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Introduction

In November 2018, the Asian Bureau of Finance and Economic Research (ABFER), the Economic Policy Group (EPG) of the Monetary Authority of Singapore (MAS), and the National University of Singapore (NUS) Business School co-organised a two-day workshop to explore the economics of digital currencies and their implications for monetary and financial regulatory policies. Leading academic researchers in monetary and financial economics were invited to speak at the workshop, which attracted a large number of participants, including central bankers, academics, and practitioners in the financial industry.[2] This document distils the key insights generated by the two days of enriching conversations and provides a summary of the authors' and discussants' presentations.

The advent of the distributed ledger technology has facilitated the development of private digital currencies. To appreciate what is new, we need to remind ourselves of the past.

Electronic transaction record keeping has been around for decades and has evolved into convenient payment systems, e.g., telegraphic clearings and transfers, credit card payments, and e-wallets. So far, these systems have been denominated in fiat currencies, each with a controller who enforces compliance with regulations and protocols on permitted member-users to affirm that all entries are credible and valid, i.e., mitigating fraudulent behaviour or double spending. In each system the controller, or an assigned

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[2] The speakers and discussants at the workshop were Franklin Allen (Imperial College London), Robleh Ali (MIT), Markus Brunnermeier (Princeton University), Barry Eichengreen (University of California, Berkeley), Charles Engel (University of Wisconsin-Madison), Gur Huberman (Columbia University), Randall Morck (University of Alberta), Danny Quah (NUS), Kenneth Rogoff (Harvard University), Andrew Rose (University of California, Berkeley), Prateek Saxena (NUS), Beatrice Weder di Mauro (INSEAD Singapore), David Yermack (New York University) and Bernard Yeung (NUS Business School). Materials from the workshop are available at the ABFER website.

operator, maintains a centralized ledger to keep track of transactions, attains correctness (and thus user trust), and strives for internal cost efficiency in administering the system. However, the cost efficiencies result in significant economies of scale which could deter entry even while the controlling party seeks to exploit the rents.

The distributed ledger technology, on the contrary, does not have a centralized controller. Instead, its built-in regulations and protocols lead to the distribution of all records, time stamped, to all users. The decentralized system allows all users to investigate and verify the integrity of the ledger.[3] Furthermore, this "trust-no-human but just the technology" system does not have to be denominated in any fiat currency. In other words, the system's technology uses intrinsic regulations and protocols to ascertain ***correctness***, allows free entrants and ***decentralized*** record keeping, and its unit of account can be itself, e.g., Bitcoin. In contrast, a centralized system is backed up by a controlling entity and often rested on fiat money which is issued by a monetary authority with mandates specified by the state. However, an open distributed ledger backed system, thus far, incurs substantial operation ***costs*** due to the computational requirements to verify that each entry follows the protocols.

The creation of private digital currencies leads to many fundamental questions. The discussions during the two-day conference focused on: (i) whether private digital currencies can be considered "money" and their impact on monetary policy and the international monetary system; (ii) whether central banks would issue their own digital currencies and the impact of such actions; and (iii) the usage of the distributed ledger technology in the financial system.

II. Private digital currencies as money and their impact on monetary policy and international monetary system

Present day monetary systems are already mostly digital with a trusted third party keeping track of transactions on a centralized ledger. These transactions involve customer deposits held with commercial banks, and bank reserves held by commercial banks with the central bank. The latter, together with cash

[3] A distributed ledger may be permission free or permission based. In the case of Bitcoin, the distributed ledger is open; an entrant just needs to run the software necessary to conform to the protocol (e.g., to mine a Bitcoin). Currently, some applications of the distributed ledger technology impose a permission requirement.

in circulation, forms the monetary base which is the basis for money creation by commercial banks through lending (and deposit) activities.

As described above, the distributed ledger-based system allows the development of a unit of account and possibly a medium of transaction by-passing any centralized third party, including the government. Naturally, one would question whether this technology-driven digital entity truly constitutes money and how its introduction would impact the monetary system and policy. Currently, private digital currencies, even in aggregate, are fairly insignificant, and they cannot yet be money for a number of reasons.

First, there is an efficiency consideration. Historically, there has been a tendency for currency and coin issuance to be increasingly concentrated in the hands of the central government. Using a uniform stable currency enhances informational efficiency; in contrast, having multiple currencies increases the costs of acquiring information on relative prices and on the credibility of each of the different currency issuers. Currently, high volatility in the prices of private digital currencies impedes their ability to serve as a unit of account and medium of transaction, although a limited few could serve as a store of value.

Second, stable money, serving as a unit of account and medium of transaction, including for taxation and redistribution purposes, is a public good that is too important to be left to a decentralized system. Moreover, publicly-used money needs to be managed to secure price and financial stability, and counter business cycles. Currently, it is not clear if private digital currencies can be algorithmically designed to carry out these functions. Price and financial stability is a public good, justifying governments' historical concern with retaining control over monetary management.

Third, there is an issue of mitigating socially undesirable behavior. Private digital currencies allow for anonymous transactions, many of which may arise from socially undesirable or illegal activities. A government may then have to limit the proliferation of private digital currencies which allow anonymous transactions. A state can reduce the liquidity of private digital currencies simply by prohibiting their conversion into legalised currencies. Indeed, if governments can cooperate internationally to make all private digital currencies non-convertible, they can drastically reduce their use in tax evasion and other illegal transactions.

The original motive for developing private digital currencies, e.g., Bitcoin, may include weakening the government's monopoly on seigniorage, but the world's monetary authorities have been successful in

keeping prices stable, except in a few countries with political instability or a high level of corruption[4]. Internationally, stable fiat currencies can serve as substitutes to unstable currencies and thus constrain a government's ability to impose a high inflation tax. Finally, while the development of private digital currencies may stem from some people's desire to be independent of centralized control in transactions, this conflicts with the public's preference for stable money.

In summary, the likelihood of private digital currencies, as currently designed, replacing national currencies is likely to be limited at this point. Given that the share of overall transactions involving private digital currencies also remains relatively small, their effects on monetary policies or the international monetary system are also likely to be insignificant at present, aside from possibly helping to loosen somewhat the effects of capital controls. Last but not least, one should be cautious in using private digital currencies as investment and retirement products because they are unregulated and may not be backed by any underlying asset.

III. Central Bank Digital Currency

Central banks may opt to issue their own digital currency, which is referred to as a Central Bank Digital Currency (CBDC). It can be made accessible throughout the economy or only at the wholesale level. In a 2018 survey of central banks, 69% said they were studying the implications of introducing a CBDC. However, central banks are generally cautious and not many are currently committed to the actual issuance of CBDCs.[5] There are both positive and negative considerations associated with the issuance of a CBDC.

The positive considerations stem from the fact that CBDC accounts provide a useful source of economic data and facilitate effective and flexible monetary policy.

First, CBDC transactions contain detailed microeconomic data and thus convey information on economic trends that may be used to inform monetary policy.

[4] Currently high inflation countries include Venezuela, Zimbabwe, South Sudan, North Korea, Argentina, Iran, Sudan, Liberia, Haiti, Sierra Leone, Angola, Ethiopia, Turkey, Uzbekistan, and Nigeria ranging from 282,973% to 11%.

[5] See slides 6 and 8 of Dr. Agustín Carstens's powerpoint presentation during the workshop. These slides indicate that the numbers are drawn from BIS's Committee on Payments and Market Infrastructure central bank survey on CBDC and digital tokens. (Dr. Agustín Carstens is General Manager, Bank for International Settlements.)

Second, a CBDC can strengthen monetary policy transmission mechanisms, especially if every citizen has a CBDC account. As funds can move expediently between CDBC and bank accounts, banks have to offer deposit rates closely tied with the CBDC interest rate, leading to more immediate monetary policy transmission. A central bank can even perform targeted money creation to stimulate aggregate demand in specific segments of the economy.

Third, CBDC can result in more flexible monetary policy: if cash is abolished, a central bank will then be able to impose negative interest rates on CBDC.

Fourth, CBDC accounts, if made widely accessible, can improve financial inclusion.

However, we do have to be aware that these latter uses of CBDC blur the boundaries between monetary and fiscal policies, including redistribution policy.

Meanwhile, the negative considerations stem from the structural impact that the creation of CBDC may have on the country's financial system.

First, through a CBDC, citizens can hold deposits at the central bank, which raises the number of digital transactions performed at the central bank. This creates concentrated operation risks (e.g., exposure to relentless hacking) and calls for system back-ups in a geographically diverse manner.

Second, central banks would have to absorb the responsibility of "knowing your clients"; that is, safeguarding against money laundering and similar illegal transactions becomes a direct central bank responsibility.

Third, demand for safe assets may lead to depositors reallocating funds from commercial bank deposits to CBDC, eventually leading to what resembles a "narrow banking" system where CBDC becomes "narrow" money. Also, the digital system facilitates savers' fund movements between private sector banks and the central bank. Banks will have to directly source deposits from the central bank or to offer deposit rates very close to the CBDC deposit rate. Further, the system raises the efficiency of fund transmission but reduces banks' potential payment intermediation income. How these changes will impact commercial banks' risk-taking behaviour is unclear. However, the view is that there will be rapid "runs" whenever a bank shows signs of weakness. While this may (or may not) make individual banks more risk-averse, system-wide financial stability may be weakened. A central bank can provide deposits

to commercial banks to safeguard adverse spillovers, but this potentially increases the prominence of the central bank's role as lender of last resort and gives rise to increased concerns over moral hazard in the commercial banking system.

Fourth, as the potential dominance of the central bank in the payments system could negatively impact banks' and big tech companies' potential earnings from managing payments, there may be strong resistant to the creation of an open CBDC.

These positive and negative considerations clearly justify central banks' exhaustive ongoing work on understanding and exploring CBDCs and the related technology.

IV. The usage of the distributed ledger technology in the financial system

Undeniably, the distributed ledger technology (DLT) that underlies many new private digital currencies could potentially lead to revolutionary changes in the financial system.

A distributed ledger (DL) system is more transparent, auditable and resilient than a centralized ledger system. The DL system records transactions or contracts in a decentralized manner across different locations and people, with each record being time stamped. Hence, the full transaction history is visible to anyone. The open records' reliability and accuracy rest ***not*** on the capability and integrity of a central authority. Rather, information is typically etched on the decentralised ledger using cryptography and can be modified only using keys and cryptographic signatures. The resultant database is harder to modify and more resistant to cyber-attacks than centralized ledgers (because all the distributed copies need to be attacked simultaneously).

Earlier generations of DLT tended to be slow in processing transactions and costly to operate and were thus not very scalable. For example, Bitcoin is based on a type of distributed ledger technology known as the blockchain – a sequence of chained blocks. Acquiring the proof of work to become a part of the chain greatly slows down operation and raises costs. Other decentralised ledgers have resorted to restricting access to only a subset of permissioned users; this prevents fraudulent changes to the ledger while reducing the costs of processing transactions. Indeed, some business-to-business transactions have

begun using private permission-based blockchain systems, leading to more efficient and scalable distributed ledger record keeping.[6]

The resilience, auditability and scalability properties together have led to efficiency enhancing applications in Singapore's financial system. "Project Ubin" allows MAS to offer a central bank digital Singapore dollar on a distributed ledger platform for inter-bank transactions. The platform allows for decentralized netting of payments but preserves privacy, allows tokenization of physical assets, and results in improvements to efficiency, cost, speed and risk management in cross border transactions.[7] Such systems can be extended to increase the efficiency and security of DLT-based payments systems. Likewise, the distributed ledger technology can be expanded to raise efficiency and speed in currently cumbersome trade financing arrangements. Many big-tech companies in Asia and the US are developing such systems, e.g., Libra, that save on payment intermediation costs and expand clients' choices.

Besides the application to payments, DLT has also been increasingly harnessed for another key function of the financial system – borrowing and lending services. However, both regulators and investors need to exercise caution. For example, as discussed in the workshop, ICOs allow firms to borrow by issuing coins which can then be traded on cryptocurrency exchanges. This enables firms to raise funds from international investors without having to meet local legal standards of issuing debt or equity. However, the lack of regulatory oversight has led to relatively high instances of scams among ICOs. There is a need to regulate ICOs to ensure that only qualified investors can participate in them. Yet, even seasoned investors need to have the right skills in computer science, law and finance to invest in ICOs.

V. Taking Stock

The discussions in the workshop were useful in clarifying the manner in which private digital currencies could prove destabilising. While the jury is still out on this, current private digital currencies do not carry out significant roles as a unit of account and a medium of payment, and are a relatively small asset class at this point. At present, they therefore have a negligible impact on monetary policy and the international

[6] See Ali, Robleh, (2019). "Cellular Structure for a Digital Fiat Currency," MIT Digital Currency Initiative, paper presented at the workshop.

[7] This project is the collaboration between MAS, the Singapore Exchange, banks, technology companies, and academic institutions. At a later stage, Project Ubin was linked with Project Jasper of the Bank of Canada.

monetary system. However, they may slightly boost international payment flows, and can facilitate the conduct of anonymous transactions, some of which could stem from illegal activities.

The participants also provided a framework to evaluate the prospects of CBDC. A monetary system with CBDC implies a greater degree of movements of deposit funds between CBDC accounts and deposit accounts. It raises the effectiveness of monetary policy as the CBDC interest rate and bank deposit rates will be closely tied because they are close substitutes. If cash is eliminated, central banks can even implement negative interest rate policies. Data from CDBC accounts will also give the central bank potentially valuable information about the economy. Yet, CBDC's potential impact on the structure of a financial system deserves a high level of attention. CBDC deposits may displace traditional bank deposits and may also become narrow money, with the central bank becoming fund provider for commercial sector financial intermediation. Fluid movements of funds between CBDC accounts and bank deposit accounts may increase financial institutions' exposures to runs. Banks may reduce their risk-taking but the overall impact on financial stability is unclear. Clearly, a central bank will have to be more vigilant in safeguarding financial stability and against banks' moral hazard behavior. Finally, concentrating transactions at the CBDC level may create significant operation risk at the central bank.

Finally, the workshop provided greater clarity on the usage of the distributed ledger technology in the financial system. Innovative applications of distributed ledger technology, particularly those that economize on operation cost, can be efficient, resilient and scalable. The key is that the technology, given its distributed record keeping, is more resilient to cyberattacks than centralized record keeping and the "intrinsic to technology" user rules and regulations allow for greater user trust. These innovations have the potential to increase efficiency for within and cross border payments, trade financing, and the like, all of which reduce the reliance of centralized control and transform current practices.

VI. A summary of the presentations and discussions

The following is a summary of the presentations and discussions in the workshop.

Mr. Edward Robinson, DMD and Chief Economist, MAS, gave the opening remarks. He pointed out that electronic money and payment systems are not new, with the US Federal Reserve making telegraphic transfers in the 1910s and credit card payments beginning in the 1950s. These innovations have made

payments more efficient but have not impacted the monopoly of fiat monies. Supply of private digital currencies, enabled by encryption technology, first appeared around 2008. While this has increased over the years, their share of transactions is currently still limited. A fundamental understanding of the demand side and the underlying technology is called for. In a global environment where central banks have generally managed to keep inflation in check, the demand for private digital currencies does not seem to be driven by the need to mitigate seigniorage. Rather, Mr. Robinson noted that private digital currencies cater to the demand for increased anonymity and privacy in transactions. Nevertheless, such anonymity may also facilitate transactions stemming from illegal activities. Furthermore, the advance of the technology may have other effects on the payments and financial systems. Thus, the distributed-ledger technology behind digital currencies may be a supply-driven innovation shock. He also pointed out that the privilege of currency issuance brings with it an enormous responsibility – in safeguarding the integrity of a country's supply of money.

With these and many other important questions in the minds of academics, practitioners and policymakers, Mr. Robinson encouraged a vigorous intellectual discourse on digital currency based on established paradigms in economics and finance, in order to develop an internally consistent narrative on this fast-moving development. With this objective in mind, MAS, ABFER and NUS collaborated to organize this workshop, gathering globally renowned experts to discuss the implications of new digital currencies from a range of perspectives, including the history of currencies, monetary theory and policy, financial structures, and technological developments in DLT.

In his Keynote speech, ***Professor Rogoff of the Harvard Kennedy School***, drew the audience's attention to two issues: digital currencies as a form of money and the implications of using the technology underlying it. He highlighted several important policy concerns.

Private digital currencies allow anonymity in their use. Yet, Prof Rogoff argued that functions such as the unit of account, the medium for final clearing of transactions among financial institutions, and especially the payment of taxes and transfers are simply too vital for modern-day countries to leave in the hands of a decentralized private sector system. He argued that, "The long history of currency innovation teaches us that the private sector innovates, but in due time the government regulates and appropriates. The same will eventually be true for innovations in digital currencies. … Indeed, governments will surely in due time have the capacity to issue secure digital currencies." He believed that trusted party "permissioned" systems will almost surely dominate "permission-less systems" in which private digital currencies reside.

The main issue with central bank digital currencies is disintermediation, similar to having only narrow banks**.**

Prof. Rogoff explained that, as a technological innovation, blockchain has a vast number of actual and potential applications outside the payments system, ranging from providing faster and better ways to have digital signatures to providing a completely different means for social networking. In terms of applications to payments system, the technology can provide cheaper, faster, and more secure payment rails, reducing the monopoly and related profits captured by credit and debit card clearing systems. Central banks have been perfectly content to allow the development of superior transactions technologies while keeping a watchful eye on price and financial stability. They will also put a significant premium on regulating anonymity. The important regulatory tradeoff is between unleashing the technology's potential for improving efficiency versus safeguarding the security and stability of the financial system.

Prof. Barry Eichengreen of UC Berkeley delivered the first workshop paper, ***"From Commodity to Fiat and Now to Crypto: What Does History Tell us?"***. His presentation focused on: (i) providing an historical perspective on the evolution of currency; (ii) using historical records to provide an analysis of stable coins, and; (iii) analyzing the cases for and against central bank digital currency.

History has shown a tendency for currency and coin issuance to be increasingly *concentrated* in the hands of the central or federal government. There are two explanations. First, from the earlier days when the modern state system emerged till the end of the 18th Century, central governments needed to wield control over currency creation (and seigniorage) in order to mobilize resources for national defense and in case of emergencies. Second, with the evolution of modern financial systems since the 19th Century, government monopoly of money issuance, either *de facto* or *de jure*, rests on the economic efficiency of a currency that is both uniform (because there is only one issuer) and stable (because it is issued in economically appropriate amounts, for example, by an independent central bank with a politically-assigned mandate to pursue price stability). A uniform currency reduces information costs because utilizing a reliable issuer's currency makes it unnecessary to have information about the creditworthiness of each and every issuer. By the same token, the digital payment services provided by Visa and Mastercard are attractive because they are information insensitive: the credit card companies protect sellers from buyers' default risk and a dollar on a credit card is convertible into a dollar one-to-one. This consideration implies that the costs of producing and obtaining information about changes in the actual and prospective value of privately issued digital currencies is an obstacle to their wider utilization.

Prof. Eichengreen pointed out that stable coins can be classified into four categories: fiat fully collateralized, crypto collateralized, partially collateralized and uncollateralized. The information efficiency consideration suggests that the first three are all inferior to a central bank cryptocurrency. For example, information asymmetry (between providers of a stable coin and coin-holders) on the value of collateral can lead to wild fluctuations of a coin's market price, speculative "runs," and huge costs and risks (on the part of the providers) to stabilize coin value. Unlike central banks, a stable coin provider cannot stipulate exchange controls (i.e., capital controls) against runs. Similarly, if they reduce the ratio of stable coin to collateral (when depleted by runs), they undermine the basis of the stable coin. The concept of uncollateralized stable coin appears to be underdeveloped, and Prof. Eichengreen noted, "It is not clear whether the architects of uncollateralized stable coins are conversant in that literature (on speculative attacks on pegged exchange rates)."

According to Prof. Eichengreen, over ninety central banks are exploring the possibility of issuing their own digital currencies, which can take the form of electronic accounts at the central bank. A central bank's digital unit could also circulate in a distributed fashion (held in mobile wallets or on electronic smart cards). The usage could be for wholesale payments only, or it could be extended to other forms of transactions.

Prof. Eichengreen described both negative and positive considerations. First, concentrating all digital currency transactions at the central bank would also concentrate operational risk. Second, CDBCs could induce runs on traditional banks as the public would be able to transfer their deposits at the push of a button. Limiting overall deposit size at the central bank would create a premium on central bank accounts, re-introducing the complexity of non-uniform currencies. Third, a central bank-based digital currency can generate more information for the monetary authority and make monetary policy more direct and effective – central banks can influence market interest rates more effectively and can set the policy interest rate below the zero lower bound; they can even provide targeted helicopter money to specific groups.

Prof. Eichengreen concluded that there is strong economic justification for a uniform digital currency and the national government is the only entity capable of credibly providing for it on a national scale. However, depending on further technological developments, the jury is still out on whether private digital currencies will be adopted more widely.

Prof. Randall Morck (University of Alberta), agreed with Prof. Eichengreen's inferences on the historical experience. He pointed out that the tension between competing versus monopolistic money creation existed at the beginning of written history: ancient Egyptians used competing moneys – metals by weight, oils and grains by volume (Janssen 1975)[8]. Private digital currencies so far have not served as an effective medium of exchange, unit of account and store of value because as Prof. Eichengreen explained, they incur high costs and are broadly inferior to fiat money in all three roles. Blockchain allegedly provides anonymity that may compensate for the costs; but at present, it largely facilitates illegal transactions: a study reveals that up to 70% of Bitcoin holdings and up to 60% of Bitcoin transactions are illegal (Foley et al. 2019)[9]. Furthermore, the energy requirements for maintaining the Bitcoin ledger restrict its scalability. Bitcoin mining already uses enough electricity to power Austria (Krause and Tolaymat 2018) and the environmental cost will only rise if Bitcoin is more widely used.[10]

Prof. Morck concurred with Prof. Eichengreen that central bank digital currencies have their advantages. First, a CBDC would allow central banks to run more effective and direct monetary policy. Currently, central banks stimulate the economy by creating money to buy treasury securities, increasing their prices, lowering debt yields and bank interest rates, so as to encourage borrowing and stimulate aggregate demand. If everyone had a CBDC account, a recession-fighting central bank could directly inject new money into the accounts of low-income people who have higher marginal propensities to consume. Second, CBDC can eliminate the roughly 3% overhead costs in credit card payments or check clearing. The Bank of Canada has successfully tested such a system for buying and selling goods, stocks, and foreign exchange. The trade-off is the cost in building geographically separated backup computers to safeguard against operation risk. Prof. Morck raised the point that commercial banks, credit card companies, securities brokers, stock exchanges, and providers of all manner of back-office settlement services would lobby intensely to prevent such efficiency (Duffie 2019)[11], while Big Finance is also a formidable foe (Johnson and Kwak 2010).[12]

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[8] Janssen, Jozef. 1975. *Commodity Prices from the Ramessid Period: An economic study of the village of necropolis workmen at Thebes*. Brill.

[9] Foley, Sean, Jonathan R. Karlsen & Tālis J. Putniņš. 2019. Sex, drugs, and bitcoin: How much illegal activity is financed through cryptocurrencies? *Review of Financial Studies* 32(5)1798-1853.

[10] Krause, Max & Thabet Tolaymat. 2018. Quantification of energy and carbon costs for mining cryptocurrencies. *Nature Sustainability* 1, 711–718

[11] Duffie, Darrell. 2019. Digital Currencies and Fast Payment Systems: Disruption is Coming." Unpublished manuscript, Stanford University.

[12] Johnson, Simon, and James Kwak. 2010. *13 bankers: The Wall Street takeover and the next financial meltdown*. Vintage

Prof. Markus Brunnermeier, Princeton University, presented his thinking (based on his joint work with ***Dr. Dirk Niepelt*** of Study Center Gerzensee and University of Bern) on ***"the co-existence of private digital currencies and central bank currencies."*** Private sector digital currencies are based on decentralized record keeping while a central bank issued digital currency is based on centralized record keeping. The decentralized approach has rigorous competition in validating an entry, but the proof of work consumes huge energy and effort. (The economic gain to taking stock of records and creating a fake entry can be huge.) In the centralized approach, entries are validated by the issuer which is cost-efficient. However, the issuer can over time be tempted to change the digital currency's value (seigniorage). Prof. Brunnermeier termed the three considerations – degree of centralization, correctness, and cost efficiency – *a digital currency trilemma*. Private digital currencies and central bank digital currency can achieve only two, but not all three, considerations.

Prof. Brunnermeier clarified some important characteristics of CBDCs. CBDCs, if available to all residents, can displace deposits. A concern is whether this triggers runs on banks and disrupts investments. Prof. Brunnermeier pointed out that CBDC is fundamentally equivalent to narrow money and has been proposed both in Continental Europe (Vollgeld) and the US (Chicago plan). First, a central bank can still provide deposits to banks for intermediation. Thus, CDBC would not affect private sector banks' access to deposits and should not reduce private sector investment. Second, while CBDC allows speedy transfer of deposits from banks to a central bank, the same central bank can equally speedily provide liquidity to banks at risk of a run. Third, while widespread reallocation of bank deposits into CBDC can erode bank profits, banks can be compensated if it is deemed desirable by the public.

Prof. Danny Quah, Dean of LKYSPP at NUS, focused his comments on the potential implications of greater utilization of digital payments platforms in general, rather than addressing DLT. First, he posited that greater utilization of digital payments may lead to information management issues. Digitization in means of payment and store of value calls for strong cyber-security protection. At the same time, there could be tension between the rights to privacy and anonymity vs authorities' rights to know for legitimate purposes and for public policy formation purposes. Digital means also lower information and access barriers, potentially raising financial inclusivity, e.g., in poor rural areas. Data integration can lead to effective dashboards that lower transaction costs, e.g., in matching buyers and sellers, and predictive rather than reactive public policy making. He thought that building trust is a challenge to all of these exciting viable developments but that legal systems are currently ill-equipped to manage the widespread

adoption of digital payments. He suggested that the answer may be a private-public partnership on digital currency provision, rather than competition, to alleviate concerns.

Prof. Charles Engel (U of Wisconsin Madison) considered ***"Implications of digital currency on the international monetary system and monetary policy,"*** conditional on private digital currencies becoming viable and established, even though many uncertainties remain.

Prof. Engel pointed out that anonymity of private digital currencies makes it much easier to evade capital flows management policies. The "traditional" view of economists (and the IMF) is that free capital flows is desirable for efficiency considerations, and that capital controls are costly to enforce and induce corruption. However, there are situations in which the ability to monitor and manage capital flows is desirable: (i) to stop transactions stemming from illegal activities from crossing borders; (ii) when individual investors do not internalize the externality in home investment; and (iii) when incomplete information can lead to undesirable mismatch in currency exposures of assets and liabilities and in term structure, and may even lead to bubbles. Indeed, countries need to have measures to mitigate volatility in exchange rates or capital flows to maintain price and financial system stability. While preference for anonymity may motivate the development of private digital currencies, the contribution of anonymity to social welfare is questionable.

Prof. Engel believed that private digital currencies are unlikely to replace government currencies for well-managed economies, whose central banks have been successful in maintaining price stability. However, they can be a disciplining force on governments motivated by seigniorage, just like dollarization, or like currency substitution in which unreliable home currencies will be substituted by other currencies or even commodities.

Still, private digital currencies would only present a marginal immediate "threat" to monetary policy and the international financial system, except for facilitating the evasion of capital controls. The challenges for the future depend completely on how the role of digital currencies evolves: how widely they are used in transactions and are held as reserves.

A central bank digital currency, if developed and available to the public, has implications for monetary policy. Prof. Engel's starting point is that central bank digital currency is the ultimate safe asset, for its default risk is lower than bank deposits and its transaction and handling costs are lower than Treasury bills. This leads to two considerations.

First, commercial banks may be concerned about losing deposits. They still have a role in maturity transformation. However, their funding will become more expensive and lending cost will rise. A suggestion is that a central bank can provide funding to commercial banks, but that raises the need for vigilant regulators to safeguard against moral hazard problems.

Second, Prof. Engel raised a conjecture that a reliable central bank's digital currency is a safe asset and an economy may then in aggregate adjust its portfolio towards this safe asset. Greater holdings of this safe asset may encourage more lending and borrowing in local currency. Correspondingly, there will also be less of a need to invoice trade in the US dollar. This may mitigate the international financial system's strong reliance on the US dollar.

Prof. Andrew Rose (U C Berkeley, Dean NUS Business School 2019) agreed with the main conclusion that private sector digital currencies would have little immediate effect on monetary policy or the international monetary system, except that they facilitate the loosening of capital controls. He added that electronic payment arrangements are already quite prevalent so that "money" is mostly digital, but these technological innovations have not compromised the effectiveness of monetary policy. However, the potential of digital currency to increase capital mobility over time may make the choice between fixed exchange rate and monetary sovereignty sharper.

Prof. Rose commented that private digital currencies, even in aggregate, are fairly small: the total stock of them is less than 2% of worldwide currency and less than 4% of daily foreign exchange transactions. Because of the volatility stemming from their inelastic supply, private digital currencies do not meet the requirements of being money: a medium of exchange, unit of account and store of value. If the objective of creating a private digital currency is to discipline the central bank's monopoly on money supply, most digital currencies fail. More fundamentally, it is not clear if private (decentralized) digital currencies can be algorithmically designed to stabilize prices, counter business cycles and serve as a lender of last resort, all of which are currently functions residing with the monetary authority.

Prof. Rose argued that a central bank digital currency can indeed give a monetary authority the flexibility to offer negative interest rates. A central bank, however, needs to safeguard against hacking and create its own KYC (know your client) protocols and risks substituting practices for commercial banks' deposits. He further pointed out that with or without a central bank digital currency, the monetary authority's policy

assignment remains: a society gives its central bank power and independence in return for price and financial stability.

Mr. Robleh Ali (Digital Currency Initiative, MIT Media Lab) gave a presentation based on his work, "***The Structure of Digital Fiat Currencies***." He suggested that a digital fiat currency, either issued by a central bank or by a private entity, can be provided to the financial system in the future to reduce entry barriers and improve efficiency. Currently, payment systems comprise an operator running the system and members providing services to end-users. This ***centralized*** control of systems deters competing entrants. The control's core function is to prevent double spending (***correctness***), which is accomplished by having well-enforced contractual obligations and regulations extrinsic to technology. To enforce, only trusted new entrants are granted permission to join and there will be heavy penalties if rules are not followed.

Bitcoin, using distributed ledger technology, makes rules and enforcement intrinsic to technology. It is a ***decentralized*** system that solves the no double payment problem without the need to screen and monitor trusted participants. The system rejects any transaction that does not follow its rules. Indeed, all participants inside a Bitcoin system have to ***validate*** a record ***(confirm correctness)***. However, the only requirement for a participant to join the system is running the software necessary to conform to the protocol: it is largely an open system, the integrity of which is based on the system's intrinsic rules and protocol. The distinction between the controlled system and the open system is the extrinsic trust requirement in the former; the higher the requirement, the higher the entry barrier.

Mr. Ali proposed an intermediate system that addresses some of the problems associated with Bitcoin's completely decentralised ledger structure, while retaining some features of distributed ledger technology that allow for greater security and privacy for users relative to the centralised ledgers in the status quo. Essentially, the proposed system is built up from multiple different ledgers recording transactions for the same fiat currency. Each ledger (cell) in the system has its own issuer which holds central bank money equal to the amount of digital fiat currency issued in the cell. This 100 percent backing is vastly different from Bitcoin which has zero backing. In addition to the backing, the issuer is responsible for the software and protocol used to make transactions within its own cell. The cell will also have validators recording and updating copies of its transaction ledger. The validators can use Cryptokernel (a blockchain-based toolkit developed at the *MIT Digital Currency Initiative*) which allows the validators to be separate from the issuer. Transactions among cells are based on a "trustless" arrangement: rules are intrinsic to the

technology, e.g., via all cells adopting Hashed Timelock Contracts. This trustless intermediation system lowers barrier to entry.

Besides providing competition to existing payment systems, such an alternative infrastructure also diversifies operational failure risks due to cyberattacks.

Dr Prateek Saxena (NUS) commented that decentralization strengthens systems resilience because there will be no single point of failure. He added that tokenization allows fractional ownership and improves liquidity. Overall, blockchain technology has many innovative applications that are scalable and resilient.

Prof. David Yermack (Stern NYU) presented his work on "***How private digital currencies affect government policy***," co-authored with Max Raskin (NYU Law School) and Fahad Saleh (McGill University). He first presented a simple but useful classification of digital currencies along two axes: state-sponsorship and centralization. A digital currency can be private or state sponsored, which includes legal enforcement that privileges the digital currency, e.g., legal tender laws or taxation on competing money. Centralization pertains to formal barriers to entry that prevent participation in the writing and validating process of a crypto-currency network. To illustrate, the authors pointed out that Bitcoin is private and decentralized, digital currencies run by a closely held company (e.g., Google Wallet and Apply Pay) are private and centralized, a central bank digital currency is state sponsored and centralized while no candidate emerges for the state sponsored decentralized category.

The vision is that a private decentralized digital currency, e.g., the Bitcoin, is an "e-currency based on cryptographic proof, without the need to trust a third-party middleman" making money "secure and transactions effortless." The creation of private digital currencies offers an opportunity to examine the impact that alternative digital currencies have on unstable sovereign currencies in countries like Turkey and Argentina, as well as their fiscal and regulatory policies. The authors formalized a simple model comprising several propositions. First, a private sector-created digital currency offers the public the scope to diversify their asset holdings. Second, while a self-interested government would collect returns to assets and hence seigniorage, it cannot collect seigniorage on a private sector digital currency. Thus, the private sector digital currency effectively disciplines the government in collecting seigniorage. Citizens' welfare gain is greater the more the diversification benefit; that is, the more negatively returns to productive assets and to digital currency as an asset class are correlated. The authors conclude that "The

history of money … suggests that there will always be a demand for a non-state currency that serves as a check on the inflationary monetary tendencies."

Prof. Gur Huberman of Columbia Business School commented that the typology was useful. He pointed out that Prof. Yermack's analysis is more likely to apply in corrupt regimes. A private decentralized digital currency is owned by no one, rules are fixed by a protocol and participants are price-takers. Thus, there is no issue of rent extraction. Prof. Huberman raised further important questions: who supplies digital currency? How desirable is it to exclude the transfer of illegally obtained wealth? Is a digital currency, which has no underlying value, an asset? Is some flexibility in levying seigniorage desirable?

Mr. Ravi Menon, MD MAS, moderated a central bankers' panel which comprised **Dr. Agustin Carstens**, General Manager of BIS and **Ms. Cecilia Skingsley**, Deputy Governor of the Sveriges Riksbank. In his opening remarks, Mr. Menon highlighted that practitioners are concerned about the use of private digital currencies as investment and retirement products which bypass the central bank as the settling authority. He also stated that current cross-border payment systems are costly because they utilize old technology and because of the presence of multiple middlemen. However, the application of the blockchain technology has brought down costs (e.g., MAS' project Ubin leverages on blockchain-based transactions to streamline cross-border payments) and CBDCs could be another application of such technology.

Dr. Carstens provided a taxonomy of money, based on: issuer (central bank or not); form (digital or physical); accessibility (open or restricted); and technology (account-based or token-based). He further pointed out that while general usage of card payments has gone up, cash in circulation varies a great deal around the world e.g., Japan and India still have significant amounts of cash in circulation while Sweden has seen a significant fall in theirs. Dr. Carstens noted that the current system can already support domestic real-time gross settlement around the clock, though he admitted that there may be issues with cross-border payments as highlighted by Mr. Menon. He therefore did not see an urgent need for a blockchain-based means of payment. On the topic of CBDC, he noted that while a considerable number of central banks were looking into both wholesale and retail digital currencies, not many are committed to the actual development and issuance of CBDCs, as the demand for them is still muted. In terms of financial stability, Dr. Carstens also cautioned that the adoption of digital currencies means that there is an increased risk of technical vulnerabilities stemming from the nature of the technology, on top of the inherent financial market risks that already exist today.

Ms Skingsley highlighted that her country's cash in circulation had dropped by 50 per cent over the past 10 years and is now just 1% of GDP. Indeed, businesses are now not obliged to accept cash. She said that a CBDC can be account-based or token-based with wide or limited scope. A CBDC with wide accessibility could be a transmission mechanism for interest rates that would facilitate monetary policy. She also discussed Sweden's focus on public-private partnerships to build digital payments systems that can retain widespread use of and public trust in the national currency.

Prof. Franklin Allen (Imperial College, London) discussed "***Digital tokens and financial regulations.***" ICOs are done in a number of ways; a typical sequence of events is that the party making the ICO will issue a "White Paper" describing the nature of the technology being funded and the uses the technology can be put to. Potential investors can raise questions before an initial sale of "coin" is made. Promoters use the funds raised to implement the promised project while coins can be traded on cryptocurrency exchanges.

Prof. Allen referred to Cohney et al. (2018), which compared the governance of ICOs and protection of investors through computer code, and found that the ICO code and ICO disclosures often do not match.[13] Kaal (2018) points to several advantages of ICOs compared to conventional ways of raising capital, e.g., ICOs enable borderless online sales enabling promoters to bypass the usual legal and jurisdictional hurdles, continuous access to trade around the clock, and providing liquidity to investors faster than other forms of capital formation, e.g., venture capital funds.[14] However, the lack of regulatory oversight and legal recourse to the promoters is a major drawback.

ICOs raise a whole set of interesting regulation issues but many countries are still silent on their regulatory status. Countries like China and South Korean have banned ICOs outright while the US's SEC Report of Investigation (July 2017) found that a blockchain-based token qualified as a security requiring registration under the Securities Act of 1933. The UK adopts a "regulatory sandbox" approach.

The dilemma in this area is how to prevent scams without hampering innovation. Unlike other products, relying on investors' due diligence may not sufficiently safeguard against fraud as the required combination of computer science, legal and finance skills needed to understand ICOs are rare.

[13] See Cohney, S., D. Hoffman, J. Sklaroff and D. Wishnick (2018). "Coin-Operated Capitalism," working paper, University of Pennsylvania, SSRN-id3215345

[14] See Kaal, W. (2018). "Initial Coin Offerings: The Top 25 Jurisdictions and their Comparative Regulatory Responses," working paper, University of St.Thomas School of Law, SSRN-id3117224.

Prof. Beatrice Weder di Mauro *(INSEAD and CEPR)* concurred with Prof. Allen's main arguments. She pointed out that only 3.8% of ICOs are traded after launch.[15] While there might be an economic justification for ICOs, e.g., stemming from imperfections of VC, PE, crowdfunding, and seed funding, regulations indeed vary across countries and regulators are wary. Furthermore, there is a lack of clarity on regulatory protection, financial stability, financial center competitiveness and protection of investors against market failure.

Sum-Up

ABFER, MAS, and NUS are grateful to the participants for a holistic research and educational effort into the pertinent aspects of digital currencies. They provided us with a better understanding of the underlying technology, e.g., the fundamental differentiation between the distributed and centralized ledger. Technology has relaxed the constraints, but it has not made time-honored concepts obsolete. Collaborative efforts among policymakers, practitioners and academics can help us to continue to extract positive results from the continuously improving technology and applications in this area.

[15] Source: https://news.bitcoin.com/80-of-icos-are-scams-only-8-reach-an-exchange/