The Economic Limits of Bitcoin and the Blockchain

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- Overall take: ingenious, but economically limited.

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- Imagine transactions through a trusted party that keeps track of balances
  - That works just fine re: security issues listed above
  - But: requires a trusted party

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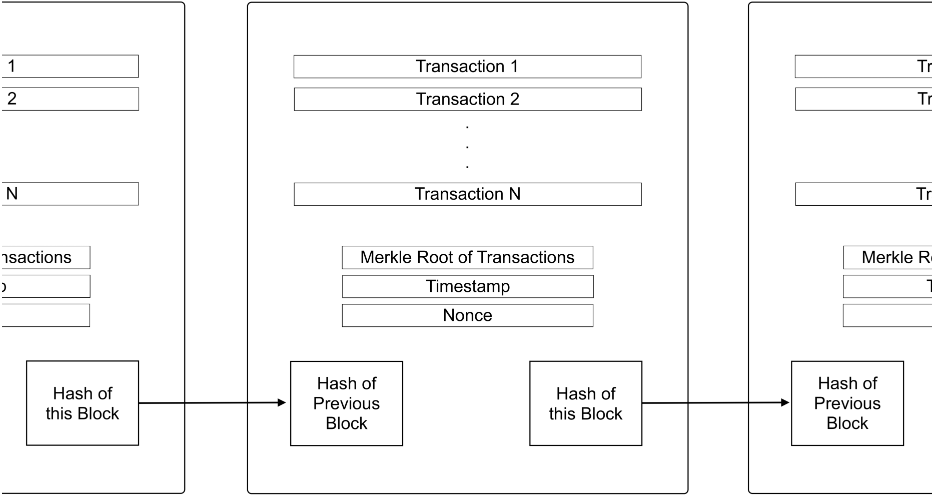
- Miner who finds a lucky hash reports their new block
  - Other miners check validity (fast), then start working on the next block
  - Winner earns reward paid in bitcoin ("block reward" ≈$100k)



Hash of this Block
Transaction 1
Transaction 2
Transaction N
Merkle Root of Transactions
Timestamp
Nonce
Hash of Previous Block
Hash of this Block
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- Anonymous, decentralized trust.
- But vulnerable to majority attack.

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- My critique is of blockchain in the sense of Nakamoto (2008), not of distributed databases more broadly

Critique in 3 Equations

Mining Equilibrium

- P_{block}: reward for winning miner
- c: per-block cost of one unit of computational power
- N: amount of computational power (each $1/N$ chance)
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Incentive Compatibility (Majority Attack)

- What is cost of majority? $N^{*}c$ per block
- α: expected duration of attack (net of rewards)
- V_{attack}: value of successful attack (discussed below)
- Incentive constraint:

$$\alpha \cdot N^{*}c > V_{attack} \tag{2}$$

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- Economics: *very expensive* form of trust. Memoryless.
  - Usual alternatives: relationships, brands, laws.
- Security: security is *linear* in amount of cpu power.
  - Example: a $1B attack is 1000x more expensive to prevent than a $1M attack.
  - Usual alternatives: cryptography, force, laws.

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  - Create new transactions that spend other participants' Bitcoins ("steal all the Bitcoins")
  - This would require not just >50% majority, but breaking modern cryptography

Attack I: Double Spending

- Attacker can double spend:
  - (i) spend Bitcoins — i.e., engage in a transaction in which he sends Bitcoins to a merchant in exchange for goods or assets
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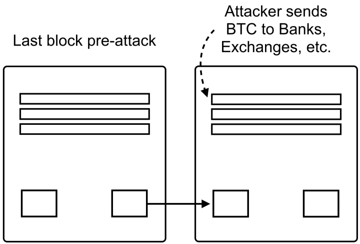
- Computational simulations
  - Escrow = 6 blocks → Implicit tax ≈ 30% ($\alpha = 3.35$)
  - Escrow = 1000 blocks → Implicit tax ≈ 2% ($\alpha = 53.5$)
- So if \$1M is easily transacted, tax from \$20k-\$300k *per transaction*

Illustration of Double Spending



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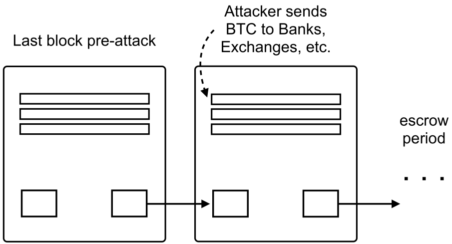

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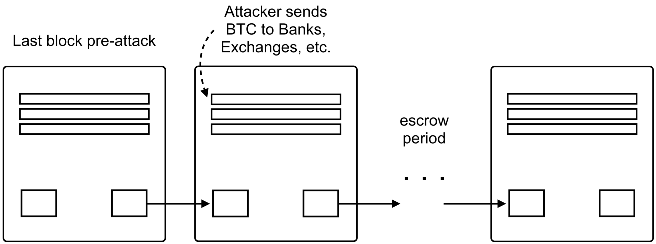

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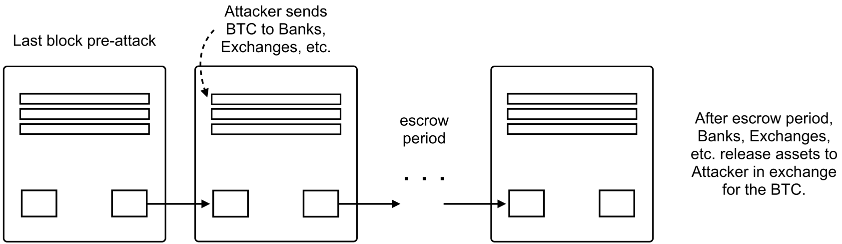

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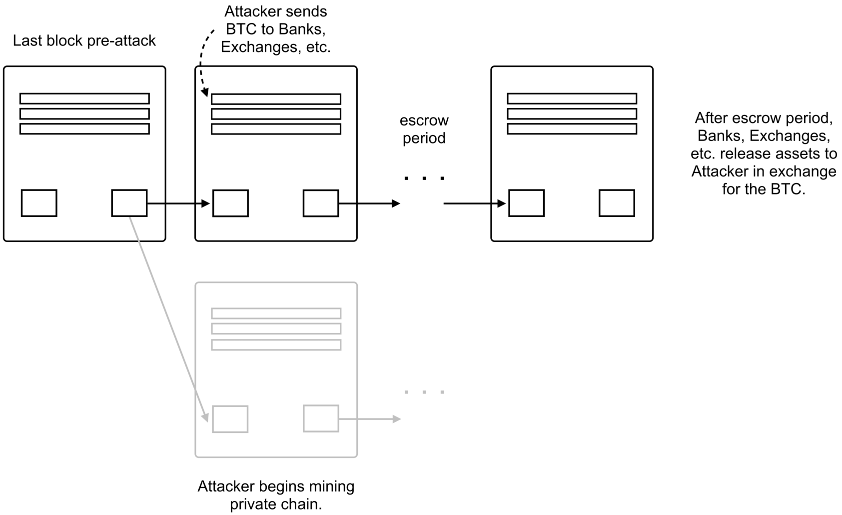

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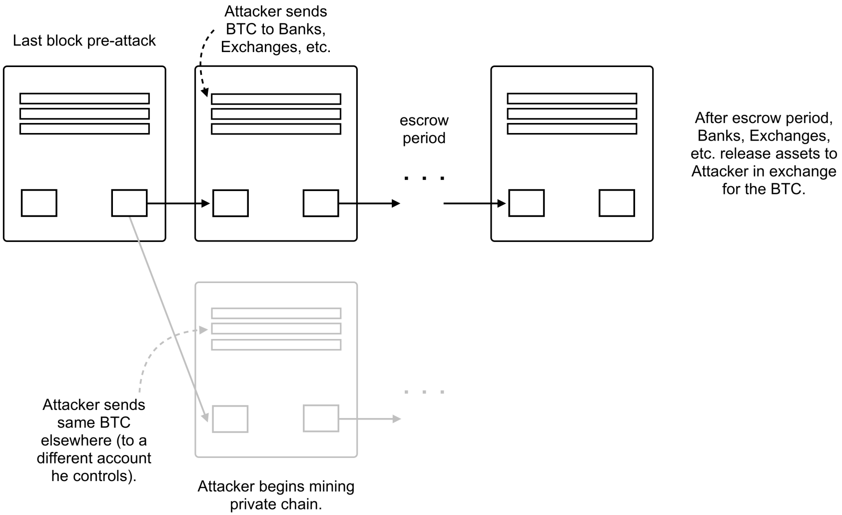

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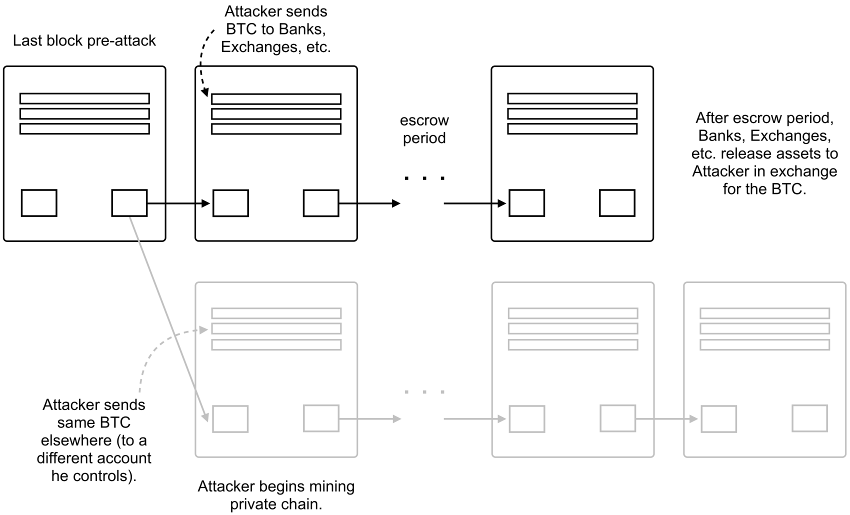

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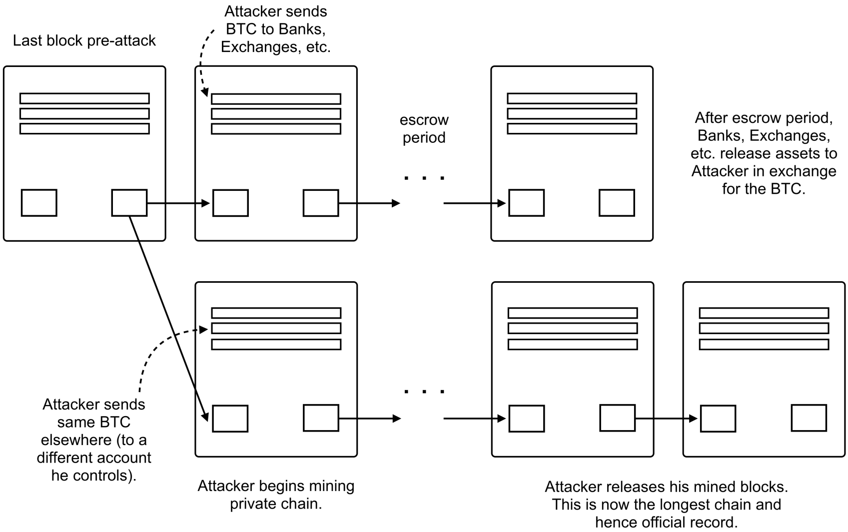

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- Casts doubt on Bitcoin as major component of global financial system
- For the system to be secure for large transactions requires implicit tax rates that render it unusable for small ones
- Surprise to CS community: that escrow period isn't more protective
  - That is, that α doesn't grow dramatically with e
  - Intuition: attacker earns block rewards while waiting for escrow to clear

Attack II: Sabotage

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  - Double-spending is pointless
  - Cost is now <u>stock value of the specific capital</u>
- New constraint:

$$N^* C > V_{sabotage} \tag{2'}$$

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- However, "pick your poison":
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  - Either: high implicit tax rates or risk of collapse

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   - If Bitcoin value falls (for other reasons): glut of chips relative to amount needed for mining equilibrium (1)

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- Model then suggests 3 possible scenarios that could precipitate collapse:

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   - As tech matures: cheap previous-gen versions, or current-gen version becomes cheap enough that electricity becomes the predominant component of cost. Flow cost not stock.
   - If Bitcoin value falls (for other reasons): glut of chips relative to amount needed for mining equilibrium (1)
2. Efficient-enough repurposable chips
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Collapse Scenarios

- Suppose, for purpose of discussion
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   - If blockchain grows in importance and repurposable chips get better at hashing. Then flow cost not stock.
3. Economic sabotage becomes sufficiently tempting
   - Futures markets grow
   - Bitcoin grows in economic importance

Examples of 51% Attacks

Name	Hash function	Date of First Attack	Amount Stolen
Verge	Scrypt, X17, Lyra2rev2, Myr-groestl, Blake2s	4/4/2018	$2,800,000
Monacoin	Lyra2rev2	5/13/2018	$90,000
Bitcoin Gold	Equihash	5/16/2018	$18,000,000
Litecoin Cash	SHA-256	5/30/2018	Unknown
Zencash	Equihash	6/2/2018	$700,000
Vertcoin	Lyra2rev2	10/12/2018	$100,000
Ethereum Classic	Ethash	1/5/2019	$1,100,000

Sources: Coindesk, Bitcoinist, CCN, and Cointelegraph. The hash functions listed here are the hash functions at the time of the attack. Often there is an ambiguity of whether several block reorganizations should be considered as 1 attack or several attacks. Because of this, only the date of the first attack/reorganization is mentioned.

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  1. Security relies on use of scarce, specialized chips
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- The analysis then points to specific collapse scenarios
- Overall message: there are intrinsic economic limits to how economically important Bitcoin can become. If it gets important enough, it will be attacked.

Conclusion: Remark

- Emphasize: model consistent with earliest uses of Bitcoin and blockchain
- Skepticism:
  - Bitcoin as "store of value" akin to gold
  - Bitcoin as a major component of the global financial system
  - Use of Nakamoto blockchain by businesses, governments

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  - Use of Nakamoto blockchain by businesses, governments
- Also emphasize: not skeptical of use of distributed databases more broadly
- What this paper highlights is that it is exactly the aspect of Bitcoin and Nakamoto (2008) that is so innovative relative to traditional distributed databases — *the anonymous, decentralized trust that emerges from proof-of-work* — that also may make it so economically limited