where transfer is entirely an institutional responsibility executed after validating the payment instruction. This though is not a binary choice: in practice almost all payments arrangements lie somewhere between these two extremes, employing a combination of institution specific and shared processing arrangements to cost-effectively fulfil regulatory and customer requirements.

We anticipate that the adoption of new cryptographically secured payments and transactions technologies will over time support a further shift towards the right-hand arrow, with greater use of shared processing arrangements and an unbundling and opening to competition of the various component transaction services (confirmation of transfer instructions, updating of records, conducting any matching settlement, confirmation of final completion, supporting transaction management services). This will fall short of the complete replacement of the current transaction roles of banks and other financial institutions by shared software as has been envisaged by some cryp-

tocurrency enthusiasts.

The second and distinct cryptocurrency novelty illustrated in Figures 5 and 6 is the possibility of a privately provided currency which floats in value against other real and financial assets, without its value being undermined by overissue (the floating privately issued money). The shared software used for cryptographic currency transfers can implement an algorithm that controls total issue, for example setting an upper limit on total issue as is the case for Bitcoin or enforcing a fixed rate of growth.

Privately provided currencies are far from new. In several historical periods, discipline of the market and need to maintain reputation has successfully prevented over-issue from undermining the value of these private issued currencies. But historically the acceptance of these privately issued currencies and their acceptance in exchange depended on the promise of redemption in physical money, i.e. in terms of representation in Figure 5, they were not floating but value linked and linked to fiat currencies. Privately issued floating currencies are new.

Will widespread use of these privately issued floating crypto-currencies supplant existing fiat money? Our judgement is that they will continue to serve only niche transaction usages. They will be favoured in specific contexts where the parties to the transaction place sufficient value on privacy and lack of state oversight (or simply on the cachet of transacting in a new form of money) to be willing to accept the associated additional costs and risks of transacting in cryptocurrency. [27] We see no prospect of mainstream adoption of cryptocurrencies in salary payments, taxes, government expenditure or in retail and business to business commerce.

What insight does our visualisation offer into the regulation of cryptocurrencies?[28] Here Figure 4 is relevant. For cryptocurrencies like Bitcoin lying at the extreme of cyber-mediation of transfers without institutional mediation, the options of regulators are limited. There are simply no institutions to regulate. The main options are banning of cryptocurrency exchange altogether (the approach taken for example in China and Belgium) and, where possible, regulating the crypto-exchanges and crypto-wallets that provide services to

27. The magnitude of these costs and risks remains an open research question such research needs to measure not just the direct costs of exchange (including of validation which currently requires costly proof of work) but also the margins of moving from fiat into crypto and then from crypto to fiat.

28. A useful review of regulation of cryptocurrencies is provided by Broby and Baker (2018); Broby (2018).

holders of cryptocurrencies. We see these institutions evolving in two distinct direction: those that welcome regulation to encourage user trust; and those that shun regulation in order to serve customers who want to avoid any form of regulatory oversight.[29]

We see greater prospects for adoption of so called 'stable coins': representations of monetary value whose values are linked to fiat money or other assets. From the perspective of monetary value (Figure 5) these stable coins are not new. We believe that is it is more illuminating to use the term stable coin to refer to all such forms of fiat backed private money, whether they use cryptocurrency or more conventional transaction technologies. The choice of the supporting technology is a secondary operational decision about how to most cost effectively deliver on user requirements and policy goals. They represent the latest round in the perennial competition between fiat, private unreserved and fractionally reserved forms of money. The greater convenience offered by modern technologies can result in privately issued fully reserved transaction money supplanting of bank transactions deposits, as already happening in China and East Africa.

What about the regulation of stable coins? The lesson of our Figure 5 is that there are only two possible approaches to issuing stable coins. One is full collateralisation as in East Africa and China. The other is partial collateralisation, i.e. fractional reserving, backed by a promise to maintain the value of the fiat coin. The policy implications are clear: a stable coin that employs fractional reserving is a bank and needs to acquire a banking license and comply with banking regulations. A fully collateralized stable coin is akin to a mutual fund and can be regulated from that perspective (though arguably mutual fund regulations may need to be adapted to provide effective customer protection to funds that offer transaction as well as investment services).

Finally, what does our visualisation contribute to the extensive discussion of central bank issue of digital currencies (CBDC). Here we emphasize that the transaction technology (Figure 4), a basis of value (Figure 5) and terms of issue (Figure 6) are related but distinct choices. In past years it was simply not practically possible to allow large numbers of participants in account based exchange of central bank liabilities. [30]The development of

29. This point is developed in more detail by Kavuri and Milne (2019).

30. Historically most central banks did allow a small number of non-banks to hold accounts and make exchanges in central bank account-based money, but this was effectively a separate parallel transactgion banking service that has disappeared with the transi-

modern transaction technologies make it now possible to widen access to central bank accounts, from licensed commercial banks, extending the right to hold deposits at the central bank to other financial institutions and, possibly, to non-financial companies and households. There are two broad possibilities:

1. Widening access to central bank deposit accounts to non-bank financial institutions and possibly large corporates, allowing their participation in interbank real time gross settlement payment schemes. Such access usually referred to as 'wholesale CBDC'can promote greater cost efficiency and competition in payments services and investment management. There is broad consensus that the issue of wholesale CBDC of this kind is only a matter of time, pending the development of the necessary supporting operational systems.

2. There is less consensus on the further development of what can be labelled 'retail CBDC' allowing any person or organisation to access central bank deposits. Here the challenge of developing the supporting transaction technologies is more difficult. Mechanisms are needed to allow such deposits to be transferred rapidly, reliably and efficiently both across central banks' books from one account holder to another and also to and from conventional commercial bank transaction accounts.

While in terms of Figure 6 the issue of retail CBDC is a trivial step (the creation of an electronic version of the physical bank notes already issued by central banks) in practical terms, developing the novel arrangements for supporting transactions as identified in our Figure 4,in a variety of payments contexts is a risky and complex investment project. Practical decisions have to be made about the integration into existing bank payment schemes such as debit cards and ATM withdrawals. The need to understand the identity of account holders and ensure compliance with KYC and ALM regulations is a burden that no central bank is likely to accept. Moreover, the demand for such retail CBDC is unknown. Investment in such a project could prove to be a costly failure because of lack of demand.

One specific idea, inspired by the widespread interest in cryptocurrencies, is that central banks should issue their own central bank cryptocurrencies, denominated in fiat currency, using cryptocurrency transaction technologies,

tion from paper based cheque and giro payment systems to electronic interbank payment schemes.

allowing these to be traded on cryptocurrency exchanges and maintaining parity against their own fiat currencies by buying and selling as necessary. [31] This avoids integration into existing payment arrangements, hence reducing the investment costs involved in such a project. This is a less risky proposition than retail CBDC since there is likely to be demand to hold it from existing cryptocurrency and cryptoasset investors for use in cryptocurrency transactions.

In our judgement, though, such issue of fiat based cryptocurrency by any central bank is unlikely. This is for two reasons: first it would still be imperative to identify all holders of a central bank issued cryptocurrency for ALM and KYC purposes, so substantial administrative and investment costs would remain; second, it would not address any of the usual economic justifications for CBDC identified in our introduction, such as promoting financial inclusion or encouraging competition in financial services.

From the perspective of our visualisations in Figures 4,5 and 6, we see two further developments beyond wholesale CBDC as more likely. The first is that central banks develop a simple substitute for bank notes with limited functionality, perhaps smart card based. Discussion of such developments alongside that of related CBDC initiatives has proceeded furthest in Sweden where the rapid decline in cash usage without corresponding decline in the costs of maintaining a nationwide service for distributing and receiving cash,has prompted detailed assessment of the potential issue of an 'e-Krona' as a substitute for cash. The new transaction technologies highlighted in our Figure 4 should provide cost-effective technological support for such a cash substitute.

The other likely development is that central banks encourage or collaborate with private sector issue of fiat-based stable coins (stable coins here are broadly defined as we prefer to include any form of fully reserved private transaction assets i.e. anything that is fully reserved in terms of our Figure 6). We anticipate that a number of central banks will build on the successful adoption of stable coins in East Africa and China and encouraging similar developments in their own jurisdictions with partial or full integration into existing interbank payment schemes (so holders should be able to withdraw at ATMs, use for debit card payments online or at point of sale, as well as for initiating mobile and online payments to other holders of stable coins and to conventional commercial bank accounts). The extent to which such

31. This idea seems to have originated with JP Koning (2014); J Koning (2016).

new forms of money use cryptocurrency transaction technologies and shared processing arrangements is a practical question determined by the commercial costs and benefits of so doing and the willingness of different institutions to collaborate together on providing improved customer solutions. Whether such private issue will be commercially viable in all jurisdictions remains as yet unclear.

Our visualisations offer less insight into the other major issues discussed in the recent debates on CBDC: the implications for financial stability, fiscal policy and monetary transmission (or the related questions prominent in the monetary literature of the appropriate roles of the state and private sector in providing monetary transaction mechanisms and stores of value). Some argue that the declining use of cash and its replacement with electronic deposits held with the central bank will remove constraints on monetary policy, effectively abolishing the effective lower bound on nominal interest rates because there will be no other alternative to holding account based central or commercial bank money. Others anticipate that substantial non-bank demand for holding monetary deposits directly with central banks will provide a major new source of fiscal financing and ease government budget constraints. A few envisage that cryptocurrency technologies could be used to shift to a system of fully reserved banking for all payment transactions, hence enhancing financial stability. [32]These issues all go well beyond the scope of what we can address in the visualisations of this paper, distinguishing and highlighting the variety of monetary transaction technologies (Figure 4), arrangements underpinning monetary value (Figure 5) and the issuance of representative money (Figure 6).

32. One of the present authors explores this possibility in Milne (2017); Milne (2018).

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