

Global Financial Systems

Chapter 20

Technology

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To accompany

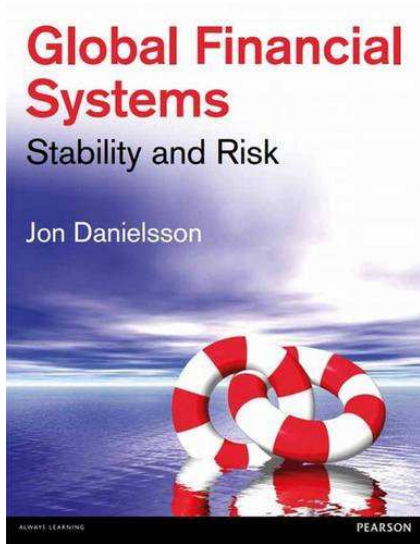
Global Financial Systems: Stability and Risk

www.globalfinancialsystems.org/

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Book and slides



- Updated versions of the slides can be downloaded from the book web page www.globalfinancialsystems.org

Thanks

- Robert Macrae
- Nikola Tchouparov

Technology

- The financial system has always been one of the earliest adaptor of technology
 - Rothschild supposedly used pigeons to get advanced notice of Napoleon's defeat in Waterloo
 - semaphores (conveying information at a distance by means of visual signals)
 - telegraphs
 - computers
 - microwaves
- Now involves fintech, blockchain, cryptocurrencies, smart contracts
- The below deemphasizes computer science as much as possible

Pros and cons of technology

- New technology can make the financial system much more efficient
- The cost of providing financial services is much cheaper
- And services provided faster
- But with all that speed comes the risk of rapidly developing crisis
- Where there is no time to react

Financial innovation

- The creation of new types of financial instruments and activities
- Historically has been quite beneficial
 - checking accounts
 - credit cards
 - ATM machines
 - etc.
- But often associated with unsavory products
 - structured credit — CDO, CDS, SIV
 - exotic derivatives
 - etc.

Controversial

- Generally viewed favorably until 2008 crisis
- At the core of allowing that crisis to happen
- Often only benefits the innovators
- Exploiting retail clients, and even sophisticated firms
- Even other financial institutions

“the most important financial innovation that I have seen in the past 20 years is the automatic teller machine”

Financial innovation “moves around the rents in the financial system”, benefiting the inventor, not the clients.

Paul Volcker 2009

Fintech

Creative destruction

- Dates back to Schumpeter in the early 20th century
 - The “gale of creative destruction” is the “process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one”
- How new ideas are continually changing how companies and industries work
- Implying that even if incumbents resist change, society should welcome it
- And that if the government gets involved with “industrial policy” it is more likely to entrench the incumbents and hinder creative destruction
- Even if the intention is otherwise

Digital disruption

- Spinoff of “creative destruction”
- Small company with few resources successfully challenging the incumbents
- Transformation of industries caused by new and emerging digital technologies and business models
- Digital disruption implies a small company with few resources successfully challenging the incumbents
 - Netflix, Airbnb, Facebook, Alibaba,....

Fintech — financial technology

- The use of technology and innovation applied to new and better forms of financial intermediation
 - Includes mobile payments, money transfers, lending (like peer-to-peer), fundraising and asset management
- Promises more efficient and cheaper products for consumers
- And helps alleviate financial exclusion — The 2 billion people without access to financial services

Impact on industry

- Who?
 - incumbents (e.g. existing banks)
 - other companies (e.g. Amazon)
 - startups
- The incumbents have identified fintech as a first order threat and priority

See recording of Axel A. Weber, Chairman UBS,
LINK

[www.systemicrisk.ac.uk/events/
interplay-markets-and-politics-public-lecture](http://www.systemicrisk.ac.uk/events/interplay-markets-and-politics-public-lecture)

Official attitude

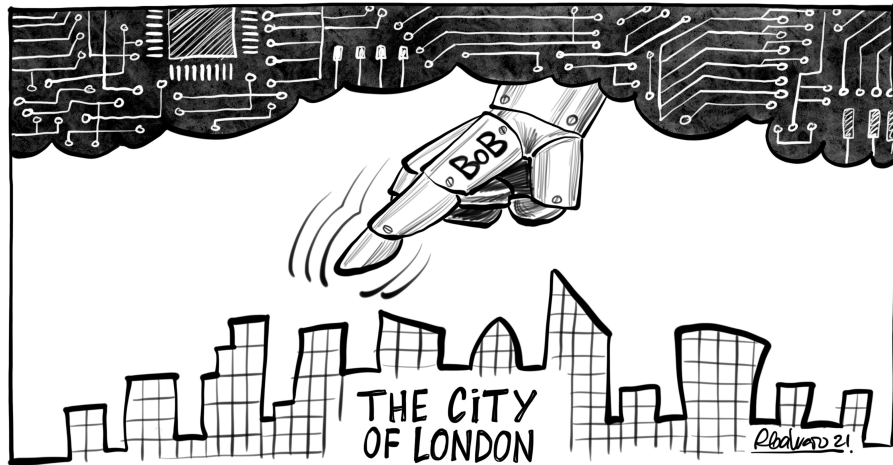
- All aspects of finance are heavily regulated
- China and Alibaba's Jack Ma — Ant capital
- Some aspects happened without the authorities noticing until too late
 - like Paypal
- Countries
 - enthusiastic supporters: Singapore, Sweden
 - others try to be: UK, Germany
 - and some are neutral or hostile: US, France, Italy, Japan
- Sandbox, a light and supportive regulatory framework for new entrants

Systemic/financial stability impacts

- Macroprudential — more heterogeneity
- Migration away from banks is good in its early stages because initially it decreases monoculture
 - make system more stable
 - concerns about unknown risks
 - and migration of controlled risks away from regulated banks to less regulated sectors
- Not true if we end up with a Google — Alibaba duopoly
- Technology can have increasing returns to scale
- Disruption could *easily* mean disrupter-takes-all

Microprudential

- Increase competition
- Migration of controlled risks away from regulated banks to less regulated sectors
- Better for consumers
- More scope for abuse



illusionofcontrol.org

Artificial intelligence — AI

- modelsandrisk.org/appendix/AI/
- AI is having a significant impact on the financial system, for good and bad

Brief overview

- Consider a continuum
- On one end we have a system with known immutable rules and full information — Like games of chess and go
- On the other we have a once-in-a-lifetime decision involving poorly understood rules that can be changed, very limited information and significant importance
- AI will outperform humans in the first, but not the second
- Then the question is where on the continuum problem lies

Micro-regulations and compliance

- AI is making rapid inroads, in the beginning it might generate new work for humans — identifying new cases to investigate
- Taking over the work of the least skilled workers
- And making new work for the highest skilled
- But over time it will move up the skilfulness chain
- Case: Anti-money laundering and fraud in financial transactions

EURISKO case

- AI called EURISKO played a naval wargame
- To win it sank its own slowest ships
- AI has to be told that is unacceptable
- A human admiral knows, And doesn't have to be told
- We cannot pre-specify every eventuality

Financial stability implications

- Chooses best practices, and is hence procyclical
- Unknown unknowns and new problems
- Trust
- Optimise against the system



Trusting data

- Double entry bookkeeping solved the problem of trusting accounting books
- Records today are almost always kept in databases (ledgers)
 - accounting data, identity management, land registers, asset ownership,...
- That can be updated maliciously or by mistake without anybody knowing — data is *mutable*
- What prevents that — creating trust — are institutions
 - legal system (police, courts), banks, government
- We trust institutions because if they cheat or make too many mistakes they would forgo future profits/benefits

profit from cheating < NPV future profits

Blockchain — Classical (cryptocurrency) sense

- A new type of database (ledger)
- Designed so information cannot be surreptitiously changed — Data is *immutable*
- The entire transaction history can be validated by anybody
- All data is public — Complete transparency
- Consensus is attained by making the ledger publicly viewable and verifiable
- Publicly audit-able — Everybody can see the blockchain
- In multiple — Nobody can (easily) change records
- Decentralized
- Integrity is guaranteed by technology not institutions

Trust model

- Public: it is assumed that the controllers of a majority of the hashing power have a strong enough incentive to keep an accurate record and so can be relied on as accurate by all others
- Permissioned: it is assumed that the permissioned entities have a strong enough incentive to keep an accurate record and so can be relied on as accurate by all others

Digital fingerprint — Hash

- Unique summary of data that is always of the same length regardless of size of data
- A tiny change to data results in a completely different hash

Data	Hash(Data)
J	c3e0836d
K	b5874a6f
London School of Economics	42765779
London School of <i>t</i> Economics	ab4ed6fe

- When done with R function

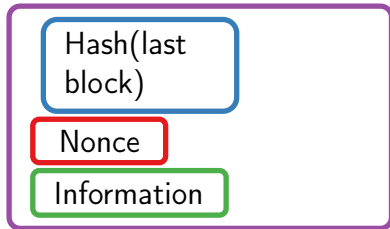
```
digest("London School of Economics", algo="xxhash32")
[1] "ab4ed6fe"
```

Nonce

- An (unique) arbitrary number used only once in a cryptographic communication
- Used only once on a blockchain
- Often a random number
- Or in cryptocurrencies, a solution to a problem
- We come back to it later

Block

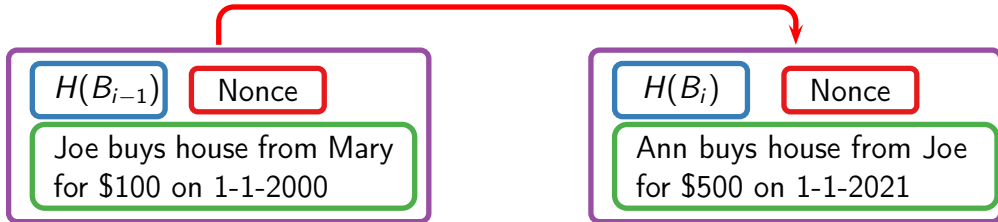
- Information, e.g.
 - ownership of house, art, money, ...
 - record of transaction, house sold by person *A* to person *B*
 - the contents and movements of a shipping container
 - steps in procurement process



Blockchain — Blocks linked in sequence



- Maybe record of a sale of a house



Updating information

- By default, blockchain is publicly visible
- A new transaction means adding a new block to chain
- Because of the hash, it incorporates previous blocks
- That can not be changed (maliciously) without it being visible as the *hashes will be different*
- Imutability

Trust — Who can add to chain?

- Originally, a cryptocurrency miner (next section)
- The cost of (maliciously) updating *past blocks* higher than profit from doing so
- That is a *public permission-less* blockchain (ledger) (next page)
- Alternative is *permissioned*

Public and permission-less blockchains

- Open to the public and anyone can participate as a node in the decision making process
- All users maintain a copy of the ledger on their local nodes
- Use a distributed consensus mechanism to reach a decision about the eventual state of the ledger
- The majority of cryptocurrencies fall under this category
- (next section)

Private and/or permissioned blockchains

- Private means not publicly visible
- Permissioned means some entity decides what can be added
 - bank, consortium, firm, government, ...
- Then the blockchain is essentially a database with special features (like preventing updates of past records, but have to trust the stewards of the blockchain)
- Libra, JPM Coin, discussed below

Are blockchains a good idea?

- Answer depends very much on whom you ask
- Some say they will revolutionize the world
- Others that blockchains are a fad that will go away
- Much depends on cryptocurrencies
- Blockchains (without cryptocurrencies) may be a useful database technology
- Not efficient compared to existing database technology
- Making it easier to resolve disputes by increasing the amount of information that both parties agree
- Important for accountants and IT people
- But not revolutionary

Cryptocurrencies

modelsandrisk.org/appendix/cryptocurrencies/

Gold standard

- Most of the world operated on the gold standard between 1873 and 1914
- Printed money could freely be converted into gold
- High price and difficulty in mining gold meant that supply of money was controlled
- The advantage is stability
- The disadvantage is that the supply of gold did not keep up with economic growth — persistent deflation
- And the miners were creating money for themselves

Fiat money

- Money created by the government without any connection to real assets
- First example is China in the 13th century — printed too much
- Second example is Sweden in 1623 — printed too much
- The temptation to print too much is why central banks are independent

Cryptocurrencies

- Replicate the gold standard with technology
- A computationally difficult problem — mining — whose solution means new money is created
 - finding nonces (a few slides down)
- The idea is that because supply is controlled, money is stable
- Money is not created by government and its integrity (trust) is guaranteed by technology

Bitcoin and other cryptocurrencies

- Bitcoin is the original cryptocurrency, dating back to 2009
- It is the most valuable (few slides down)
- It is the most technologically pure
- But not the most efficient as transactions take a long time and are costly
- Bitcoin, unlike some other cryptocurrencies, does not guarantee privacy
- Some alternatives aim to improve efficiency
- We will look at Ethereum — smart contracts — in a later section

Rise of Bitcoin — prices in USD



Accepting new blocks

- Anybody can conceptually add new blocks (create a new Bitcoin), except they have to meet a computational challenge — *mining*
- Problem is: Find value X_i such that

$$X_i = \text{Hash}(\text{Block}_i) < \text{Hash}(\text{Block}_{i-1})$$

- That value X_i is the *nonce*
- First person (miner) to find this X_i gets her block accepted
 - e.g. she has mined a Bitcoin
 - in Bitcoin, the difficulty level is increased (how much smaller the next nonce has to be compared to the current)

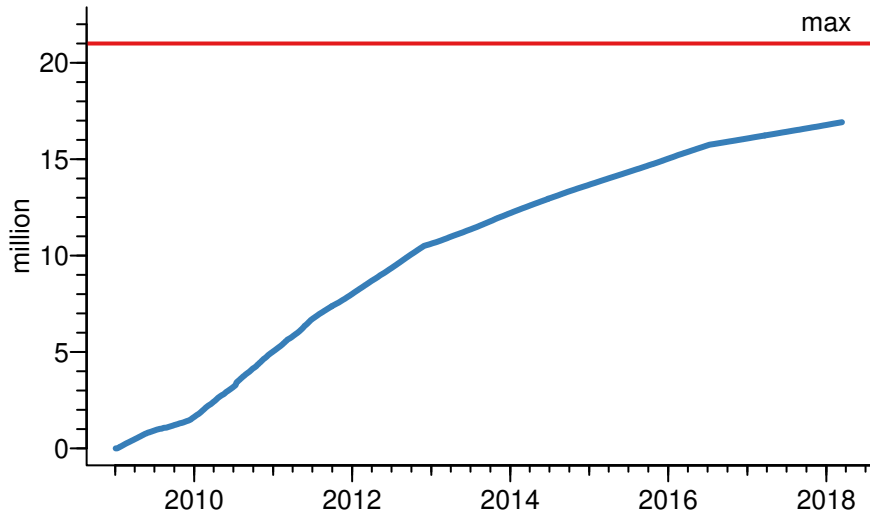
Protection against manipulation

- Suppose chain has 100 blocks
- And we want to manipulate block 50
- Then we have to change all the hashes for all blocks between 50 and 100
- And do this before anybody mines block 101
- Not economically feasible unless control hashing — 50% attack
- Except, perhaps, if block 50 is the token for something very valuable

Trust in Bitcoin

- Ensured by
 - Computational difficulties — problem is that it takes 10 minutes to update chain to reflect transfer of ownership
 - All transactions made within the 10 minute interval will be part of the next block
 - Public visibility of chain
- To manipulate the blockchain, need to recalculate all the previous nonces, and that costs more than mining a new coin
- And because blockchain is visible, everybody knows that was done

Bitcoin supply — all will be mined by about 2150



What are cryptocurrencies used for?

- Ethereum used for smart contracts (later section)
- Bitcoin, and the rest, replacements for fiat money
- The idea is that instead of using fiat — dollars, euros, yen, renminbi, ... — to make transactions (buy lunch, houses, companies, supplies,) we use bitcoin
- Cryptocurrencies will then coexist with fiat, and slowly displace them
- To date, practical usage of cryptocurrencies falls mostly one of two categories
 1. speculation
 2. criminal activities

The value proposition

- So why has the price of bitcoin gone from 7 cents on 2010-07-20 to \$20,000 ?
- No consensus as to the answer
- Skeptics would say it's an irrational bubble
- Advocates might say that as cryptocurrencies are increasingly used for transactions, the price represents the social value of cryptocurrencies
- The most obvious explanation is that as speculators have seen the price rise, they expected to continue rising

Trilemma of trust, efficiency and privacy

- Trust in Bitcoin ensured by
 - Computational difficulties — takes 10 minutes to update chain to reflect transfer of ownership
 - Public visibility of chain
- To speed up transactions or get privacy
- Trust has to give

Main Issues

a. Adjust supply

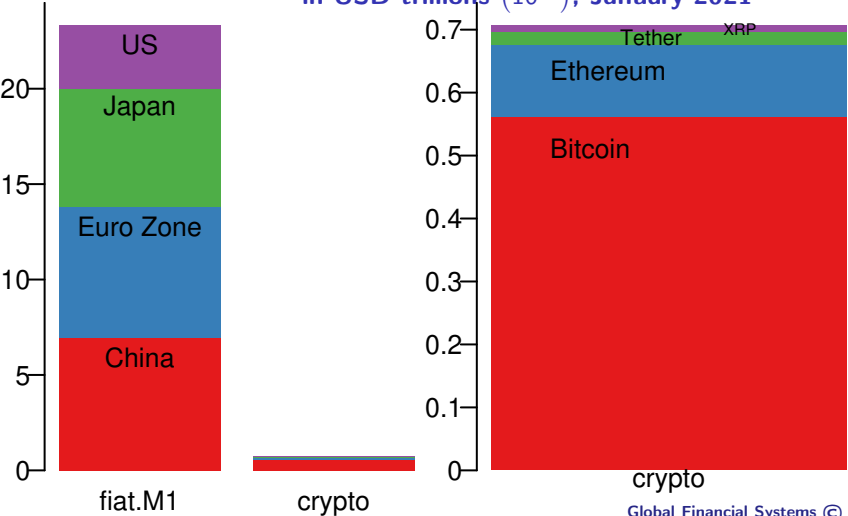
- The main premise of cryptocurrencies is that they cannot arbitrarily be created by the government
- Often with references to QE or hyperinflation (Zimbabwe, Venezuela)
- And linked to “Austrian economic” ideas (Hayek in 1970s)

Is that a good or bad idea?

- A basic premise with cryptocurrency advocates is that the central banks and governments cannot be trusted as stewards of money
- Technology can be trusted
- The skeptics might say
- Monetary policy and credible central banking government is better to be able to adjust money supply
- Like we did in 2008, otherwise we might have ended up in 1929
- Technology cannot be trusted — While the mathematical algorithm underpinning bitcoin are trustworthy, the practical implementations are not

Fiat M1 and cryptocurrency market cap

in USD trillions (10¹²), January 2021



b. Fairness — critical view

- The total value of M1 in the four main economies is about \$22 trillion, and much more if we take the rest of the world and or higher forms of money (M2, M3)
- Current market value cryptocurrencies is about \$700 billion
- If cryptocurrencies replace fiat money, speculators today will earn over 5,000% return
 - The top 1000 investors control about 3 million BTC and the top 10,000 investors own around 5 million bitcoins
- And that would not be seen as fair by almost anybody
- And hence politically infeasible

b. Fairness — advocates view

- The value proposition is overblown
- In a free-market capitalist society, those who take risks should get the rewards
- The critics are just jealous and or anticapitalist

c. Environment

- Mining is based on solving a computationally complex problem
- One that becomes more complex over time
- Uses 1% of world's electricity
- Environmentally disastrous
- Proof of stake as solution?

d. Controllers of mining

- Pools are open-ended syndicates of miners who can join and leave whenever they like
- Pools often make mining equipment (specialized computers for solving hashes)
- Roughly speaking, the marginal cost of mining equals the value of a coin
- Electricity is the most important part of the cost
- The biggest miners are AntPool with 25%, BTC.TOP with 11% and BTC.com with 11%
- 65% are in China, USA 7.2%, Russia 6.9%, Kazakhstan 6.17%, Malaysia with 4.3%, Iran 3.8%
- China does not condone their use internally

e. The incumbent technology — skeptics view

- We have very good incumbent technology — fiat money
- We can buy almost anything instantaneously at almost no cost
- Fiat money promises a stable store of value, -2% a year, (now slipping to almost -10%)
- For cryptocurrencies to take over, they need to show how they improve on fiat money
- And no good use case exists

e. The incumbent technology — advocates view

- In some countries, like Venezuela, cryptocurrencies are much better than fiat
- The central banks in Europe, US, Japan are abusing their privilege, so we are heading for Venezuela
- The governments are controlling the use of fiat that ever more intrusively — Know your customer (KYC), anti-money laundering (AML)
- Cryptocurrencies are already seeing widespread use
- We can buy almost anything instantaneously at almost no cost with them
- We can transfer money cheaper than with fiat
- Cryptocurrency enthusiasts believe crypto value will increase

Will, or can, the governments prevent the use of cryptocurrencies?

- So far, most governments have mostly ignored them — there are exceptions like China
- Fiat money is legal tender — it can be mandated for use in company accounts, paying taxes, and the like
- The governments can force vendors not to use cryptocurrencies
- Advocates dispute that
- Time will tell

Bitcoin as legal tender

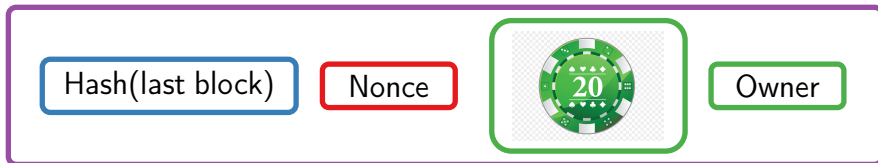
- Central African Republic and El Salvador
- Other countries considering it
- Has not been a success in El Salvador
- Price was \$47001 on day it was adopted (Sept. 2021)
- Price falls since then have made it unpopular

Digital currencies

All that is not old school fiat or cryptocurrencies

- Cryptocurrencies are based on money being a token on blockchain where the blockchain is public and mining underpins trust
- If we do away with either or both of public and mining
- But keep tokens (next side)
- We are left with digital currencies
 - Corporate: like Facebook's Libra (then Diem, now cancelled) or JPM's coin
 - Public, like central bank digital currencies (CBDC)
- There are other mining-substitutes (like proof of stake (PoS))

Tokens



- Information/record is a *token*, representing some asset
- Can be on a blockchain, but increasingly in other databases
- Could be anything, but here it is fiat money, so the 20 token = \$20
- When we change owner of token, we change ownership of the \$20
- Done by adding new block that indicates change in ownership

Accounts

- Image a credit card transaction
 1. money goes from your account to bank
 2. to payment system account
 3. to merchants's bank account
 4. to merchant's account
- Transactions/transfers typically involve money taken out of, and put into multiple accounts
- We need verification at each stage
- And there is plenty of scope for mistakes

Replacing accounts with tokens

- If money is tokens
- All we have to do is to swap tokens
- Perhaps add transfer of ownership a block to the blockchain
- Much more robust, quick, fewer errors, and cheap
- This seems to be the promise of *J.P. Morgan Coin*
- Clients of the bank can transfer money by swapping tokens
- JPM still maintains full control, hard to see any benefit from blockchain compared to other DB technologies

Libra Diem — RIP

- Facebook ~~is~~ was the lead partner in a consortium that runs a money transfer setup, relation to blockchain tangential
- Money is a basket of currencies. E.g. 50% USD, 30% JPY, 20% INR
- People transfer fiat money into a financial institution that gives them in return tokens on the blockchain
- These tokens can then be used for purchases, money transfers, and the like
- Do we trust Facebook?
- Know your customer (KYC) and anti-money laundering (AML)
- Deposit insurance, consumer protection
- Undermining the operation of domestic payment systems

Stable coins

- A type of cryptocurrency that promises that its price in fiat of money, typically USD, remains constant — stable
- The advantage to crypto investors is that they can trade crypto, using a stable coin as a temporary store of value — much cheaper and efficient than using fiat
- There are also seen as underpinning the envisioned decentralised financial system (DeFi and Web3) — Crypto banks
- They are therefore a competitor to CBDSs and the incumbent banking system

Types

- The staple coin can be based on having full or partial USD reserves, 1 USD for each coin, like Tether
- Then you have to trust the company behind the coin to keep adequate reserves, and if they are full reserves, how can The firm make money?
- Or the staple coin can be algorithmic, like TerraUSD, using a trading algorithm between maintain parity. That can be tricky, and TerraUSD fell by 60% in 2022

Issues

- We have to trust the firm running the staple coin, and some have not in very reliable
- Because stable coins touch on a much larger part of the financial system than traditional crypto currencies, like Bitcoin and Ethereum, the financial regulators have taken a particular interest in stable coins

Central-bank digital currencies

- The central bank introduces a digital currency in parallel with the current set up
- Main motivation is competition from private payment systems
- Especially foreign systems
- Bad memories of PayPal
- Most (not all) governments are reluctant to introduce CBDCs
- But feel they have no choice
- Initially on a blockchain but now usually a token with a digital fingerprint — hash — on a more traditional database

Central bank digital currencies — Obvious implementation

- Central bank creates a blockchain with tokens on its own fiat money
- CB controls blockchain (no mining, trust from CB)
- People can then swap their old school fiat money for tokens and use those for regular transactions
- Transactions then involve swapping tokens on the central bank blockchain
- Some countries find it a fantastic idea others hate it
- Very disruptive, we are essentially replacing big parts of the financial system infrastructure

Issues for governments from the obvious implementation

- All financial transactions are visible to the central bank — really good tool for monitoring and controlling people
- Gives private sector financial institutions much diminished role — more power to government
- Fine-tuning the money supply is easy because the central bank can simply increase/decrease the number of tokens
- Swapping over the technology on such a massive scale carries with it significant risks and enormous costs

- How to ensure privacy in countries that care about privacy
- If all the money is on a central bank blockchain
 - people engage directly with the central banks
 - who then oversee savings and presumably lending
 - it will have to be customer facing
 - what is the role of the private sector in such an economy?

Monitoring of citizens

- Because money will be a token on a central bank controlled blockchain
- The central bank can monitor every transaction
- They know that you got paid with block *ac32b3aa*, and used that to buy lunch, while then the shop owner used that block to pay for bread
- All transactions can be fully traced
- Of considerable attraction to some governments

The hybrid implementation A

- The implementation above is unlikely to happen
- Instead we may get a hybrid model
- Perhaps private banks face clients and use tokenized central bank money
- Clients access central bank tokens/coins by proxy
- Not compatible with existing infrastructure
- So will take long time to implement

Hybrid B

- Intermediated model
- Existing infrastructure
- Central bank blockchain is just a more efficient payment system

Adoption

- Most countries are considering CBDCs, and some have already launched them
- They don't seem very popular and use so far has been limited
- That doesn't seem to be a compelling case for them in countries that already have a well-functioning payments infrastructure

Smart Contracts

Smart contract

- Self-executing digital contract
- Facilitate exchange of anything of value
 - e.g. money, content, property, shares, ...
- Most closely associated with Ethereum, the second largest cryptocurrency
- Pre-written logic
- Stored and replicated on a distributed storage platform
- Executed by a network of computers
- That can result in ledger updates

Example: currency exchange

- Person *A* has Yen tokenized on the blockchain
- Person *B* has US dollars tokenized on the blockchain
- *A* and *B* agrees to exchange \$1000 for yen at the prevailing spot exchange rate
- They execute a smart contract that
 - Looks up the spot rate, S
 - Verifies that *B* has at least \$1000
 - Verifies that *A* has at least $S \times \$1000$
 - Simultaneously swaps tokens for these amounts
 - If it is unable to look up S or swap both tokens, the transaction fails
- Conceptually much simpler than current account based arrangements

Beyond super simple examples

- Conceptually can write a smart contract on anything that can be digitally delivered, verified and enforced
- Problem is that for anything more complicated, there are contingencies that cannot be pre-specified in the contract
- That is why we have law courts
- And the law is continually changing
- So is smart contracts would have to import law, and allow for it changing
- It is very hard to see how smart contracts can do anything beyond the super simple
- A law court may decide that one party to a smart contract was cheated, and order restitution Smart contracts can reduce the administrative costs of simple agreements but their outcomes can be disputed.

Decentralized finance — DeFi

- Peer-to-peer financial services on public blockchains, typically ethereum
- Idea is that we can get most banking type services, like borrowing, lending trading and the like, on some entity that executes all of that on a blockchain
- Promise is that such services will be much cheaper, since we don't need the infrastructure of traditional finance
- And more secure since the technology is much simpler and easy to verify than all the complexities of traditional banks
- Transparency and anonymity are also stated advantages (still need to comply with AML, KYC and sanctions)

Issues

- Everything on the previous slide is a promise, it does not exist yet
- The ethereum blockchain is slow and expensive
- In the most pure form, all we have is technology, so there is no recourse for when things go wrong, and no micro prudential regulations

Alternatives

- Several alternative technologies promise similar benefits as digital money
- But grounded in the traditional financial system
- The standout success is the Brazilian PIX
- And India's Unified Payments Interface (UPI)
- Better case for, and easier to adopt in countries that Don't have an advanced payment system and were most people use incumbent technology

PIX

- Brazil was very cash based, wiring money or using credit cards was very expensive
- Online payments often involved paying for a payment slip in shops or post offices.
- Private sector fintech proposed alternatives early last decade
- The Central Bank of Brazil didn't want that and used its power and determination to launch an alternative, PIX, in November 2020

Benefits

- Easy to use
- Free to use for individuals and very cheap for firms
- Beggars ask for money with a qr code
- The central bank compelled banks and other financial firms to use it
- Money can be privately sent and received with qr codes
- More popular than debit and credit cards
- One in five transactions in Brazil happen on its app

Issues

- Lightning kidnappings, where people are forced to transfer money on their mobile phones
- Consequently, some people have two phones, one at home for PIX, and one for use outside without it
- PIX has introduced nighttime limits on transactions
- Central bank staff has been on strike, creating concerns about how the system operates

Future

- Off-line use and deeper integration into banking
- Payments with installments
- Even use abroad
- Big step towards CBDCs
- Key to its success was the firm determination of the Brazilian central banks to mandate banks to support it
- Model for other countries