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Development of Financial Markets and Institutions

XIII. Cryptocurrency and Central Bank Digital Currency

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XIII. CRYPTOCURRENCY AND CENTRAL BANK DIGITAL CURRENCY

1. Bitcoin
2. Beyond Bitcoin
3. Central Bank Digital Currency
4. Literature

1. BITCOIN

THE PREHISTORY OF BITCOIN

Cypherpunk Monetary Discussions

- The cypherpunks in the 1990s concerned with online privacy, security of information
- In part inspired by the desire for private (non-government issued) money
- In part inspired by free banking theory

Early Attempts at Digital Money and Related Technologies

- E-gold, launched 1996 – users held accounts denominated in gold
    - Legal troubles from 2007 meant decline
- Hashcash 1992, 1997: a proof-of-work protocol for email, to protect against spammers
- Bitgold proposed 1998 by Nick Szabo but never implemented
    - Combines many of the elements later used in bitcoin (cryptography, proof-of-work)

THE PROBLEM

P2P in the Digital World

- Peer-to-peer transactions are not possible in the digital world
- There is no digital “cash” to send from person to person
- Trusted third parties necessary to facilitate and verify transactions (Byzantine Generals)
- Double-spending: the same amount is spent twice, defrauding one recipient (at least)

Central Third Parties Necessary

- Central third parties: credit card companies, banks, paypal
- A system so dependent on central authorities is vulnerable: single point of failure
- Potential privacy concerns
- Abuse of authority → inflation

THE SOLUTION: BITCOIN

"A Peer-to-Peer Electronic Cash System"

- Proposed by Satoshi Nakamoto in 2008
- A decentralized payments system, payments validated and recorded in the "blockchain"
- Individual transactions authorized by private key and broadcast to the network
- Only the public signature is known, the address from which or to which bitcoin is sent

The Blockchain

- Transactions collected in blocks and validated by proof-of-work
- A new block is added to the blockchain every 10 minutes
- The blockchain is a cryptographically "sealed" record of all transactions with bitcoin
- Miners rewarded for adding blocks, verifying payments – overcoming P2P problems

BITCOIN MINING

Proof-of-Work

- Each block is secured by a mathematical puzzle, the proof-of-work
- Miners compete in solving the puzzle, the first to solve it broadcasts it to the network
- New bitcoin are created as a reward for mining blocks, at the moment 6.25 per block
- Proof-of-work difficulty automatically adjust to mining power

Blocks and Blockchain

- The longest blockchain is the correct one, new blocks only added to the longest chain
- If two blocks are broadcast simultaneously, different nodes work on different blocks
- Once next block broadcast, the longest chain is kept, the other discarded
- The production of bitcoin is capped at 21 million, thereafter rewards only from fees

MORE ON THE BLOCKCHAIN

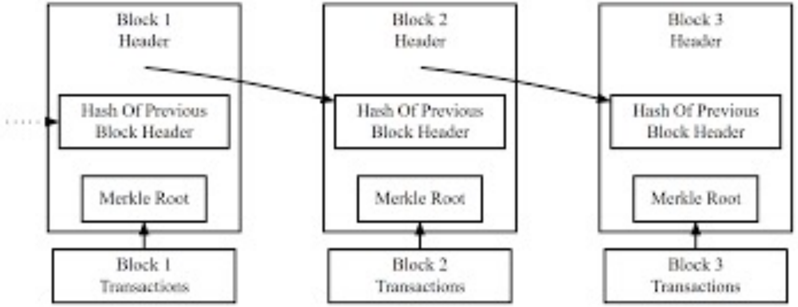
Size of Blocks

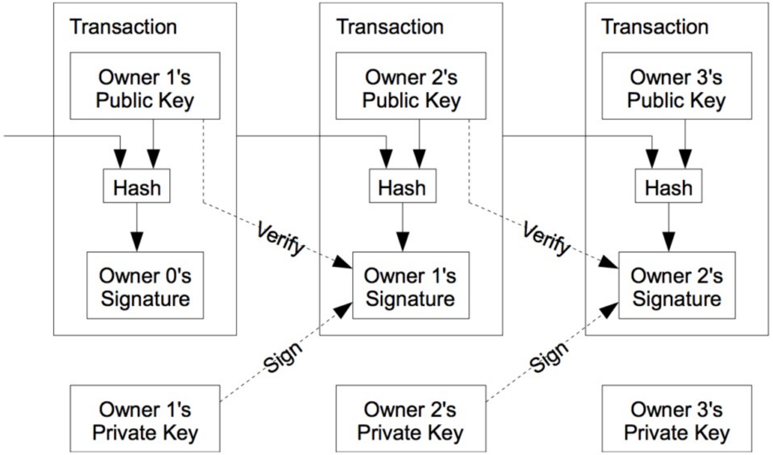
- Originally, there was no size limit on the individual blocks
- Miners simply gathered all the transactions into the next block
- 1MB limit introduced early, to protect the blockchain from "bloat"
  - ➢ People with malicious intent could spam the blockchain with micro-payments
  - ➢ Thus making the blocks too big to be economically broadcast

Limited Space

- Lack of space on each block for all transactions
- Transaction fees introduced to economize the space
- Fee automatically set according to the demand for space
- In times of high use, these fees have been high - $50 or more

BLOCKCHAIN AND TRANSACTIONS





BITCOIN AND PRIVACY

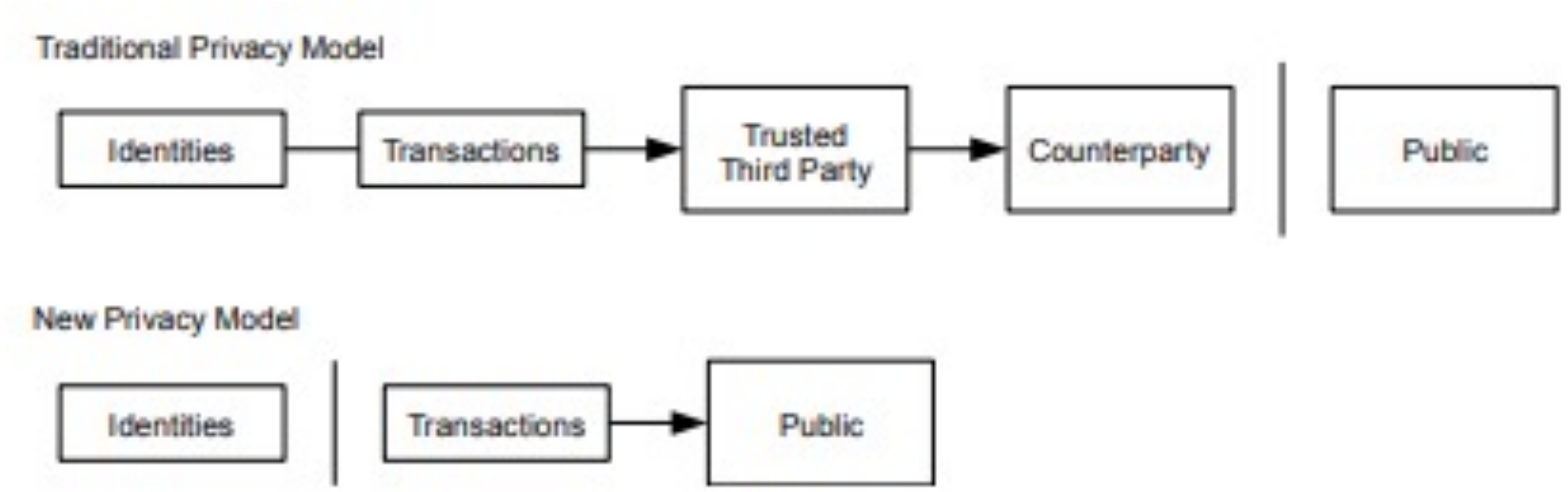
Traditional System

- Intermediaries key, they have data on the transacting parties and the amounts sent etc.
- This data is private, not available to the public
- But potentially everything is accessible to everyone

Bitcoin

- Transactions data are public in the blockchain – but they cannot be tied to individuals
- All that can be seen are the amounts sent and the addresses sent from and to
- It is still possible to lose privacy: if a link is made between an address and an individual
  - ➢ KYC regulations on bitcoin exchanges
  - ➢ Bitcoin detectives can track down ownership and spending of coins

BITCOIN AND PRIVACY (BITCOIN WHITE PAPER)



DOUBLE-SPEND AND 51-PERCENT ATTACKS

The Problem of Double-Spending

- Double-spend: the same bitcoin transferred to different wallets
- A coin first goes to one, but before validation, it is reversed and send to someone else
- Alternatively, a dishonest miner or node must replace one block with another
- This is no problem so long as a majority of nodes are honest

51 Percent Attack

- A dishonest node will have to control 51 percent of computing power
- Limited rewards: he can only reverse the previous block, falsify the latest transactions
- Mining is costly, is dishonesty really profitable?
- High opportunity costs: honest bitcoin mining

BITCOIN GOVERNANCE

Open Source

- The software behind bitcoin is all open source, publically available
- Bitcoin Improvement Proposals (BIP) debated in the community
- Once rough consensus is achieved, the proposal is integrated into the software
  - ➢ Uploaded to the recognized code repository
  - ➢ Only a few persons have access to the code repository
- The proposal is only integrated once users (nodes) download and install it

Consensus and Forks

- Ultimately, there is no central authority
- If consensus is not achieved on a BIP, but some want to implement it, a fork happens
- Two blockchains emerge: one with the old and one with the new software
- Their past is the same, but from the fork, we are dealing with two new coins

MINING BOOM

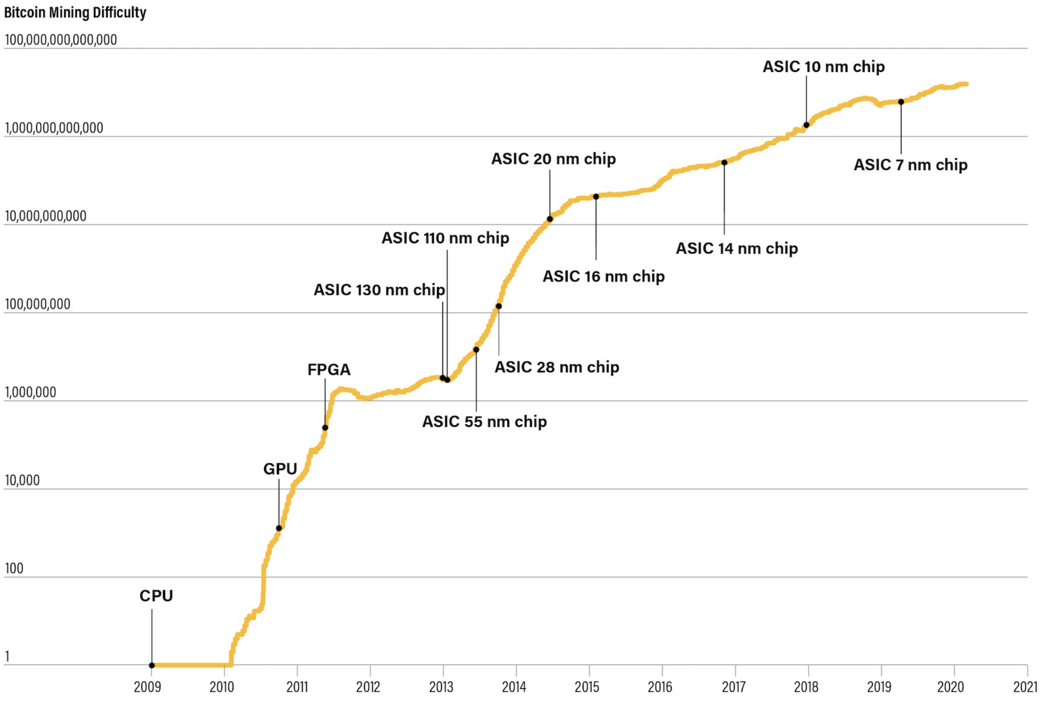
Technological Progress

- Bitcoin mining began with simply downloading a client to your laptop
- As mining became more profitable, mining hardware advanced
- From CPU to GPU, from laptops to dedicated rigs to large-scale mining operations

Economic Factors Determining Mining

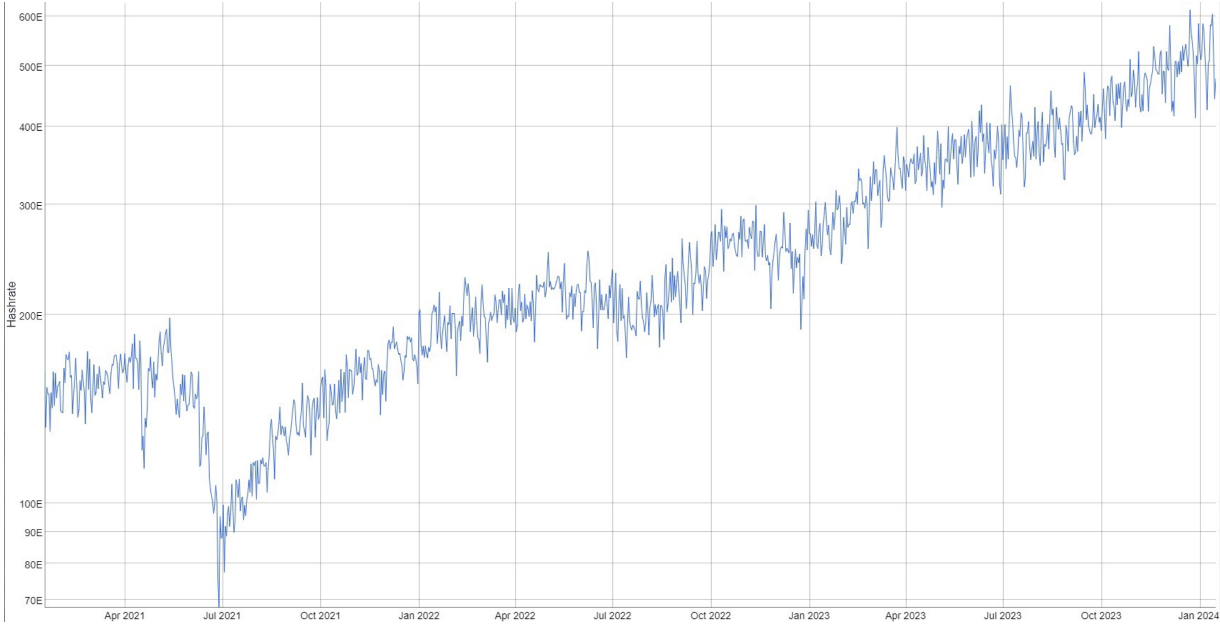
- Bitcoin price, chance of mining the next block, input costs
- Rising bitcoin prices means more resources are dedicated to mining
- Falling bitcoin prices eliminate profits, mines are turned off, switched to other purposes
- The main inputs: hardware rigs and electricity
- Miners locate where electricity is cheap, migrate according to seasonal changes
    - ➢ E.g., wet season in China

MINING DEVELOPMENT (SOURCE: COINDESK)



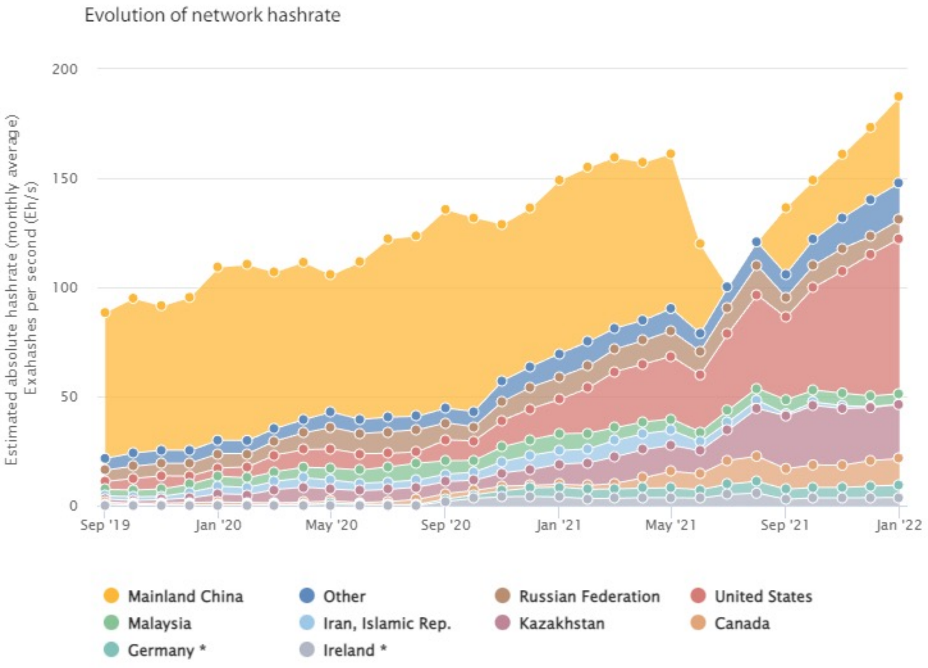
HASHRATE AND POW

- The number of "guesses" per second
- It measures the computational power assigned to the blockchain
- The larger, the more secure the blockchain is
- And the more resources are devoted to bitcoin mining



Source: bitinfocharts.com

BITCOIN MINING BY COUNTRY, 2019 – JAN. 2022 (SOURCE: CBECI)

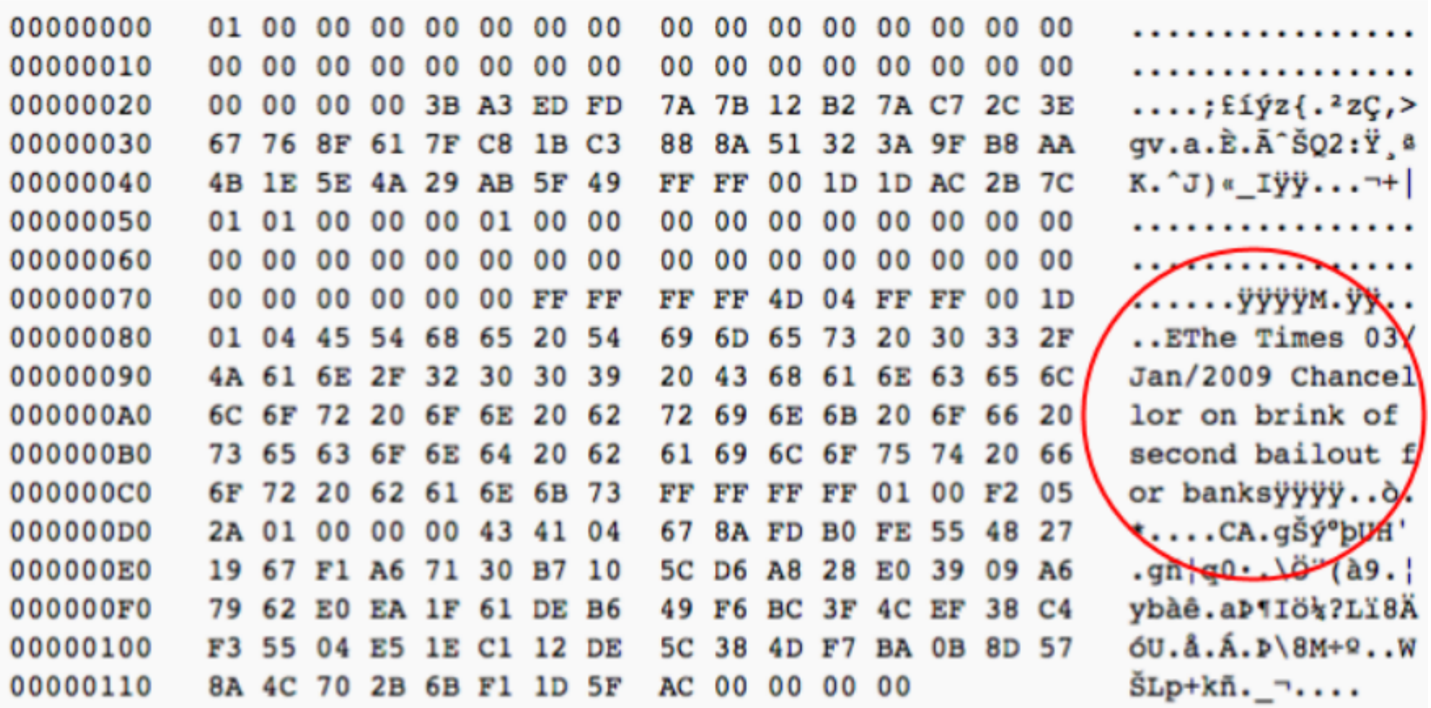


2. BEYOND BITCOIN

OTHER USES OF THE BLOCKCHAIN

- Secure records on the blockchain (sales, land titles, marriages)
- Smart contracts
- Contracts that automatically execute once certain conditions are met
- Decentralized finance (DeFi)
- Decentralized lending platforms
- Initial coin offerings – ICOs
- To fund new startups
- ...there seems to be a lot of scam going on here
- The original bitcoin blockchain can be used for some, not all of these purposes

THE GENESIS BLOCK MESSAGE



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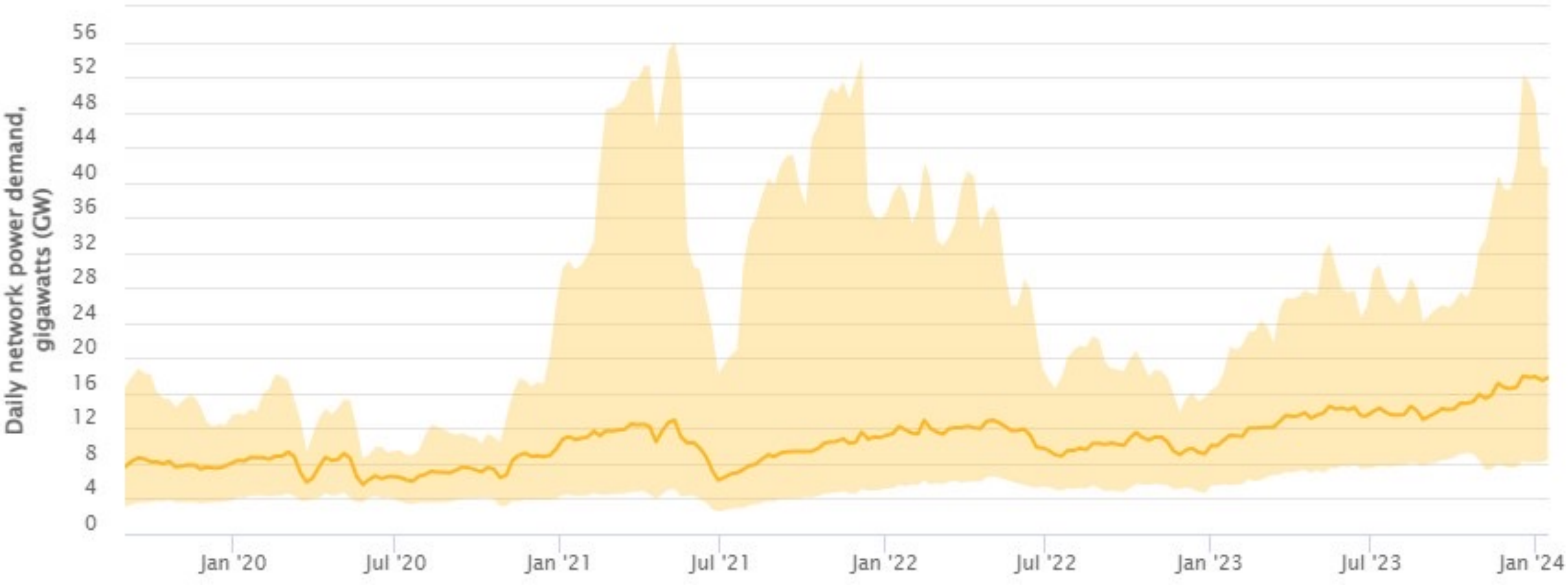
NEW CRYPTOCURRENCIES

- Since the basic software is publically available, it is very easy to launch your own crypto with your own specific features
- The joke coin dogecoin (2013) was an early example
- Mainly to make fun of crypto speculation
- Since then championed (?) by Elon Musk
- Dog Money by Remy
- Litecoin (2011) another early example
- Ethereum, announced in 2013 and public 2015 a more “advanced” blockchain
- More possibility for smart contracts
- Basis for tokens, scripting…
- Coins with enhanced privacy features another important category

PROOF-OF-WORK OR PROOF-OF-STAKE?

- PoW has been criticized for being too costly, using too much electricity
- Bitcoin mining uses more power than a country like the Netherlands (roughly 100 TWhs annually)
- These estimates come with a great deal of uncertainty, however
- PoS is an alternative way to mine new blocks
- How many coins a miner stakes determines his "power"
- Energy needs minimized
- Criticized for fostering centralization
- Implemented on ethereum, no plans for bitcoin

BITCOIN NETWORK POWER DEMAND, 2018-2023



WHICH BITCOIN? THE BLOCKSIZE WARS

Hard Forks of Bitcoin

- Leading to several versions of bitcoin
- Bitcoin Core (BTC) and Bitcoin Cash (BCH) are the most important ones
- Each is an independent coin and blockchain
- Bitcoin Core is the "main" bitcoin

The Core Issue: the Blocksize

- Should there be a limit on the size of each block?
- Tradeoff: cheap transaction with bigger blocks
- Vs. larger fixed costs for mining, the danger of centralization

BLOCKSIZE

The Blocksize Limit

- The blocksize limit was added in 2010 by Satoshi, set at 1MB
- A security feature for the network: to avoid spamming that could take bitcoin down
- Transactions free at this point, therefore spamming was a potential risk
- Spamming could in theory raise the size of new blocks indefinitely
- Hence the limit – but it was only meant as a temporary security measure

Problems of the Limit

- The number of transactions limited to about 3 per second – much too little
- Scaling is impossible with this limit, transactions become very costly
- Transaction fees introduced, people bid for (artificially) scarce space on the blockchain
- Transaction fees became very high, defeating the purpose of bitcoin

THE BLOCKSIZE WARS

The Big Block Arguments

- It's impossible to scale bitcoin with small blocks
- Blocksize increases can easily be programmed into bitcoin
- The extra data storage needed is not a real problem
- It's reasonable to expect continuing improvement – Moore's Law also applies here

The Small Block Arguments

- Bigger blocks compromise the bitcoin network
- Costs of running a node increases
- Centralization of mining into fewer hands results
- Larger blocks are not necessary: bitcoin is only for ultimate settlement

RESOLUTION: BITCOIN CORE

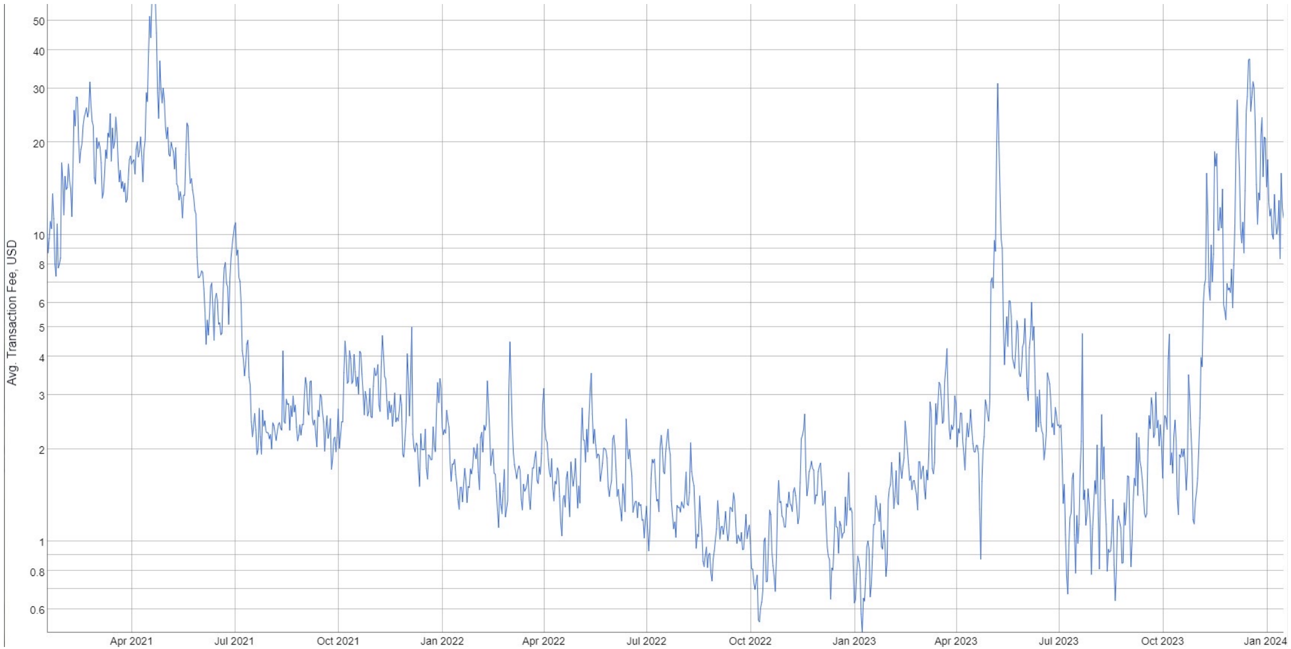
Small Block Solutions

- Block size limit, but BIP "segregated witness" would effectively raise the limit to 2MB
- Side chains and a "secondary layer" proposed: Blockstream and the Lightning Network
- Most of the (Chinese) miners were convinced by the Core team 2015

Developments Since

- Transaction costs rose on bitcoin from late 2016/early 2017 on, tops of over $50
- Much less more recently – generally below $1, but daily purchases effectively priced out
- Widespread adoption hampered – Steam discontinued December 2017
- The role of bitcoin (BTC): it's a store of value, a settlement asset – not cash
- Lightning Network has grown in popularity since 2021

BTC TRANSACTION FEES, 2021-2024



Source: bitinfocharts.com

RESOLUTION: BITCOIN CASH

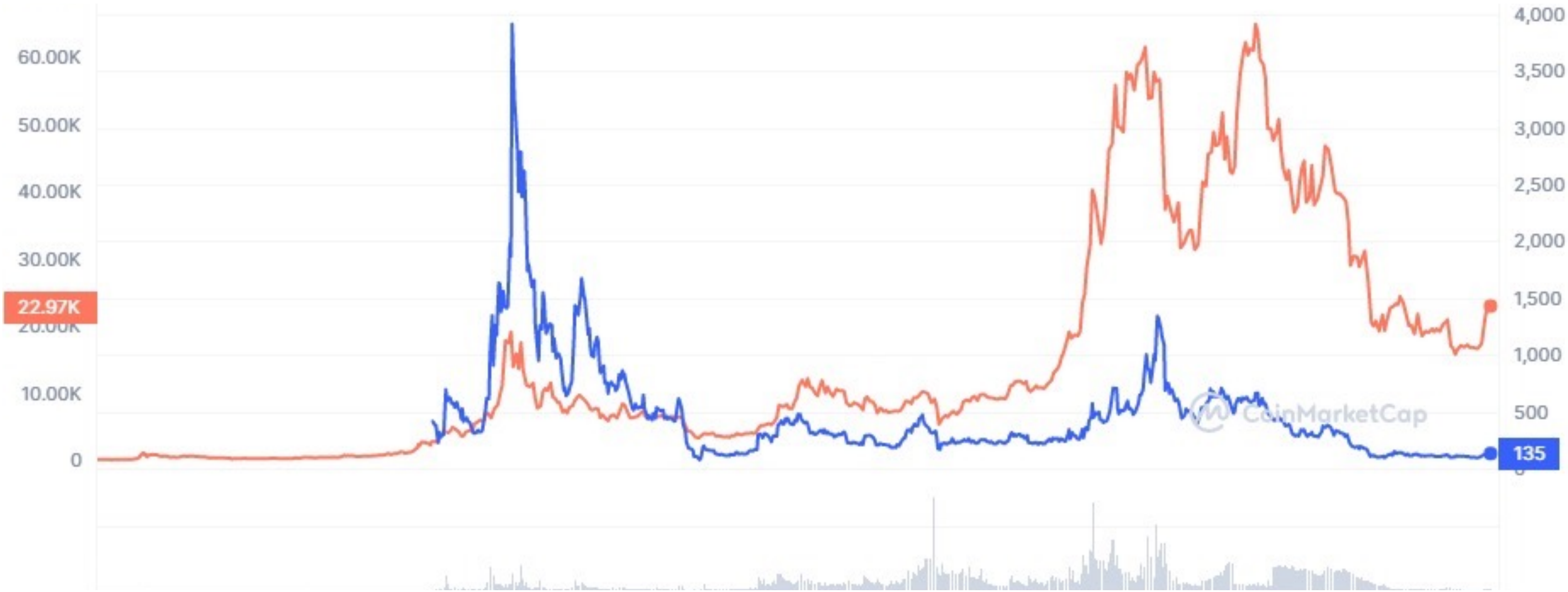
Hard Fork

- BIP that would raise the blocksize limit to 8MB rejected
- Hard fork from bitcoin (BTC) in 2017 lead to Bitcoin Cash (BCH)
- Most hashing power with BTC, “original” developer team with BTC
- Market value of BTC higher

Development Since

- Bitcoin Cash was very popular in the first years, but its popularity has since declined
  - ➢ Retail use of cryptos generally has declined
  - ➢ High fees on BTCs discourage it, confusion over forks?
- Innovation in traditional financial system caused costs to plummet
- In Europe, a hidden subsidy to credit card use make credit cards more desirable

BITCOIN CASH VERSUS BITCOIN CORE PRICE



Source: coinmarketcap.com

3. CENTRAL BANK DIGITAL CURRENCY (CBDC)

ORIGINS OF CBDCS

Early Discussions

- Academic discussions began around 2014-2015
- Discussions among central bankers in response to the rise of bitcoin
- Papers by BIS (2020), ECB (2020), Federal Reserve (2022)
- China (since 2014, active since 2020) and a few other countries already have a CBDC
- But little adoption so far: promoted via distributions, lotteries

Core Idea behind CBDC

- A digital form of the currently used currency (euro, dollar…)
- For use in the digital world, to promote financial inclusion
- Exchangeable at par with other forms (physical cash, bank money)

DESIGNING A CBDC

Blockchain or Central Issuer?

- Tokens
- Accounts with the central bank

Wholesale or Retail?

- Wholesale: a CBDC only available to banks and financial institutions, a settlement asset
- Retail: private persons have access to CBDC

Immediate or Mediated Access?

- Immediate: private persons have immediate access to CBDC
- Mediated: CBDC is administrated in accounts by banks, others

PURPOSES OF CBDC

Central Banks Want to Stay Relevant

- Claim that bitcoin shows demand for CBDC
- Claim that only central banks can provide a stable digital currency

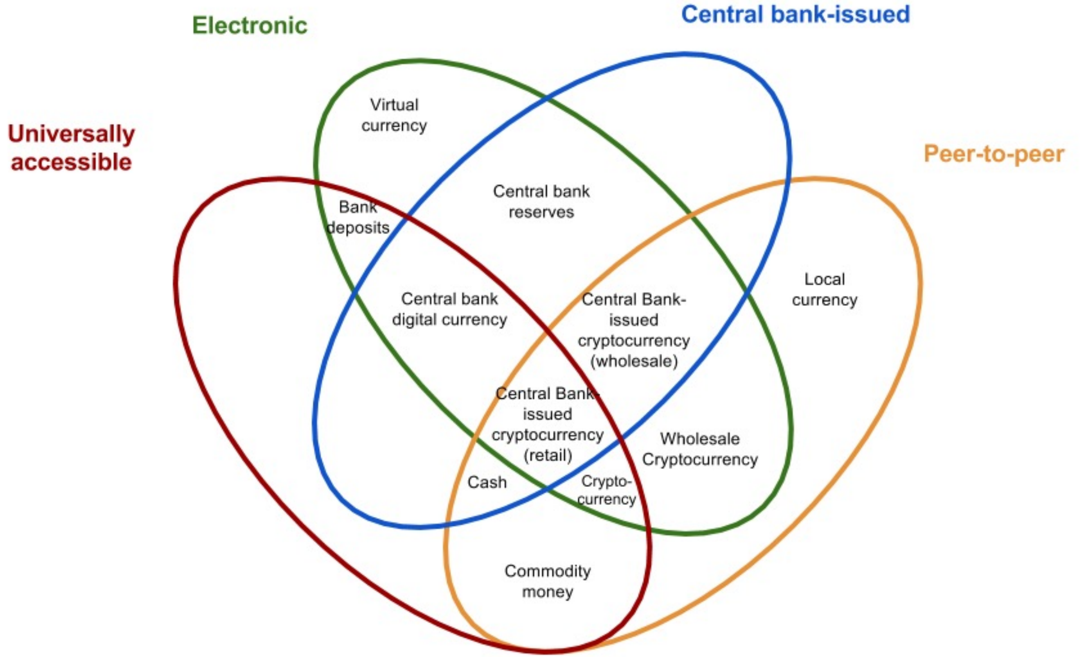
CBDC Necessary for Security

- To combat money laundering (Rogoff 2016)
- Prevent financing terrorism
- Privacy important, but conditional, CBs will have access to all transactions (ECB 2020)

CBDC a Potential Tool for Monetary Policy

- Negative interest rates
- Limits on cash holdings

THE MONEY FLOWER (BIS 2020)



CBDC AND MONETARY POLICY

Potentials of CBDC for Monetary Policy

- The "zero lower bound" on interest rates (Goodfriend 2000; Bordo & Levin 2017)
- Interest rate manipulation is difficult/impossible when nominal rates are low
- Negative rates → cash hoarding
- With a CBDC, a negative rate can be imposed on cash holdings

Encourage Spending, Penalizing Hoarding

- In a recession, it becomes possible to avoid "leakage" into hoards
- The central bank can penalize / outlaw "excessive" cash holding
- It can program money to lose value over time
  - ➢ E.g., after 1 month, holdings in excess of x euros will decline by 1 percent per month

CBDC, MONETARY POLICY AND PHYSICAL CASH

Physical Cash an Important Limit

- Negative rates can be avoided by shifting from CBDC to cash
- Same with programmed devaluation

Physical Cash and Other Concerns

- Surveillance through CBDC can be avoided through cash, other payments systems
- "Transparency" in this case really means complete government oversight and control
- Cash, private cryptos make this impossible – CBDC makes it possible, if no alternatives

Contradictory Central Bank Plans

- They want to respect privacy, they don't want to eliminate cash
- Their stated goals for CBDC can only be achieved by eliminating financial privacy, cash

CHINA, CBDCS AND INTERNATIONAL TRANSFERS

Wholesale CBDC as an Alternative to the Dollar

- China (and others) have plans for linking CBDCs
- E.g., BIS's Project mBridge (BIS 2022)
- One possible purpose: an alternative international payments system

Independent of the Dollar System

- It would make international trade risk less costly for countries not aligned with the U.S.
  - ➢ E.g., Iran, Russia, China
- Alternative to SWIFT for international payments
- Possible purpose: fixing exchange rates, recreating a system like Bretton Woods
  - ➢ Very unlikely

4. LITERATURE

LITERATURE

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