Virtual Coinage: Network Evidence on Decentralized Currencies

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Virtual Coinage: Network Evidence on Decentralized Currencies

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Society for Economic Measurement Meeting, July 24, 2015
Virtual coins: biggest innovation in payment systems and coinage

Peer-to-peer trading/lending emerged—new paradigm:

1. (Digital) protocol for trust building: cryptography ensures traders/peers are treated fairly and securely
2. Eliminating monopoly powers: peers are equally privileged, ex ante no entry costs
3. Technology as substitute for central banks: no political influences
4. Small networks: chance of repeated interaction is high
5. Validation and coinage externalities: miners rewarded with seigniorage
Digital currencies: first real life example (since 2009) of large scale decentralized currencies

No central bank: trust guaranteed—addresses are public, all transactions are registered and verifiable

Miners (voluntarily) coinage services: solve cryptograms, seigniorage rewards (deflation is built in)

Commitment technology: increasing difficulty of cryptograms

Old unanswered question in monetary economics: sustainability of decentralized currencies
Difference with local currencies

- Before only “local currencies” used in small communities to support local empowerment
  - Examples: BerkShares (2006) in Berkshires Massachusetts, Ithaca Hours oldest local currency
  - Trust based on local knowledge
- Bitcoin on contrary (large):
  1. Quasi-anonymous transactions
  2. Trust due to digital ledger (memory: all transactions recorded and verifiable)
  3. No intermediary
Methodological interest

- **B-dataset**: all transactions are recorded
- **Examples**: compute velocity directly (assess extent of speculative trading), compute network statistics (assess market microstructure)
Digital currencies: unit of account, store of value

- Not really: fluctuates too much → fixed supply but speculative demand
- Excess volatility and prone to bubble
- Not the stable Hayek money
- Intrinsic value given by the cost of computing (it is partly commodity money)
- BUT market value depends → traders expectation that it will accepted tomorrow (self-fulfilling expectations)
Digital currencies: medium of exchange

- Not widely accepted (low velocity for transactions)
- Trend in purchasing power vis-a-vis USD and EUR quite stable
- But real exchange rate in short run highly volatile
Seigniorage costs and collective externalities

- The validation service: a collective externality
- Incentive to miners: rewarded with seigniorage
- New coins are created through human capital
- Agents sort into miners or traders depending on whether they have wealth or human capital
- More an * assortative network rather than random search*
Road-map

- Monetary statistics (velocity, purchasing power)
- Asset price: volatility and bubbles
- Market concentration
- Network statistics (static and dynamic): degree distribution, Gini coefficient, clustering, assortativity, connected component...
- Linking volatility of price to network metrics through principal component regression
Main facts of interest

- Highly volatile and prone to bubbles (supply fixed, but speculative demand)
- Highly concentrated→concentration cycles related to operating costs (Hashrates)
- Shumpeterian cycles: higher difficulty, more innovation, higher rents
- Highly clustered, becoming more assortative and more connected: few middlemen acting as gatekeepers
- Highly unequal: high Gini coefficient
- For prices market structure matters
Evolution of Transactions (Compared to Traditional Currencies)

- **Average Bitcoin market price** (last six months): 150 US dollars
- **Volume**: 14.4 millions Bitcoin in circulation, equivalent to about 4 billions

Compared to:
- a. 1.37 trillions USD in circulation
- b. 1.06 billions euro in circulation

- First three months 2015: average about 500 bitcoins transactions per minute

Compared to→Average of 130 VISA processed transactions per minute

- Average bitcoin transaction size is 0.27 bitcoin, equivalent to $67.03

Compared to: average dollar transaction size of $70.59
Figure: **Velocity (ratio trades over transactions)**: large speculative motives, limited scope for medium of exchange.
Figure: **Real exchange rate** of bitcoin relative to US dollars, using euro as a numeraire good. Highly volatile, but trending upward.
Figure: **Price volatility:** Close to Close Estimator, $\sigma_{CC} = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (R_i - \bar{R})^2}$

where $R_i = \log \left( \frac{C_{i+1}}{C_i} \right)$ and $\bar{R} = \frac{1}{n} \sum_{i=1}^{n} R_i$. 
Figure: **Bubble.** Difference bitcoin market price and the total cost of mining. Cost of capital (software, electricity) is commodity value of Bitcoin. Data for first semester 2014: burst of the bubble from a pick in 2013.
Figure: **Market concentration versus entry costs.** Herfindahl-Hirshman Index ($HHI := \sum_{i=1}^{N} s_i^2$) versus Hashrate ($\hat{h} = \frac{\lambda 2^{32} D}{t}$, with $D$ being difficulty and assuming that cryptogram solution follows a Poisson process).
Figure: **Degree distribution**: rather steep, hence unequal (few nodes with many degree). Not random network, but rather concentrated.
Figure: **Estimated power law exponent.** $p(d) = cd^{-\gamma}$, as $\gamma$ get smaller, the distribution is more fat-tail or characterized by very few nodes with high degree, and many nodes with low degree.
Figure: Gini coefficient. Metric for inequality, $G := \frac{2}{n} \sum_{i=1}^{n} \frac{id(i)}{d(i)} - \frac{n+1}{n}$, where $d(1) \leq \ldots \leq d(n)$ are the sorted degrees in the network. It captures also market concentration and potential to profit extraction.
Figure: Clustering. Metric $C := \frac{3t}{s}$, where $t$ is the number of triangles and $w$ is the number of 2-star. The clustering is the tendency of nodes to form small groups with many links. It fluctuates with market concentration.
Figure: Assortativity: measured by the Pearson correlation coefficient. Negative typical of technological networks Bitcoin blends social and technological component since it is semi-anonymous (role of reputation).
Figure: Largest Connected Component of each network consists in the set of all nodes that are connected among them and disconnected by the other nodes.
Figure: **Reciprocity.** $r := \frac{1}{m} \#\{(i, j) \in N \times N | a_{i,j} = a_{j,i} = 1\}$, it represents the probability that, for a given link, there exist a link in the opposite direction. Measures the extent of *trust* in a semi-anonymous network. It collapsed after Mt.Gox bankruptcy.
Log-linear static model augmented with a linear trend:

$$\log(p_t^B) = \beta_0 + \beta_1 x_{1t} + \cdots + \beta_p x_{pt} + \beta_{p+1} t + \epsilon_t, \quad t = 1, \ldots, n.$$ 

- Explain most variations in prices:
  - connected and largest strongest connected component
  - the power law exponent (of the degree distribution)
  - the density
  - the reciprocity
  - assortativity
Figure: Actual observation versus fitted PCR equation.
Theoretical Underpinning

- Sorting model (Becker 1973): agents sort themselves into traders (liquidity shocks), speculative (expectations), miners (no wealth but human capital)

- Production function for Bitcoin: automated process to substitute central bank, input → cost and miners’ human capital:
  \[ B = z(n)^{\gamma_1} (k)^{\gamma_2} \]

- \( n \) number of miners each with ability \( h \), and \( k \) the software capital needed

- Commodity value of Bitcoin is \( MP_h = \frac{\partial B}{\partial h} \), \( MP_k = \frac{\partial B}{\partial k} \). Bubble component: subjective expectation of traders

- Miners’ abilities are distributed according to distribution \( G(h) \)
Theoretical Underpinning

- To produce sorting link $z$ and $h$ as follows:

$$F^h(z) = H[z - g(h)]$$

- Traders and miners enter market if their discounted value higher than outside option

- Sorting condition:

$$V^M(\tilde{z}(h), k(h)) = V^T(h)$$

- Under complementarity two opposing equilibria for miners:
  - low human capital (and no wealth) → many miners
  - high human capital → concentrated market
Conclusions

- B-data allow for several insights
- No stable currency, primarily used for speculative purposes
- Varying degree of concentration depending on hashrates: entrepreneurial cycles
- Inequality remains
- Network evolution (mainly due to net demand, supply is fixed) determines asset price volatility
- Assortative matching (no random) with self-fulfilling expectation in price formation