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# Discussion of: Miner Collusion and the BitCoin Protocol
# by Alfred Lehar and Christine A. Parlour

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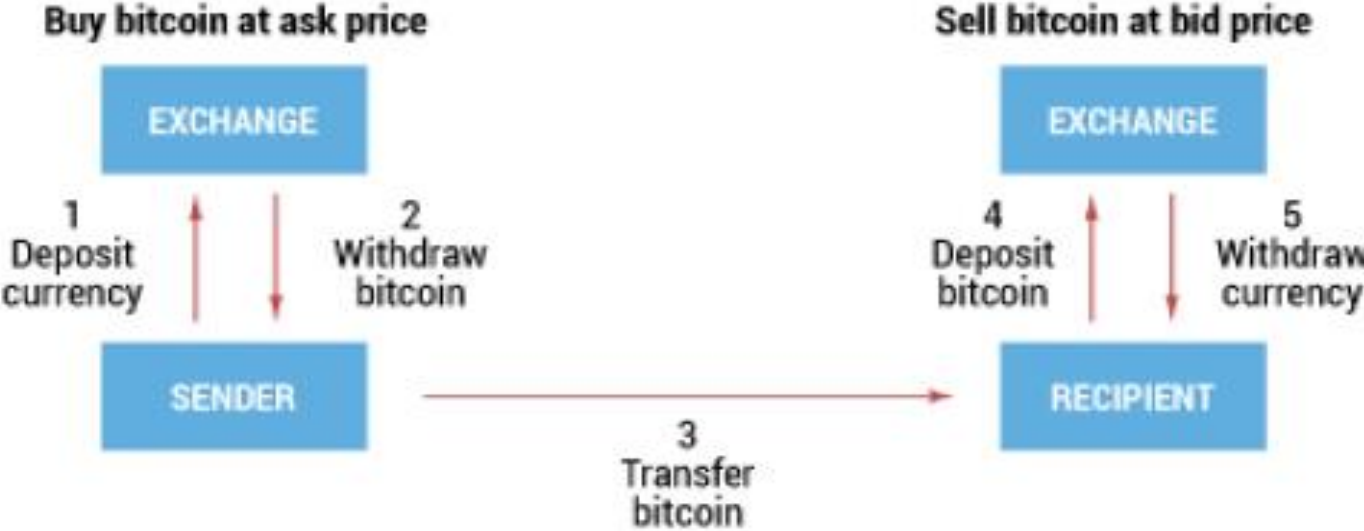
**Federal Reserve Bank of New York**

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# Friction in Bitcoin Ecosystem

- Why friction matters:
  - Bitcoin as asset: matters to investors
  - Bitcoin as medium of exchange: affects exchange rate with fiat currency

- Sources of friction:
  - Bitcoin-fiat money exchange: Costs and delays
  - Complexity of bitcoin ecosystem

- Issues: Capacity constraints, mining and transactions fees

# Bitcoin: Interface with Traditional Finance



Bitcoin as a Value Transfer System with Exchanges

Buy bitcoin at ask price

EXCHANGE

1 Deposit currency  2 Withdraw bitcoin

SENDER

3 Transfer bitcoin

Sell bitcoin at bid price

EXCHANGE

4 Deposit bitcoin  5 Withdraw currency

RECIPIENT

Note: "Exchange" here can also refer to a dealer such as a company running a "Bitcoin ATM."

# Two Views on Bitcoin Capacity Constraints

- Bitcoin protocol push miners' block rewards (in new coins) to zero
  - Transactions fees (paid by users) reward miners when arrival rates are high

- Fixed protocol and high transactions demand: bitcoin may be non-viable
  - Competitive, price-taking miners earn zero expected profits; users determine fees
  - High demand: congestion queuing: transaction fees>0; waiting times in equilibrium
  - Fees too low & mining non-viable (Huberman, Leshno, Moallemi 2017) or too high & discourage user participation (Easley O'Hara Basu 2019)
  - Users migrate to traditional payments system (Hinzen, John, Saleh 2019)

- This paper:
  - Capacity endogenous: Unused even with fees
  - Miners act as if they price discriminate
  - Competitive mining, but mining pools act collectively
  - Undermine decentralization + security of a blockchain ("selfish mining. Eyal and Sirer (2014) and Eyal (2015))

# Rising importance of transaction fees

Easley, O'hara and Basu 2019

Panel B: Percent of miner revenue derived from transaction fees
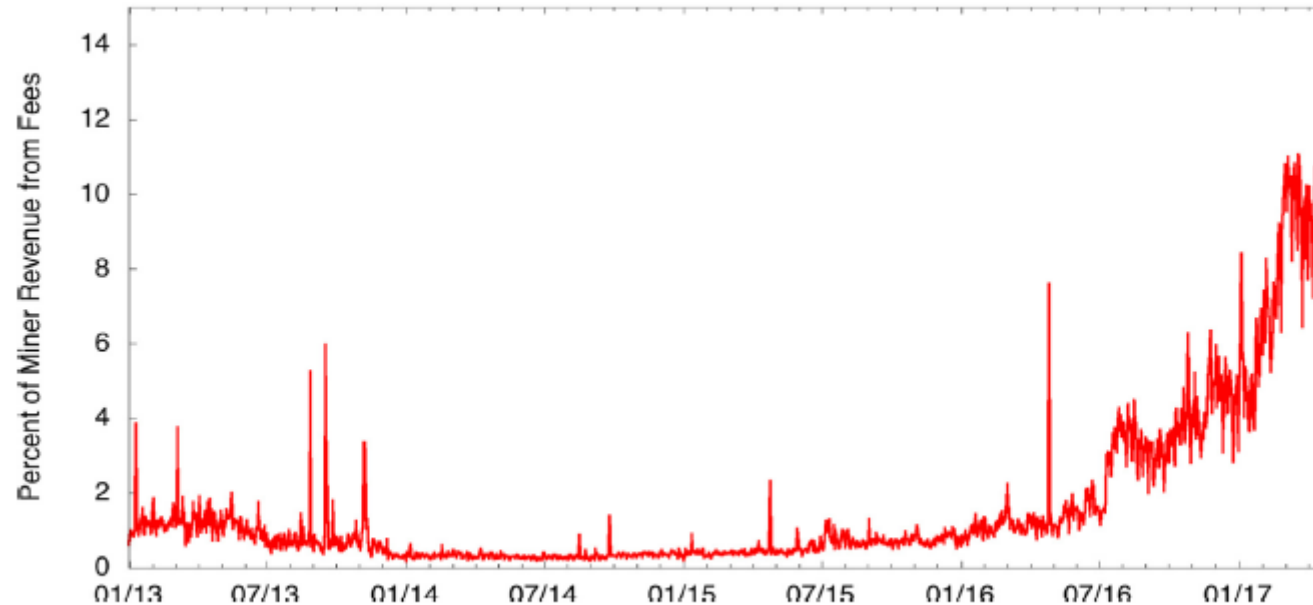


**Fig. 1.** Total bitcoin transaction fees. This figure gives yearly data on the level of transaction fees [measured both in US dollars and in bitcoins (BTC)] and on the relative importance of transaction fees for overall miner revenue.

# Outline of Discussion

- Summary of paper

- Dynamics of mining pools

- Incentives to collude in mining ecosystem

- Empirical results

- Conclusion

# Summary: Model

- Empirical observations
  - Capacity is not constrained: excess capacity even on worst day
  - Not due to lack of demand or empty mempool
  - Miners choose to "leave money on the table"

- Model: this behavior is optimal if miners price discriminate
  - All orders executed by price priority; full capacity
  - Miners execute orders by price priority; ration strategically

- Rationing equilibrium:
  - If servicer commits to execution probabilities for certain bids, then can induce higher bids from those with greater immediacy
  - Servicer executes high bid with prob. 1 and all other bids with prob. < 1

- Sustain collusion by punishing deviation: full capacity mining forever
  - Unique equilibrium?

# Dynamics of Mining Pools

Cong, He, Li 2019: mining pools have close to 100% share of hash rates since 2015
- Pool shares appear to mean-revert
- Empirically, larger pools charge higher fees but grow slower
- Price discrimination by any one pool possible, but may be temporary
- Other limits to pool size: no increasing returns to scale in cryptography
  - Individual miners belong to multiple pools: can "undo" power of pools

Figure 1: The evolution of size percentages of Bitcoin mining pools

This graph plots (1) the growth of aggregate hash rates (right hand side vertical axis, in log scale) starting from June 2011 to today; and (2) the size evolutions of all Bitcoin mining pools (left hand side vertical axis) over this period, with pool size measured as each pool's hash rates as a fraction of global hash rates. Different colors indicate different pools, and white spaces indicate solo mining. Over time, Bitcoin mining has been increasingly taken over by mining pools, but no pool seems to ever dominate the mining industry for long. The pool hash rates data come from Bitcoinity and BTC.com, with details given in Section 5.
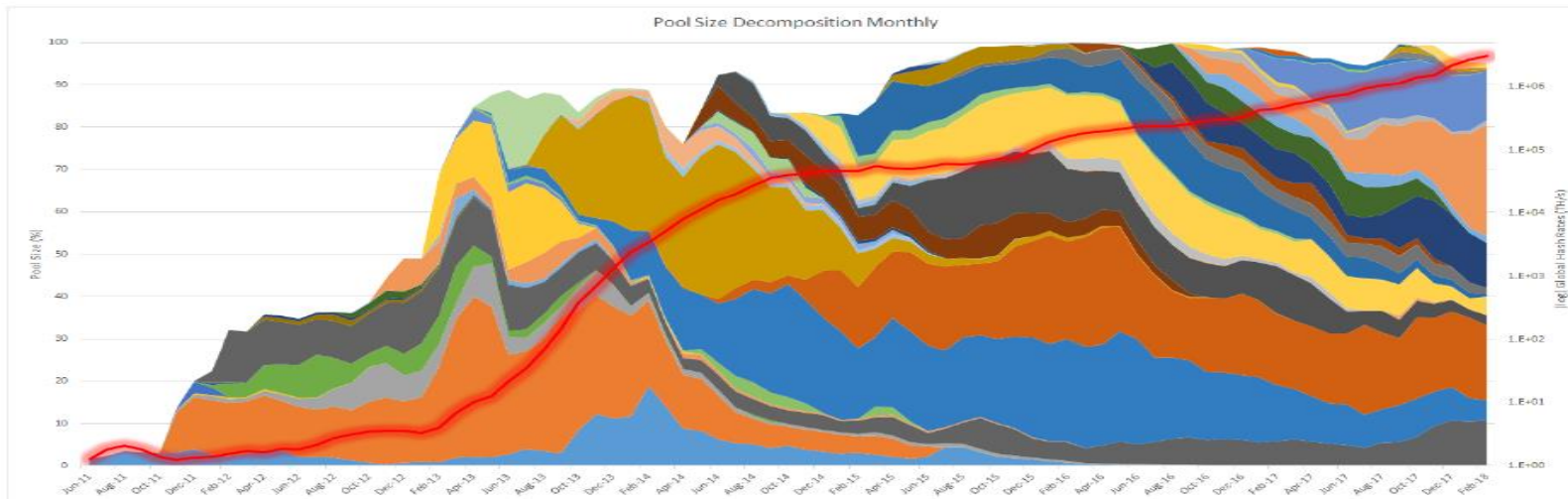
# Mining Pools' Incentive to Collude

- Mining pools:
  - Offer differentiated (wrt software, payment method etc.) services
  - Most important: sell insurance to individual miners (as high upfront costs)
  - Benefits of risk sharing increase with aggregate mining activity
- Aggregate hash activity increased with growth of mining pools: consistent with rationing?

- Pool managers decide which blocks to mine
- Mining pool combines hash rates of many miners to solve single cryptographic puzzle
- Pool's mining rewards (including transaction fees) shared with between miners & pool owners in proportion to hash rate contributions
- Pools have incentive to price discriminate to increase profits

- Pools often owned by specialized mining equipment manufacturers (e.g. Bitmain Technologies)
  - Make most money from selling or renting equipments
  - Incentive to set low transaction fees to maximize revenues from equipments (Ferreira, Li, Nikolowa 2019)

# Empirical Analysis

- Regressions of fee spread on measures of immediacy
  - Also explain activity variables?

- Highly skewed distributions: Quantile regressions?

- Results suggestive of Pr. Discrim. but other explanations possible:
  - Fees higher during the week: due to higher value trading + bitcoin futures
    - Volatility effect (i.e. trading increases volatility)?
    - Diff in diff: Compare before and after bitcoin futures?
  - Higher Kimchi premium asso. w higher fees: Arbs value immediacy - share profits w miners
    - Cross-currency trades involve more delays and higher volatility (Choi, Lehar, Stauffer 2018)

- Some results have unclear mechanisms
  - Fees higher when min. outtime lower (funds spent sooner)
    - How do immediacy seekers pressure senders to lower outtime?
  - Flows to and fro from exchanges & gambling sites transact at higher fees: exch. traders & gamblers desire immediacy
    - Why not move off-exchange?

# Conclusion

- New empirical facts about bitcoin capacity and fees

- New view of mining ecosystem: miners price discriminating between bidders with high and low valuation

- Model: is price discrimination sustainable in long-run?

- Empirics: many suggestive results but need to rule out alternative interpretations