Law of One Bitcoin Price?

Alexander Kroeger and Asani Sarkar
Analysis Group and FRBNY

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The views stated here are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of New York, or the Federal Reserve System.
What is Bitcoin?

- Bitcoin is a virtual currency, launched 2009
  - “Unregulated, digital money, issued and usually controlled by its developers, and used and accepted among members of its specific virtual community” (ECB 2012)
  - Decentralized: mutually agreed set of codes ("bitcoin protocol")
  - Not issued and regulated by central authority
  - Does not constitute legal claims on issuers (unlike FR notes which are technically claims on assets of FR system)
  - Blockchain: public ledger on which entire history of bitcoin transactions is recorded

- Likely benefits: bitcoin protocol may reduce fees, time, risk in transferring value (e.g. 10-min settlement vs 1-2 days for ACH)
  - Accepted for payment by range of businesses and non-profits
  - Startups: proposed new businesses

- BUT bitcoin is not widely accepted unit of account in and of itself
**Bitcoin Value Transfer**

- Bitcoin to bitcoin between digital wallets relatively frictionless (though less so recently due to bottlenecks in network capacity)
- Need to exchange bitcoin for fiat currency in most cases (e.g. major retailers use 3rd parties to receive bitcoin from customers)
  - Buy bitcoin from exchanges using fiat currency
  - Bitcoin receivers typically don’t hold it but exchange back to fiat currency
    - Volatile exchange rate between bitcoin and fiat currency
    - Low correlation with fiat currency

Note: “Exchange” here can also refer to a dealer such as a company running a “Bitcoin ATM.”
For digital-marketing agency Cooperatize.com, taking bitcoin for payment was easy enough, all co-founder Roger Wu had to do was obtain a digital wallet. The number of transactions the New York-based firm has made since [2014]? Zero. “The biggest thing is are people willing to pay in bitcoin?” Wu said. “The reality is that most of our customers are other businesses and other businesses don’t use bitcoin.” Even as the euphoria over bitcoin reached a fever pitch last week as the price surged to almost $3,000, slow transaction times and inertia are helping to prevent it from achieving widespread usage. Adoption has slowed, according to Morgan Stanley, after a slew of companies from Microsoft Corp. to Expedia Inc. initially trumpeted its use, and hurdles remain when it comes to longer-term viability. “We see few reasons for consumers to use bitcoin over a credit/debit card given that paying online with bitcoin represents a marginally more inconvenient way to pay,” Morgan Stanley analysts wrote in a 33-page report released June 13. Processing costs for bitcoin and other digital currencies are likely to grow, they said. Time Inc. and Dell Inc. said they’ve stopped accepting the cryptocurrency, with the computer maker citing low usage.

--Justina Lee, June 19 2017, Bloomberg
3 exchanges wrt BTC-E for US $ - bitcoin transactions
- Volume-weighted average price per day; 2013-2016
- BTC-E prices persistently lower by an average of 2%; max=20%
- Directional: both average signed and absolute price differences > 0
Bitcoin Price Differences II: Mean-reverting

3 exchanges wrt Bitfinex for US $ - bitcoin transactions:
- Absolute price differences > 0 on average
- Not directional: average signed price differences = 0
Why are Price Differences not Arbitraged?

• Textbook arbitrage since identical assets, unlike other cases where arb fails
  • Buy bitcoin on BTC-E
  • Sell or short (by first borrowing bitcoin) on Bitstamp or Bitfinex

• What are the frictions that prevent this arbitrage?
Arbitrage Frictions: Implicit & Explicit Trading Costs

- Bid-ask spread smaller than price difference
- Trading fees:
  - Per transaction fees: 0.2 to 0.5 % BTC-E
  - % trading fees: Bitfinex and Bitstamp
  - Withdrawal/deposit fees

Sources: BTC-E, Bitfinex, as of December 8, 2015
Arbitrage Risk: Price Volatility

Figure 7: Intraday Volatility of Bitcoin Prices

The figure shows the intraday volatility of the bitcoin price index and the absolute value of the difference in prices of bitcoin trading on Bitfinex and BTC-e. The data is obtained from bitcoincharts.com.
Arbitrage Risk: Execution Delays & Exchange Failure or Fraud

- Delays in executing transactions
  - Transfer US $ into exchanges: 5-10 days via wire in BTC-E
    - Custodian banks refuse wire transfers and FX transactions with local banks where bitcoin exchanges have accounts (WSJ, Apr 26 2017)
  - Transfer bitcoin between digital wallets: short; 3 confirms of 10 minutes each between BTC-E and Bitstamp/Bitfinex
    - Avoid by short selling but not offered by all exchanges and may require additional fees

- Exchange fraud and failure:
  - By 2013, 18 of 40 exchanges failed (Moore & Christin, 2013)
  - Mt. Gox: had largest market share, lost $460 M to hackers in 2014
  - BTC-E: more opaque re ownership, location of ops
    - persistently lower price relative to other exchanges
    - Fined $110m by US Treasury in July “for operating as a criminal venture”; shut down, recently reopened
Data

- 15 exchange pairs, price in US $
  - UTC time stamp, amount traded, price
  - Bitcoincharts.com: aggregates trading histories of many but not all exchanges
  - 70% of bitcoin-USD market 2015-August 2016
  - Notable absent exchanges: Gemini, OkCoin, LakeBTC

- Bid/ask spreads and daily sum of orders
  - Bitcoinity.org
Hypothesis: Liquidity Differences Explain Price Differences

- Panel regressions for exchange pair i, time t

\[
\text{PriceDif}_{i,t} = \beta_0 + \beta_1 \text{LnAvgBAspread}_{i,t} + \beta_2 \text{LnAvgOB}_{i,t} + \beta_3 \text{LnAvgUSDVol}_{i,t} + \beta_4 \text{LnAvgNetworkFee}_{i,t} + \beta_5 \text{AvgPriceSD}_{i,t} + \varepsilon_{i,t}
\]  

(1)

- PriceDif: absolute price difference, % of average price
- LnAvgBAspread: log of quoted bid-ask spread, % of mid-quote
- LnAvgOB: log of daily sum of orders in order book within 1% of average daily price (“inside depth”)
- LnAvgUSDVol: log of daily volume
- LnAvgNetworkFee: average transaction fee for all transactions added to blockchain (common to all exchange pairs)
- AvgPriceSD: intraday price SD, divided by price
Hypothesis: Market Segmentation Explain Price Differences

- Add indicator for retail/institutional traders:

\[
PriceDiff_{it} = \beta_0 + \beta_1 \text{LnAvgBAspread}_{i,t} + \beta_2 \text{LnAvgOB}_{i,t} + \beta_3 \text{LnAvgUSDVol}_{i,t} + \beta_4 \text{LnAvgNetworkFee}_{t} \\
+ \beta_5 \text{AvgPriceSD}_{i,t} + \beta_6 \text{BothRetail}_{i,t} + \beta_7 \text{OneRetail}_{i,t} + \epsilon_{i,t}
\]

(3)

- BothRetail: Both exchanges retail (defined as trade size on day “t” < 75th percentile of trade size in past 30 days relative to other exchanges)
- OneRetail: one of exchange pair is retail
Distribution of Trade Sizes Across Exchanges

- Distribution of trades sizes (denominated in bitcoins): all bitcoin-USD exchanges in 2016
Hypothesis: Risk Premia Explain Price Differences

- Add panel and period fixed effects:

\[
PriceDiff_{i,t} = \beta_0 + \beta_1 \text{LnAvgBAspread}_{i,t} + \beta_2 \text{LnAvgOB}_{i,t} + \beta_3 \text{LnAvgUSDVol}_{i,t} + \beta_4 \text{LnAvgNetworkFee}_{i,t} \\
+ \beta_5 \text{AvgPriceSD}_{i,t} + \beta_6 \text{BothRetail}_{i,t} + \beta_7 \text{OneRetail}_{i,t} + \varepsilon_{i,t}
\]  

(3)

- Panel FE: indirect measure of relative exchange risk due to fraud, governance etc.
Which Hypotheses Explain Price Differences?

• Illiquidity explains 24% of price differences
  • Higher bid-ask spread: higher price differences
  • Higher inside depth: lower price differences
  • Higher volatility: higher price differences
• Higher retail presence: Higher price differences
• Adding panel fixed effects: explain 37% of price differences
Panel Fixed Effects Estimates

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<tr>
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<tr>
<td>Bitfinex, Bitstamp</td>
<td>0</td>
<td>0</td>
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<td>Bitfinex, Coinbase</td>
<td>0.228**</td>
<td>0.133</td>
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<td></td>
<td>(0.0746)</td>
<td>(0.0897)</td>
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<td>(0.0184)</td>
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<td>-0.193*</td>
<td>-0.180</td>
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<td>Bitstamp, Coinbase</td>
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<td></td>
<td>(0.0570)</td>
<td>(0.0915)</td>
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<tr>
<td>Bitstamp, Itbit</td>
<td>-0.107*</td>
<td>-0.0408</td>
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<td>(0.0363)</td>
<td>(0.0377)</td>
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<tr>
<td>Bitstamp, Kraken</td>
<td>-0.418***</td>
<td>-0.396***</td>
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<td>(0.0755)</td>
<td>(0.0772)</td>
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<tr>
<td>Btce, Bitfinex</td>
<td>0.920***</td>
<td>0.872***</td>
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<td></td>
<td>(0.0413)</td>
<td>(0.0604)</td>
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<td>Btce, Bitstamp</td>
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<td>(0.0381)</td>
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<td>Btce, Coinbase</td>
<td>1.148***</td>
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<td>(0.111)</td>
<td>(0.178)</td>
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<td>Btce, Itbit</td>
<td>0.711***</td>
<td>0.727***</td>
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<td></td>
<td>(0.0585)</td>
<td>(0.0945)</td>
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<tr>
<td>Btce, Kraken</td>
<td>0.296***</td>
<td>0.270</td>
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<tr>
<td></td>
<td>(0.0574)</td>
<td>(0.128)</td>
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<tr>
<td>Itbit, Coinbase</td>
<td>0.0322</td>
<td>0.0142</td>
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<td></td>
<td>(0.0722)</td>
<td>(0.114)</td>
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<tr>
<td>Kraken, Coinbase</td>
<td>-0.431***</td>
<td>-0.445**</td>
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<td></td>
<td>(0.0530)</td>
<td>(0.130)</td>
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<td>Kraken, Itbit</td>
<td>-0.420**</td>
<td>-0.350**</td>
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<td></td>
<td>(0.106)</td>
<td>(0.0986)</td>
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<tr>
<td>Constant</td>
<td>4.162***</td>
<td>7.604**</td>
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<td>(0.642)</td>
<td>(2.096)</td>
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Observations: 9,380
R-Squared: 0.366
Std. Errors: Clustered by Exch. Pair

- FE estimates for BTC-E related pairs larger, consistent with greater exchange risk premia due to governance issues.
- Separate regressions support the idea that BTC-E has higher risk premia associated with its trading.
Dynamics of Price Differences and Illiquidity

- Time series show short-term reversals for some exchange pairs and more persistent behavior for others

- How persistent are effects of illiquidity and volatility on the price differences?

- Estimate VARs by exchange pair with Network fee, Volatility, Volume, Depth, Bid/Ask Spread and absolute price differences
  - Generalized IR functions
Impulse Responses: BTC-E vs Bitfinex

Response of price differences to liquidity and volatility shocks are more persistent on BTC-E
## Speed of Adjustment and Price Discovery: BTC-E vs Bitfinex

### BTC-E relative to other exchanges

<table>
<thead>
<tr>
<th></th>
<th>Bitcoin</th>
<th>Coinbase</th>
<th>ItBit</th>
<th>Kraken</th>
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<tbody>
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<td>Long-term price relationship?</td>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
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<td>Long</td>
<td>Long</td>
<td>13</td>
<td>7</td>
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<tr>
<td>Information share BTC-E (%)</td>
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<td></td>
<td></td>
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<tr>
<td>After 100 days</td>
<td>0.18</td>
<td>2.22</td>
<td>7.00</td>
<td>18.04</td>
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<td>Standard Error</td>
<td>0.29</td>
<td>0.22</td>
<td>0.29</td>
<td>0.30</td>
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### Bitfinex relative to other exchanges

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<th>Bitcoin</th>
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<th>Kraken</th>
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<tbody>
<tr>
<td>Long-term price relationship?</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>Speed of adjustment: exch to Bitfinex (dys)</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>5</td>
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<tr>
<td>Information share BTC-E (%)</td>
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</tr>
<tr>
<td>After 100 days</td>
<td>13.23</td>
<td>5.05</td>
<td>14.45</td>
<td>28.12</td>
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<tr>
<td>Standard Error</td>
<td>0.33</td>
<td>0.27</td>
<td>0.32</td>
<td>0.33</td>
</tr>
</tbody>
</table>
Conclusions

- Intra-exchange bitcoin price differences explained in part by microstructure frictions

- What explains remainder?
  - Exchange related institutional and counterparty risk?
  - Fungibility concerns due to ongoing association of bitcoin on certain exchanges with illegal activities (e.g., money laundering)?

- Certain impediments to mainstream adoption:
  - Need to exchange bitcoin with fiat currency leads to price risk
  - Price uncertainty inhibits use of bitcoin as store of value