Central Bank Digital Currency

Digital Assets - Week 5 (Lecture)

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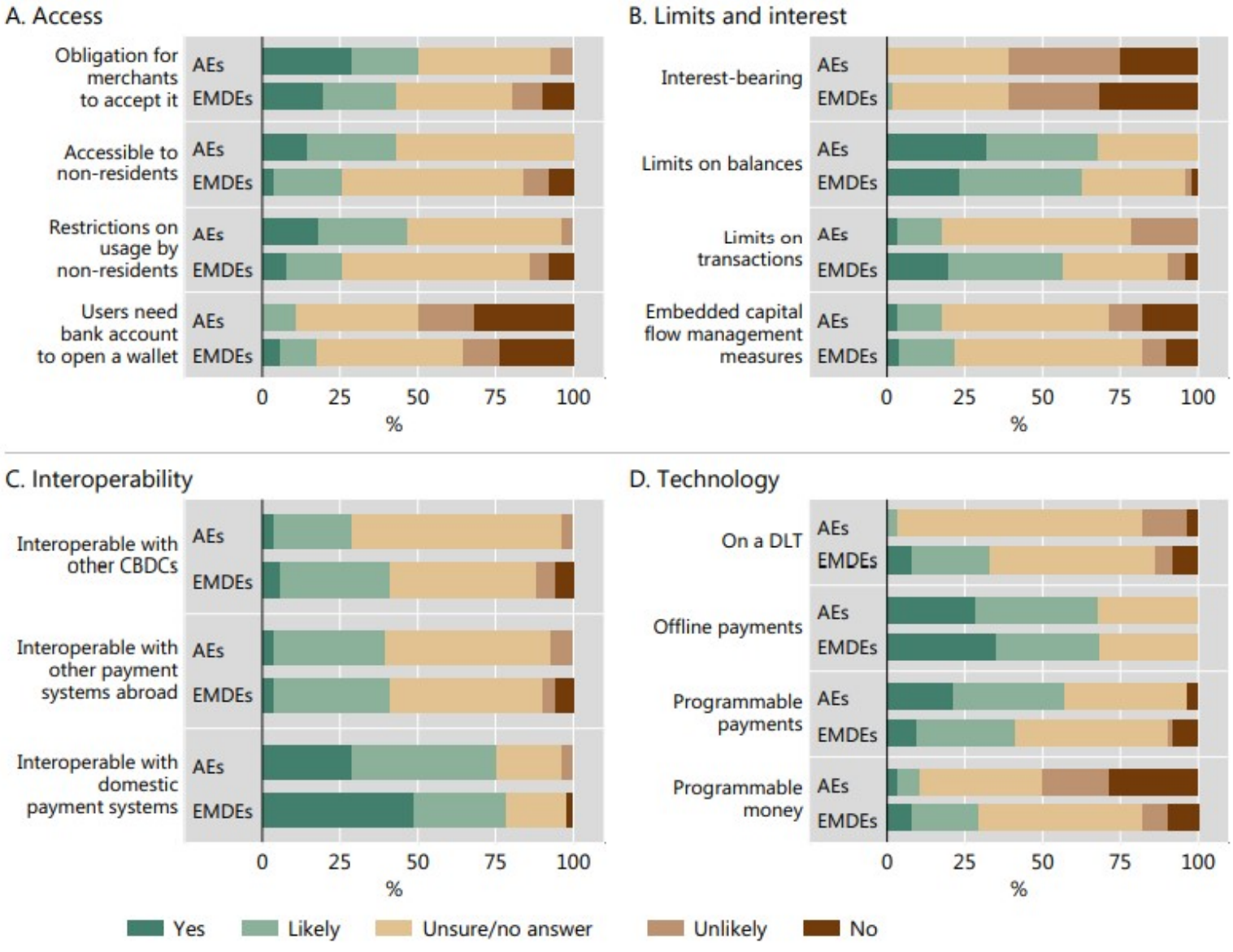
Outline

Must CBDC use DLT?

Must CBDC use DLT? - I

Must CBDC use DLT? No (though it could be)

- There are already digital monies (CB and private) without DLT/blockchain
- Vast majority of proposed wholesale CBDC pilots have involved DLT in some form
- Less information on retail CBDC ledger - its implementation is still being considered in Europe and UK
- The 'blockchain trilemma' (discussed in later lectures) may prevent a fully blockchain-based retail CBDC
- Arguably more likely for wholesale where permissioned blockchains and/or greater levels of trust/oversight can allow faster processing



Possible (retail) CBDC design features *Source:* *BIS - 2023 survey of CBDCs and crypto*

Must CBDC use DLT? - II

Various central banks are exploring/have explored hybrid mechanisms

- 'Trigger' solution has been considered by the Bundesbank (in concert with the Deutsche Boerse)
  - Uses 'traditional' CB money (in the TARGET2 large value payment system) to settle the cash leg of a DLT-based securities trade
  - Relies on APIs and messaging networks to link the two systems
- See also the Bank of England's 'synchronization' approach
  - Interoperability of systems handling funds (RTGS) and assets (DLT and legacy FMI)
  - Coordinates instant and/or atomic actions across multiple systems

Must CBDC use DLT? - III

The BIS are currently espousing a 'Finternet' vision

- DLT is prominent within it
  - 'Unified ledger': assets and money are collocated on a ledger, as part of a connected set of ledgers
- Some sort of on-chain fiat money required for settlement
  - Plausible that a wCBDC could provide this
- Could envisage other safe and liquid moneys emerging:
  - *Tokenized CB money:* 'reserve/wCBDC backed tokens'
  - *Tokenized bank deposits:* representing 'traditional' deposits on chain (still settles, ultimately, on the CB balance sheet)
  - *Stablecoins:* bearer instruments backed by HQLA
- Unclear if central banks/regulators will ever make peace with moneys like DAI

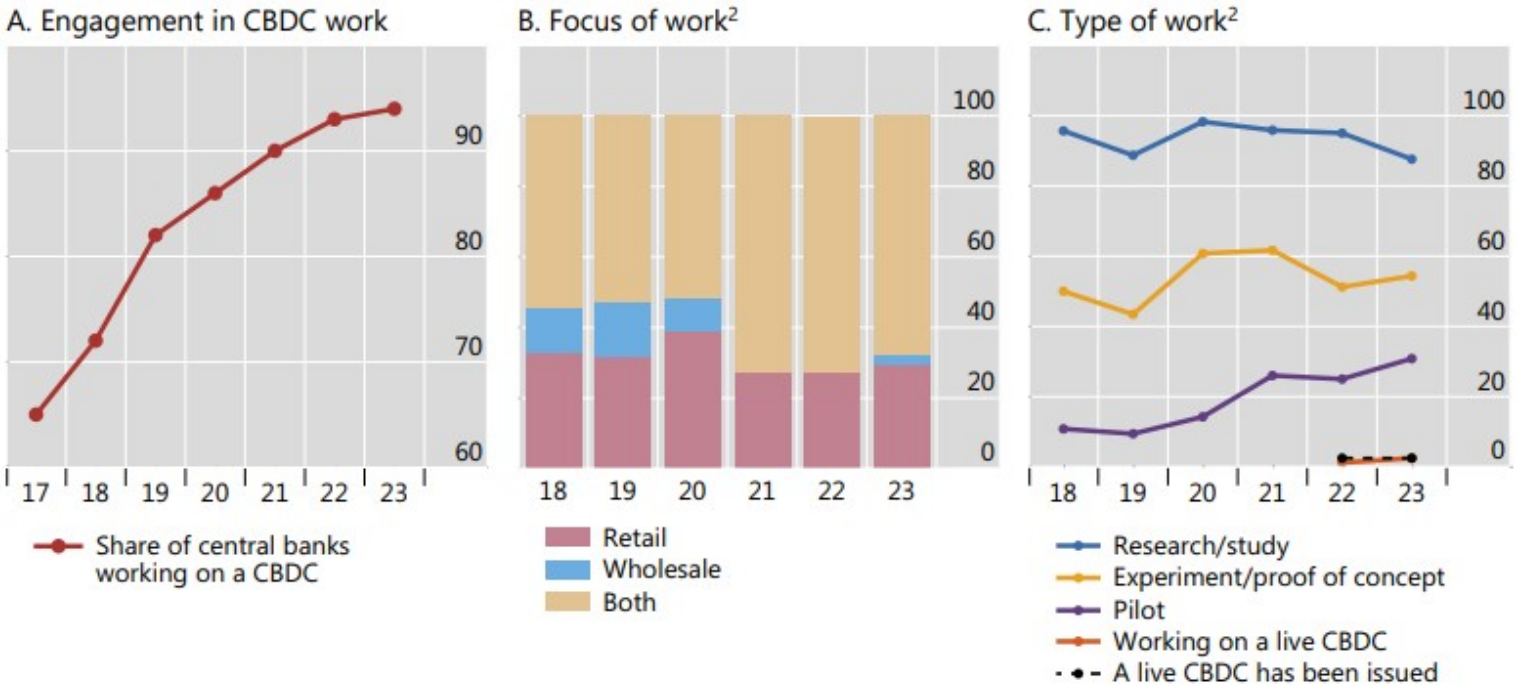
Retail CBDC

Retail CBDC

- Retail CBDC relates to public digital money that is to be used by households and firms
- This would be completely novel (in contrast to wCBDC, which we arguably already have, in the form of reserves)
- Some key explorations are:
  - Digital Yuan / e-CNY (already in very wide circulation - though with limited takeup)
  - Digital Euro / D€
  - Digital Pound / D£
- Some have recently stalled (e.g. Bank of Canada) - and recent BIS polling suggests *some* cooling in enthusiasm

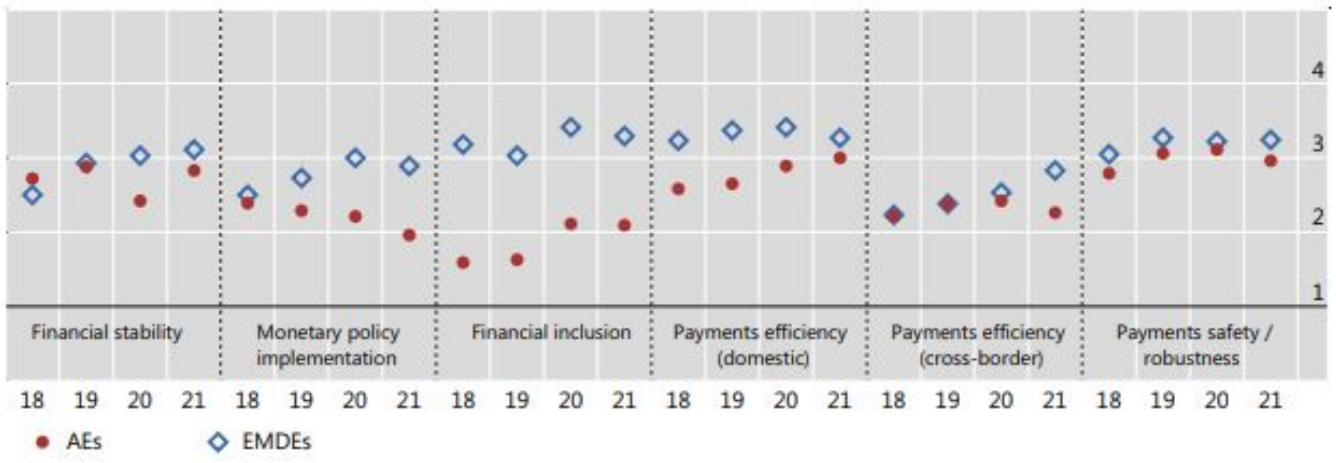
As a percentage of respondents

Graph 2



CBDC activity *Source:* *BIS - 2023 survey of CBDCs and crypto*

Motivation - Retail CBDC



Trends in motivation for exploring Retail CBDCs (AE: Advanced Economy, EMDE: Emerging/Developing Economy) *Source: BIS (2022)*

Motivation - Retail CBDC

- Advanced economies emphasize
  - Domestic payments efficiency and safety
  - Financial stability (esp. response to stablecoins)
- Emerging/developing economies emphasize
  - Financial inclusion
  - Domestic payments efficiency and safety
  - Financial stability
- The relative weighting of importance is somewhat intuitive
  - But note, there is much variation even within AEs or EMDEs

Financial inclusion

- Large fractions of the world's population have no access to safe and efficient payments technology
  - Lack of bank accounts
  - Cost, difficulty and *danger* of holding large amounts of cash
  - Disproportionately affects the poor and *unbanked*
  - But developing countries have higher *smartphone* ownership
- Can even be some concerns in developed economies
  - Current payment providers may not find it profitable to serve certain communities or geograhical areas
- Decline in cash raises urgency of this
  - Traditionally cash has provided an 'outside option' that bounds how bad bank and other payment services can be
  - But cash decreasing in relevance $\Rightarrow$ disciplining power is $\downarrow$

Payment efficiency - I

- In countries where cash (or backwards commercial banking systems) is the only game in town, replacing/supplementing it is a first order concern
  - Another reason why retail has been emphasized in developing/emerging economies, but less so in developed
  - In UK, for example, payments for households and non-financial firms are *extremely* efficient/low cost (see UK Parliamentary scepticism on scope for further improvements)
  - In Brazil, there are also great existing options (Pix) - so arguably less need for CBDC
  - See also E. Asian countries with excellent Real Time Payments (and India's UPI)
  - e-CNY adoption in China is apparently still very low, despite a lot of official support - perhaps reflects quality of and familiarity with AliPay, WeChat

Payment efficiency - II

- After early investigations, beginning to see rCBDC pilots reflect the idiosyncrasies of jurisdictions
  - In Asia instant payments and super apps (Ali, WeChat...) are very prevalent and high quality
- e-HKD is a useful example
  - Their CBDC investigations are emphasizing tokenization, programmability and offline payments
  - Things that Octopus/Alipay/WeChat can't do
  - 'Offline' perhaps response to persistent cash use in taxis!
- In Europe (see Cipollone speeches in the readings) the situation is different
  - Fragmented banking and payments sector (despite SEPA)
  - Not especially innovative financial players
  - MC/Visa dominant for cross Europe payments (and Alipay is making inroads) - concern over 'strategic autonomy'
  - D€ (and maybe D£) may provide a unified rail for households and for fintech developers building on it

Payment resilience

- CBDC provides an additional option for payments infrastructure
  - If others are disrupted (natural disaster, hacking, too-big-to-fail players), then CBDC can step in
  - Seems to be one stated motivation for e-CNY
  - Private digital payments have cash as fallback - but cash usage is in dramatic decline in many countries

Privacy, anonymity and pseudonymity

- Cash can be used completely anonymously
  - Difficult to replicate with digital money (though see cash top-ups of HK Octopus card)
  - In practice, unrealistic for a system at scale
- Most popular DCs can be pseudonymous in usage
  - Example: In bitcoin, while all transactions are public (necessary for its verification) the payer and payer's public addresses do not reveal 'true' identity
  - *But*, transactions are traceable and careful data analysis of transactions can be revealing
  - 'Privacy coins' can be essentially anonymous - though with practical limits on scale of transaction (will discuss more later in course)

Privacy, anonymity and pseudonymity

A broadly used CBDC is very unlikely to have *complete* anonymity

- Some people think this is a feature, not a bug, and others, the opposite. . .
- Cryptoanarchists are prominent in development of private DCs - CBs and financial regulators are different!
- Some form of KYC and AML will have to be present in any CBDC system
- Concerns over CB (and 'government') surveillance are very reasonable in many jurisdictions

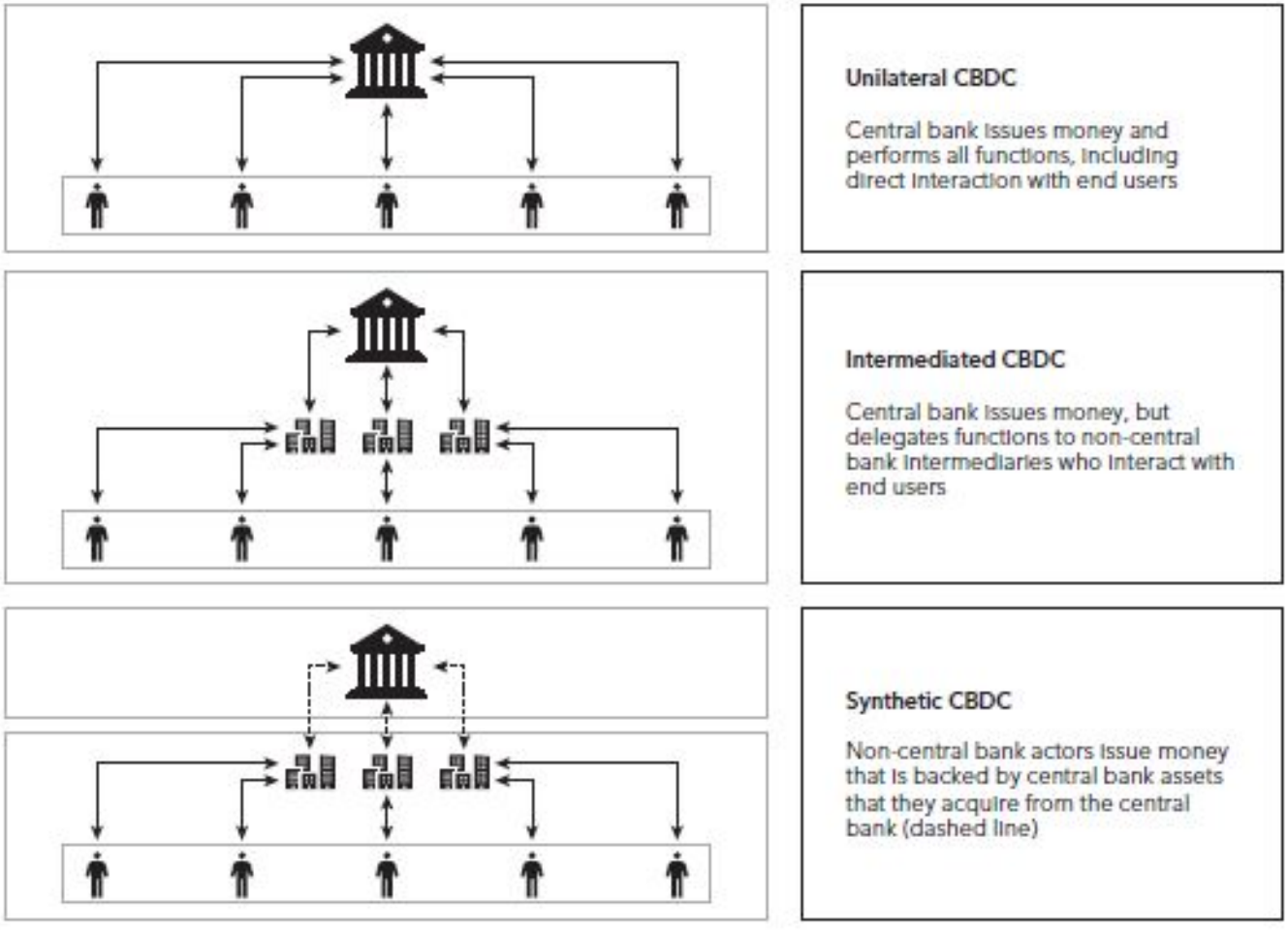
Some argue that CBDC could enhance privacy relative to private payment rails

Design solutions

Some fairly low-tech solutions

- Two tier system where CB issues CBDC but wallets and transactions handled by private sector entities
- Enhanced privacy/anonymity for offline and small-value transactions
- Separation of powers - judicial oversight (warrants etc.)

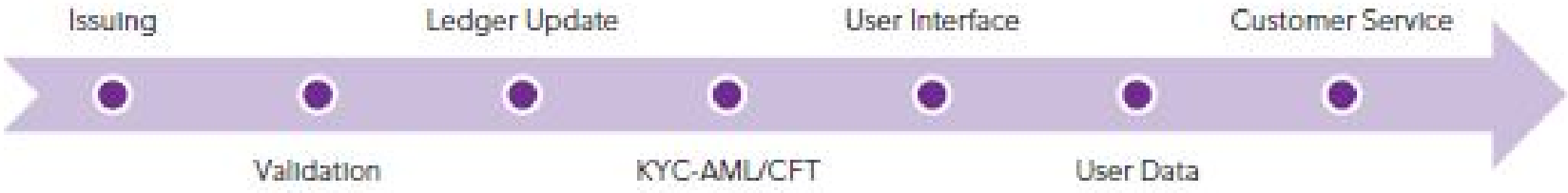
Centralized, decentralized or hybrid



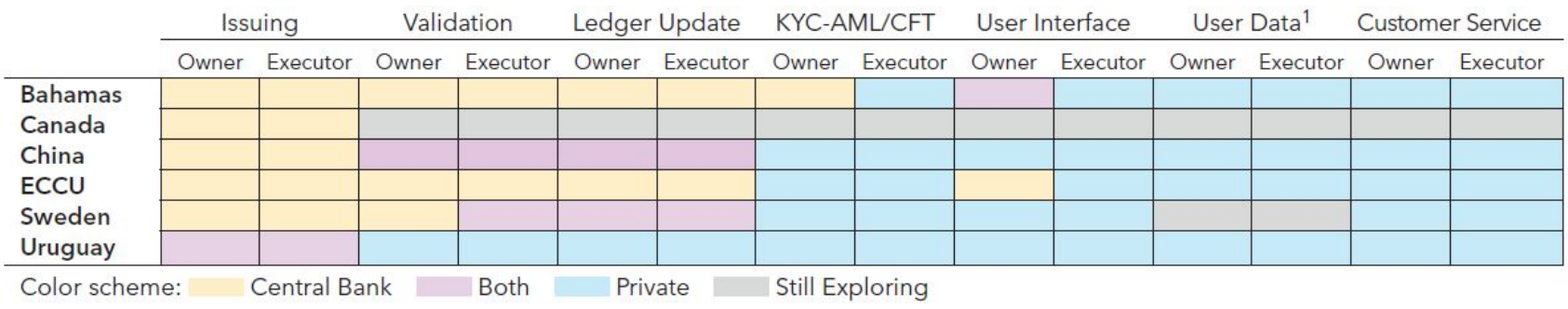
Possible CBDC operating models *Source:* *IMF (2022)*

Privacy (and other?) benefits of hybrid schemes

- Some degree of anonymity - in line with existing experience - can be enabled through the use of a hybrid scheme or 'intermediated' CBDC
- There are *other* reasons (beyond privacy) why this would make sense
  - Avoids CB being regarded as overmighty (see Ted Cruz)
  - Leverages existing bank (or other payment provider) systems and experience (e.g. KYC, AML)
  - Computation efficiency (even with DLT improvements and permissioned systems)
  - Frees private sector to compete and innovate on customer service and technological solutions
- Not all functions implicit in running a CBDC have to be executed by CB but...
  - What are the risks of relying on the private sector?
  - Will markets yield an optimal outcome for payments systems and money issuance?



CBDC functions *Source:* *IMF (2022)*



CBDC functions - divisions of roles *Source:* *IMF (2022)*

Design solutions

Some exciting high-tech avenues:

- Zero knowledge proofs (prove that you know something without revealing what you know)
- Homomorphic encryption (encrypt data in a way that some mathematical operations on it are still feasible without decryption)
- Synergies with decentralized identity and self-sovereign identity solutions (paradigm shift in how people control their identity and grant authorization)
- Privacy pools

Massive (and profitable) work to be done in this area

Alleviating the ZLB

- If CBDCs were to replace cash completely **and** it were to pay a non-zero, and possibly negative, interest rate then the CB could drive short rates 'arbitrarily' below zero
- Not strictly necessary to *eliminate* physical cash
  - Could suspend 'on demand' provision of cash after some limit that allows adequate amount for 'real world' transactions
  - Or could set a disadvantagous exchange rate - worse than par - between cash and CBDC to discourage hoarding
  - But these seem to be almost completely off the table politically
- Now rare to hear CBs or even academics push this argument
  - See UK Parliamentary Report and broader discussion about 'death of cash' - people will likely not accept the complete phasing out of cash or even convertibility restrictions
  - CBDC barely understood as is, let alone with the complexity of interest bearing CBDC

Enhancing the transmission mechanism

- If one interprets CBDC as 'reserve accounts for all' (not just for banks) then there are strong parallels
  - Interest rate on CBDC (and unlimited convertibility) should lock in a floor
  - See speech by Benoit Coeure (2018)
- Note: If CBDC provided on demand (unlimited convertibility) at par and has a zero interest rate, then we are back to an even tighter ZLB (!)

Enhancing the transmission mechanism

CBDC is a natural extension of current trends in monetary operations. For example, most central banks already pay interest on the reserves of commercial banks, which are a large portion of the total monetary base. The Federal Reserve has expanded its capacity to pay interest to an even wider range of counterparties by borrowing funds in the US Treasury repo market. Moreover, the Federal Reserve Banks now maintain segregated deposit accounts for systemically important financial market utilities, so that the customers of those utilities know that their funds are secure, liquid, and interest-bearing.

- CBDC and the future of monetary policy, Bordo and Levin (2018)

Damaging the transmission mechanism?

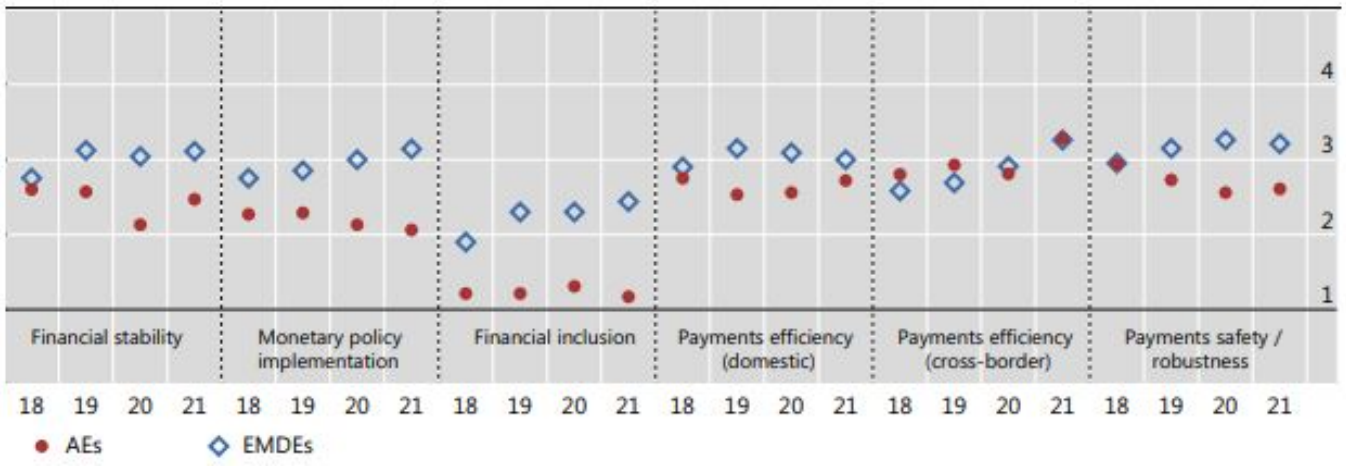
- Consider a multi-country CBDC framework where domestic citizens can nevertheless use a foreign CBDC in token form
- Then - in the case of a mismanaged 'local' currency or in the case of a loss of confidence for whatever reason, the domestic economy may experience 'Digital Dollarization'
- Locals may abandon the local CBDC - thereby eliminating the local CB's influence upon the economy
- Such phenomena are not new on a deep level (why we use the term 'Dollarization') but might be more prevalent, with faster currency 'flight' in a CBDC setup
- But this then raises the question whether a mCBDC with 24/365 access under standardized protocols will be entered into in the first place...

Enhancing *fiscal* policy?

- CBDC (esp. 'account based') would allow fiscal stimulus payments from 'Treasury' to be *immediately* credited to peoples' account
  - Recall a common CBDC aim is to reach the unbanked and expand financial 'inclusion'
  - Might further enhance stimulus as the poor tend to spend larger proportion of stimulus money than the rich
- Other possible opportunities (dangers?) from fiscal coordination
  - Could implement helicopter money (create *additional* CBDC to give to people, rather than transfer from Treasury account)
  - Blurs already fading line between monetary and fiscal authorities, as might mass purchase of government bonds in initial open market operation to issue CBDC
  - Fatas and di Mauro (2018) also note risks of purchasing (risky) assets *other* than domestic sovereign debt, which conceivably might be necessary if the scale of CBDC issuance is 'large'

Domestic wholesale CBDC

Motivation - Wholesale CBDC



Trends in motivation for exploring Wholesale CBDCs (AE: Advanced Economy, EMDE: Emerging/Developing Economy) *Source: BIS (2022)*

Motivation - Wholesale CBDC

- Motivations somewhat similar to retail but some intuitive differences
  - Cross-border payments efficiency importance $\uparrow$
  - Financial inclusion importance $\downarrow$

Domestic wholesale CBDC

Progress on domestic wholesale CBDC (wCBDC) has progressed in waves of pilots:

1. Interbank payments with limited functionality, and using DLT tools designed for permissionless systems
2. Interbank payments with more advanced functionality, and exploiting permissioned blockchains
3. Securities settlement and ledger interoperability
4. Exploring a broader DLT/tokenized ecosystem

Comments:

- Wave 4 is arguably not simply about wCBDC - but relates to broader re-engineering of financial system (eg e-HKD+)
- There is already, essentially, a fully fledged wCBDC is now in existence - part of SNB's Project Helvetia III
- See uploaded wholesale CBDC survey (written by me) in the readings for a lot more detail

wCBDC - Liquidity and the security lifecycle

- Payments and securities settlements systems found to be implementable - at scale - with DLT
  - Hope for reimplementing RTGS and CSD activities
- Possible - though not necessarily desirable - to remove reliance on central bank for settlement
  - Helps with robustness (no single failure point)
  - But pilots also explored partial reduction of CB's role (retaining for dispute resolution, say)
  - Gridlock resolution / liquidity savings mechanisms possible despite decentralization
- Smart contracts could automate regulatory requirements, distributions, collateral management
  - See Project Ubin in Singapore and Project Inthanon (phases 1 and 2) in Thailand
  - Collateral efficiency and mobility is a key goal of tokenization and blockchain

wCBDC - Atomic settlement

- Atomic settlement is a goal for most securities settlement systems
  - Either all parts of a trade succeed, or all fail
- Difficult to achieve in legacy systems but simple with smart contracts if assets/money on same chain
  - More complicated if assets are on different ledgers, but interoperability solutions do exist
  - Hash Timelock Contracts (HTLC) and oracles/bridges are needed
- Atomicity and the ability to settle rapidly ⇒ less collateral needed **and** assets not locked up for an extended settlement window

wCBDC - Atomic settlement on single chain

As discussed in this nice BIS note the process for atomic settlement on a single chain is:

1. Seller and buyer each send their tokens to a single smart contract (along with any other necessary data)
   - Note, they don't necessarily send them at the same time
2. The smart contract can execute the trade on receipt of the second token (and data)
   - There may be other conditions that need to be satisfied
   - The actions of the smart contract are implemented as the relevant transactions are added to blocks

3a. If the transaction(s) is(are) successfully added to blocks then the tokens are delivered to the appropriate recipients
   - Note that the settlement isn't necessarily immediate
   - The key is that every step succeeds or every step fails

3b. If the transaction is not validated then the tokens remain with their original owners

wCBDC - Preventing inefficient private money creation

- Tokenization may take off - implying a huge demand for on-chain fiat
  - Finality and absence of credit and counterparty risk make CB money especially suited to large value financial transactions
  - In its absence private sector will create money to fill gap
- Possible market failures in private money creation
  - *Financial stability:* Long history of private money being created that is 'fragile' (see the 'run on repo' in the GFC)
  - *Efficiency/market functioning:* There is great concern that 'too many' moneys will be created, fragmenting liquidity
  - *Efficiency/market functioning:* Private payment networks may lead to uncompetitive market structure
- CBDC could aim to crowd out private moneys (to an extent)
  - If CB satiates demand for liquidity, then private liquidity provision will be less profitable
  - In a different context, this argument is sometimes made to justify large CB balance sheets

wCBDC - Promoting innovation

- Financial markets are likely to thrive if they have access to a safe settlement asset
- At the moment (always?) stablecoins have important limitations (as discussed in pervious lectures)
- As such, it is plausible that innovation and further development of on-chain finance, could be stimulated by wCBDC

The use of a high-quality, safe and stable CBDC for the settlement of digital asset transactions would unleash the potential of the emerging digital assets ecosystem while reducing the overall risk profile of such transactions.

David Newns, Head of SDX, May 2022

and

Without digital cash to facilitate true [Delivery-versus-Payment] on and across blockchains, we will not realise the full potential of the digital revolution in financial markets. This is where central bank digital currency or CBDC comes into the equation.

Tom Phillips and Paul Pirie, JP Morgan Chase, October 2022

wCBDC - Permissioned blockchains - I

- Early wCBDC pilots experimented with Ethereum protocol
  - Learning ‘blockchain basics’
  - Minimal concern for confidentiality, scalability, finality
- The ability to scale the systems, while preserving confidentiality, soon became a focus
  - Confidentiality, speed and finality especially important in high value finance
- Permissioned blockchains offered one approach to achieving these goals

wCBDC - Permissioned blockchains - Providers

- Various companies/consortia emerged offering blockchain platforms and services
  - R3 (Corda), Consensys (Quorum), the Hyperledger Foundation (Fabric and Besu), and Digital Asset
- Adaptable to particular use cases and designed for enterprise applications
  - Performance improvement (and immediate finality) from more trusting consensus mechanisms (Practical BFT, Istanbul BFT, Proof of Authority, Raft)
  - Speeds and robustness depend on how many and which nodes construct, propose, validate or vote on blocks
  - Tweaked network structure for quick validation/commitment (contrast to 'flat' structure of Bitcoin, Ethereum...) to allow parallelization and specialization

wCBDC - Permissioned blockchains - Greater trust

Why could faster consensus mechanisms be used?

- Parties must be approved to join the ledger
- Access is closely controlled, in line with agreed policies
- Once granted access, users prove their identity on the basis of digital signatures managed by a trusted Certificate Authority
- Plausible that any perpetrator of bad actions can be identified and heavily punished
- All this allows stronger trust assumptions (recall bitcoin and ethereum are essentially trustless)

wCBDC - Permissioned blockchains - Confidentiality

- Pseudonymous public blockchains for 'retail' use raise issues of privacy - these are multiplied in the context of large value payments among smaller sets of participants
- Various techniques have been proposed to enhance confidentiality
  - Sub-networks
  - Private transactions / masked information
  - Disguising identities
  - Off chain information
  - Trusted execution environments/hardware
- See appendix D and section 5.2 of my uploaded wholesale CBDC survey

wCBDC - Confidentiality solutions - I

- Sub-networks
  - Corda: 'need-to-know' p2p communication where transactions only known to counterparties
  - Fabric: Channels can be set up between sets of participants, featuring a private blockchain
  - Tradeoff? Greater risk of data loss ('full' chain not shared across so many nodes)
- Private transactions / masked information
  - Quorum: All nodes see transactions but details are encrypted in a way only a subset can understand them
  - Similar techniques can be used to mask parts of transactions (useful for partial revelation for regulators)

wCBDC - Confidentiality solutions - II

- Disguising identities
  - UTXO approach ⇒ a payment may carry information - including counterparties' ID - from earlier payments
  - Can solve by using 1-time-use identities, or 'snipping the chain'
  - Fabric offered an 'identity mixer' that disguises ID while assuring that the counterparty has appropriate credentials (apparently used in Saudi-UAE Project Aber)
- Off chain information
  - Sensitive information can be stored off chain, but only encrypted versions of it being stored on chain
  - Fabric allowed 'private data collections' of which only the has was stored on chain

wCBDC - Zero knowledge methods

- An increasingly dominant approach to privacy (and blockchain scalability) is 'zero knowledge'
  - We touched on it briefly in *'Intro to cryptography'* pre-record
  - Very active area of research (and very difficult to understand)
  - Conceptually elegant and reduces the need for more 'clumsy' solutions like sub-networks
  - Used to imply computational bottlenecks but research is gradually reducing this
- ZK proofs allow a party to prove that they know a fact, without disclosing the fact
  - Proofs take the place of the underlying sensitive data
  - Can be operated upon and shared within the DLT system
  - A few examples...

    prove a certain computation has been done correctly without revealing the answer

    prove that adequate funds have been transferred without revealing the amount

    prove a identity is valid without revealing the identity

International wholesale CBDC

International wCBDC - Improving payments

- As discussed in the pre-record, international payments are horribly slow and costly
  - Often rely on correspondent banking
  - Laden with complicated manual processing
  - Influential institutions exploit market power and extract rent
  - Private sector may not provide correspondent banking services to poor countries
- Hard to quantify the precise savings that are possible but they are likely substantial

International wCBDC - Improving payments

Global corporates move nearly $23.5 trillion across borders annually. They predominantly rely on the wholesale cross-border payment processes of correspondent banking networks that cost approximately $120 billion in transaction charges annually

High transaction costs ($27 average cross border fee per transaction, excluding FX), long settlement times (not uncommon for payments to take 2-3 days to reach end beneficiary), and the lack of transparency (limited visibility of payment status).

- Oliver Wyman / JP Morgan, 2021

International wCBDC - Improving payments

International remittances cost an average of 6.4% for $200. A transaction could involve up to four intermediaries. Fluctuating exchange rates exacerbate inefficiencies. And the burden is disproportionately borne by underprivileged segments, with fees for cross-border retail payments reaching 10%.

- OMFIF, 2023

International wCBDC - Improving payments

consumer cross-border payments often incur bank fees averaging over 11%, which can erode the value of smaller transactions. B2B payments are impacted, with fees averaging 1.5% and processing delays up to several weeks. Nearly half of Citibank's corporate clients identify high costs as a pain point, and 59% cite slow speeds as an issue.

The lack of transparency in traditional payment systems worsens existing challenges. In 2023, U.S. eCommerce firms experienced an 11% failure rate in cross-border transactions, resulting in $3.8 billion in lost sales. The difficulty in identifying the cause of failure impedes recovery efforts and erodes customer trust, underscoring the need for a more efficient and transparent payment solution.

- PYMNTS.com, 2024

Project Dunbar

- Project Dunbar is one of (many) CBDC pilots coordinated by the BIS
- Involved Reserve Bank of Australia, Bank Negara Malaysia, Monetary Authority of Singapore, and South African Reserve Bank
- Explored setting up a shared platform for international settlements using CBDCs issued by multiple central banks

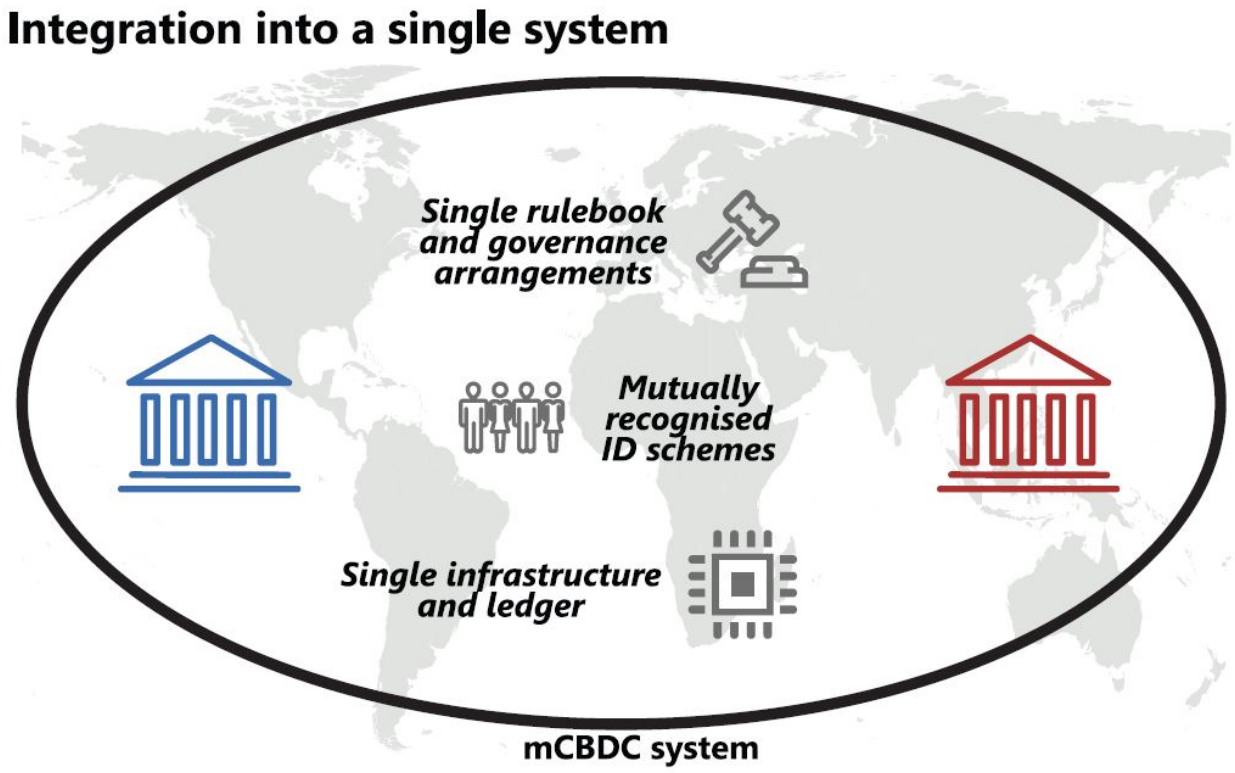
Project Dunbar

Unlike domestic payments, where banks can pay each other directly on a single national payments platform, there is no single international platform today for cross-border payments and settlements.

A multi-currency common settlement platform would enable transacting parties to pay each other in different currencies directly, **without the need for intermediaries such as correspondent banks.**

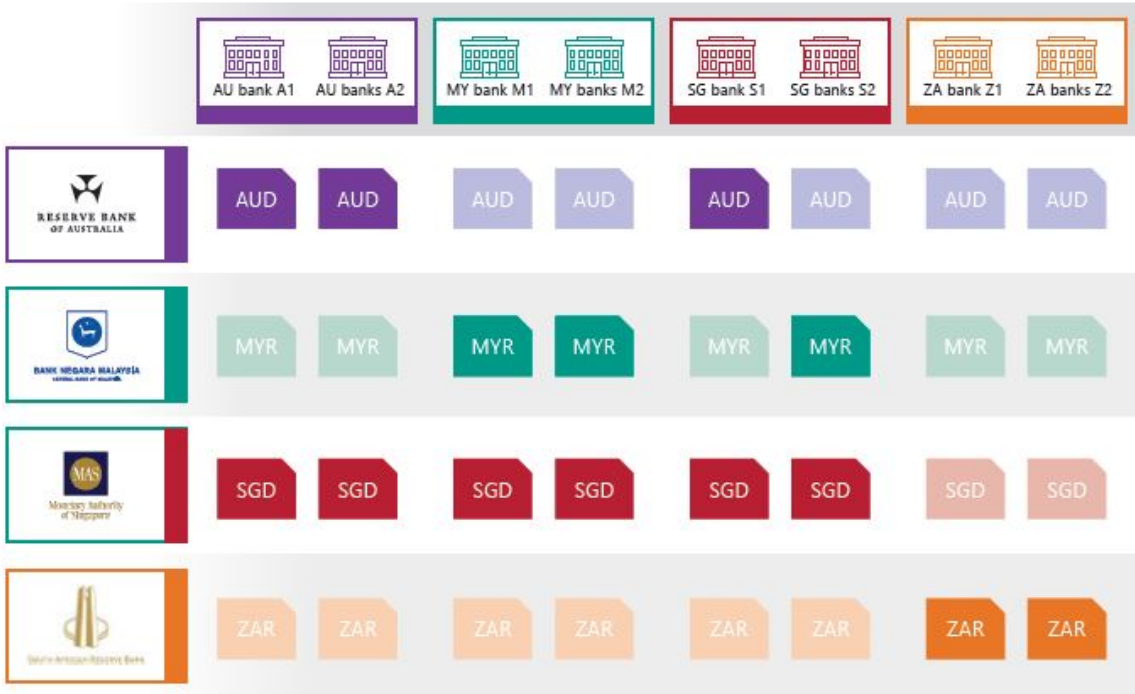
- BIS Project Dunbar

Project Dunbar



A multi-CBDC platform (Project Dunbar) *Source: BIS (2022)*

Project Dunbar



As an example, Singapore-headquartered bank S2 is a banking group with licences to operate in Singapore and Malaysia. It would likely already have access to the national payments systems of both jurisdictions and access to the two currencies (Singaporean dollars and Malaysian ringgit) in central bank money, shown in solid colours. The multi-CBDC platform is intended to allow the bank to hold CBDCs directly even in jurisdictions in which it does not have a presence – such as Australia and South Africa. In this way, it can hold Australian dollars and South African rand issued by the respective central banks, shown in shaded colours. This allows all banks participating in the platform to hold all currencies, enabling them to transact directly with each other. S2 can hold AUD CBDC and use it for payment to South African bank Z1 directly, which was not previously possible.

Transacting on a multi-CBDC platform (Project Dunbar) *Source:* *BIS (2022)*

Project Dunbar

- Commercial banks can hold currencies (wCBDC) from jurisdictions where they have no presence
  - Sidesteps the need for correspondent banks
  - Transactions can settle 'immediately' on a single ledger
  - Unified system offers opportunity (perhaps) to pool KYC/AML approach - or encode necessary logic in smart contracts for 'straight through processing'
- Dunbar had a very 'open' model - banks could access money (wCBDC) issued by central banks of other countries
  - Access to reserves are traditionally very tightly controlled, according to local policies and regulations)=
  - Tradeoffs between *technological* simplicity of settlement, and governance issues

Cross-border CBDC - Technology isn't the problem...

Yet competing priorities and history show that these benefits will be difficult to achieve unless central banks incorporate cross-border considerations in their CBDC development from the start and coordinate internationally to avoid the mistakes of the past.

- BIS (2021)

Project mBridge etc

Dunbar has effectively been superseded by Project mBridge

- Involves BoT, CB of UAE, the Digital Currency Institute of the PBOC, HKMA and SAMA (plus many 'observing' CBs)
- mBridge recently reached 'minimum viable product' status and the BIS is withdrawing, after scheme reached 'maturity'

Project mBridge etc

Other cross border pilots are also being run by BIS and partners

- Agora: modernizing correspondent banking using tokenized bank deposits, interacting with tokenized wholesale CB money (possibly wCBDC?)
- Mariana: cross border trade of wCBDCs using AMMs (!)
- Mandala: enhancing interoperability of cross border regulatory/compliance protocols

Part of a broader cross border payments drive

- Nexus: linking instant payments networks
- Aperta: cross border open finance
- Icebreaker: cross border retail CBDC

Thanks for listening