Blockchain structure and cryptocurrency prices

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Any views expressed are my own and do not reflect those of the Bank of England or Federal Reserve System.

Abstract

- A cryptocurrency has two distinctive features:
  1. a price determined by the extent of its monetary usage;
  2. a blockchain structure that restricts settlement capacity.

- Novel price formation. Speculation takes up blockchain space, making it perform worse as money. That reduces its price.

- This crowding-out raises riskiness of buying cryptocurrency, explaining high observed price volatility.

Cryptocurrencies are not much used as money...

Ohio is the first state to accept Bitcoin tax payments

Updated Nov 26, 2018;Posted Nov 26, 2018

Cryptocurrencies are not much used as money...

Oct 2, 2019

Ohio businesses can no longer use Bitcoin to pay taxes – but will they care?

Fewer than 10 businesses ever used the platform

... so why are prices so volatile?

- Purely speculative assets (Krugman, 2018)
- Fixed supply schedule (Saleh, 2018)
- Market manipulation (Gandal, Hamrick, Moore & Oberman, 2018; Griffin & Shams, 2019)

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But then we should see high volatility for any unregulated worthless asset in fixed supply. What makes cryptocurrencies special?

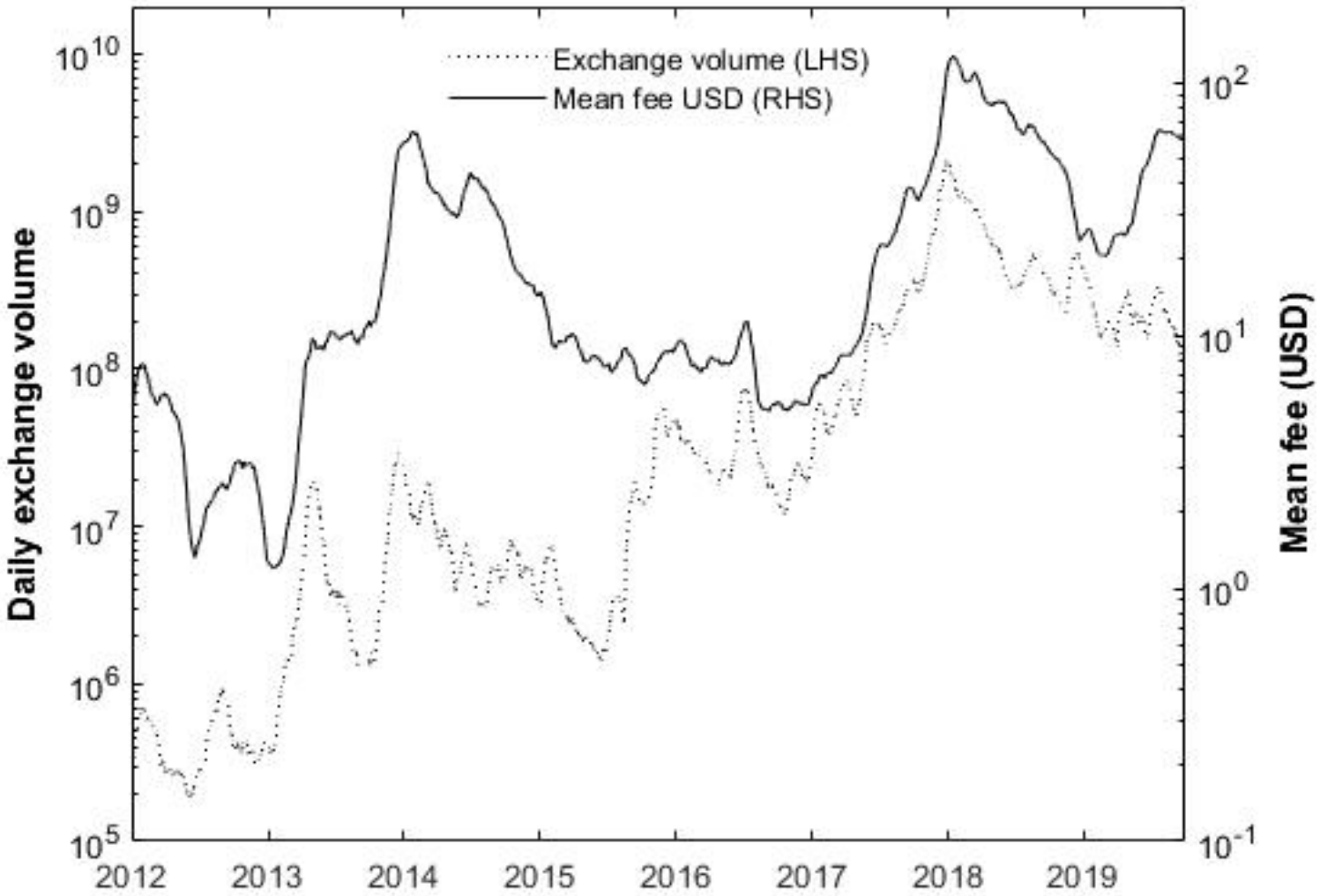
What makes cryptocurrencies special?

1. **Endogenous value:** Monetary tokens with value determined by their usage as a medium of payment.

2. **Blockchain structure:** Transfer of ownership of cryptocurrency is final only when it is recorded on the blockchain, which has finite and exogenous capacity.

Mining fees respond to speculative demand ...

30-day backward moving average



...and have affected the efficacy of crypto as a medium of payment

A bitcoin conference has stopped taking bitcoin payments because they don't work well enough

- The North American Bitcoin Conference, held in Miami next week, said it has stopped accepting last-minute ticket payments in bitcoin
- Bitcoin's slow transaction speed and high fees have led many merchants to rethink their decisions to accept payments in the cryptocurrency

Saheli Roy Choudhury

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CNBC

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Households

- Three assets: consumption good (numéraire), crypto, and cash.
- At T_0, a unit mass of risk-neutral households. Each aims to maximize utility from consumption over T_1, T_2. No budget constraints.
- Each household can consume at most one unit of consumption good at T_1. Consumption at T_2 is discounted by factor $\rho < 1$.
- At T_0, each household chooses whether to use crypto or cash to buy a unit for early consumption.

Crypto technology

- Crypto is embedded with a superior payment technology. Strength of technology is R, determined by nature and observed by all households.
- If a household pays using crypto, she gets a non-pecuniary bonus of $Rg(y)$, where $y \in [0, 1]$ is total number who use crypto. Strategic complementarities: $g(y)$ is increasing.
- Households face a coordination problem. Focus on payoff dominant outcome.

Cost of waiting

- Consumption takes place at T_1 only if payment settles. Cash always settles at T_1.
- Blockchain capacity $N \sim Z_\lambda(n)$, parametrized by block rate λ. Pointwise decreasing in λ.
- If use crypto, households can choose a fee $f \geq 0$. Priority assigned according to fees.

Speculators

- Value of crypto is $v(y)$: increasing, $v(0) = 0$.
- At T_0, a mass M of speculators is born. Speculators observe R and infer $v(y)$.
- They use their information to trade on an exchange; i.e. expected payoff depends on beliefs about households' actions. Unit trades.
- Market maker sets the price contingent on a noisy signal of order flow $z = x + u$, where x is total speculators' order and $u \sim U[-\ell, \ell]$.
- If buy order, crypto must be moved off exchange to buy consumption goods, so speculators face blockchain capacity problem, with discount factor ρ. If sell, immediate consumption.

Timeline

T_0

- Technology R realized by nature.
- Households and speculators born and observe R.
- Households choose payment method and fee.
- Speculators choose trade order and fee.
- Market maker sets price and trading takes place.

T_1

- Blockchain capacity N realized.
- N crypto payments and all cash payments settle, and early consumption occurs.

T_2

- All remaining consumption occurs and game ends.

Strategic complementarities stronger than substitutes

Assumption

If a household believes all others use crypto, and all speculators buy, payoff from using crypto is higher than when everyone uses cash.

$$\frac{Z_\lambda(1+M)}{Z_\lambda(0)} \leq \frac{g(1)}{g(0)}.$$

Equilibrium

Result 1

There is a unique threshold equilibrium.

All households use crypto, and all speculators buy, if $R > R^*$. All households use cash, and all speculators sell, if $R > R^*$.

$$R^* = \begin{cases} (1-\rho)\,\frac{Z_\lambda(1+M)}{g(1)}, & \text{if } \rho V \geq 1-(1-\rho)Z_\lambda(1), \\ \frac{1-\rho}{g(1)}\left(Z_\lambda(1)+\rho V\,\frac{Z_\lambda(1+M)-Z_\lambda(1)}{1-(1-\rho)Z_\lambda(1)}\right), & \text{if } \rho V < 1-(1-\rho)Z_\lambda(1). \end{cases}$$

R^* is decreasing in the block rate λ, and increasing in the measure of speculators M.

Price formation

- More speculators $M \rightarrow$ Higher threshold $R^* \rightarrow$ Lower beliefs about payment usage $y \rightarrow$ Lower price.
- More buy-side trading can reduce the market maker's price. This implies pricing function can be locally decreasing in demand!

Price volatility

- Define *price volatility* as the standard deviation of the change in price from prior to posterior:

$$\Gamma := \sqrt{\mathbb{V}\left[\frac{\text{price}}{\mathbb{E}[\text{price}]}\right]}.$$

Impact of blockchain capacity on price volatility

Result 2

In the threshold equilibrium, price volatility is:

$$\Gamma := \sqrt{\frac{M}{\ell}\left(\frac{B(R^*)}{1-B(R^*)}\right)},$$

where $B(R)$ is distribution function of R.

As block rate λ falls, or measure of speculators M increases, R^* rises, and the volatility increases.

Imperfect information (households only)

Suppose $\frac{g(y)}{Z_\lambda(y)}$ is increasing for all y.

Result 3

Suppose R is uniform, and each household i observes imperfect signal R_i, where $R_i \sim U[R-\sigma, R+\sigma]$ iid.

1. There exists $\bar{\sigma}$ s.t. $\forall \sigma < \bar{\sigma}$, there exists a threshold equilibrium. Households use crypto iff $R_i > R_\sigma^\dagger$.
2. For any $\delta > 0$, there exists $\sigma_\delta > 0$ s.t. $\forall \sigma < \sigma_\delta$, households use crypto if $R_i > R_\sigma^\dagger + \delta$, and use cash if $R_i < R_\sigma^\dagger - \delta$.

In this sense, the threshold equilibrium exists and is unique in the limit as $\sigma \to 0$.

What might happen in the future?

Amara's Law

"We tend to overestimate the effect of a technology in the short run and underestimate it in the long run."

Unlike most other technologies, speculation gets in the way of adoption.

1. **Hype phase:** Little adoption, lots of speculation. Prices low and volatile.
2. **Adoption phase:** Price stabilizes, speculation falls. Adoption begins.

Conclusions

- This is the first paper to endogenize both the financial market for cryptocurrency and the market for blockchain space.
- Speculation leads to less monetary usage, lower prices, and higher price volatility.
- The results rely on two distinctive characteristics of cryptocurrency:
  1. Finite blockchain capacity $\rightarrow$ crowding out effect.
  2. Endogenous value determined by usage $\rightarrow$ pecuniary effect.