Law of One Bitcoin Price?

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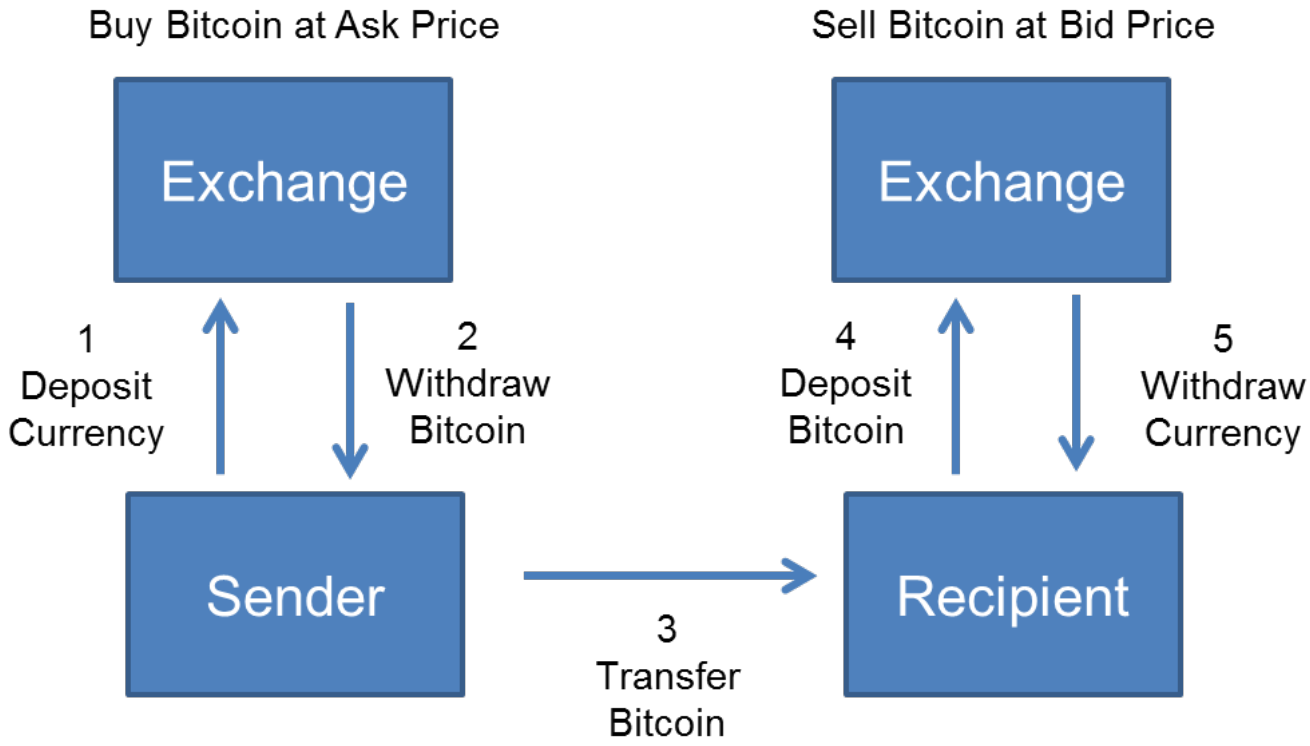
What is Bitcoin?

- 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

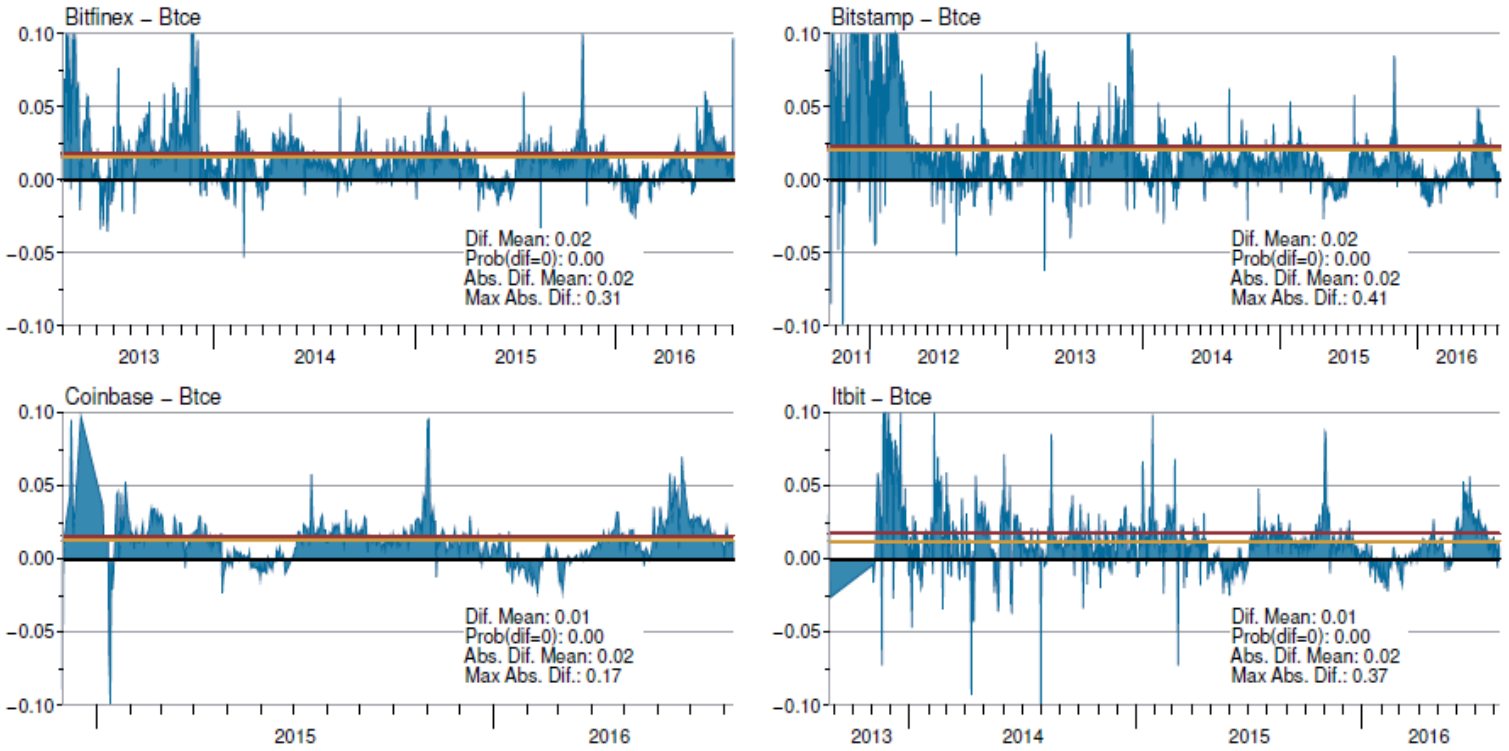


Note: "Exchange" here can also refer to a dealer such as a company running a "Bitcoin ATM."

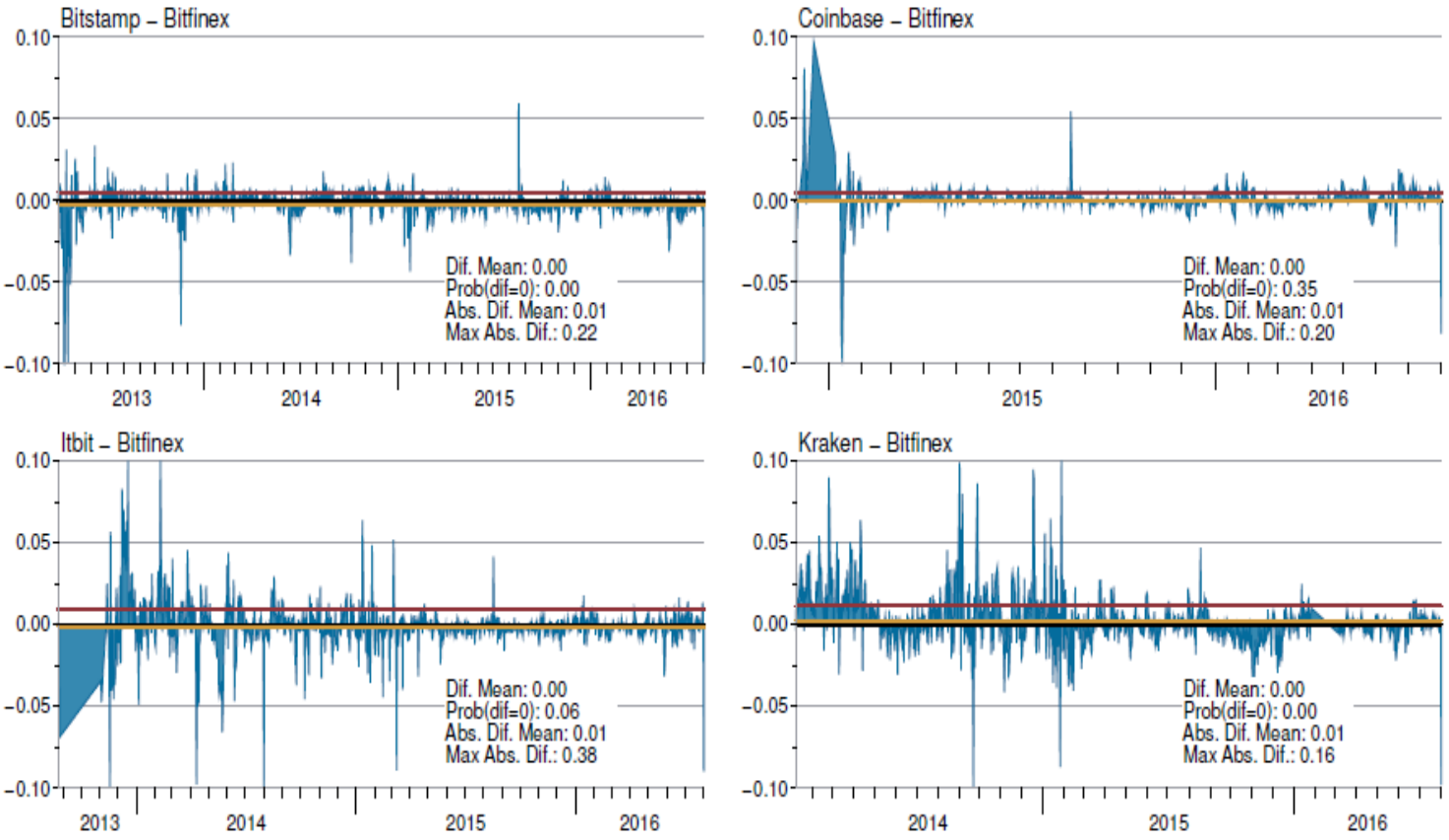
- Bitcoin to bitcoin between digital wallets relatively frictionless (e.g. China)
- Need to exchange bitcoin for fiat currency in most cases (e.g. major retailers use 3rd parties to receive bitcoin from customers)
  - Buy bitcoin from exchanges using fiat currency
  - Bitcoin receivers typically don't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

Persistent, Directional Bitcoin Price Differences

- 3 exchanges wrt BTC-E for US $ - bitcoin transactions
  - Volume-weighted average price per day; 2013-2016
  - Average difference is 2% wrt BTC-E prices; max=20%
  - Average signed and absolute price differences



Mean-reverting Bitcoin Price Differences

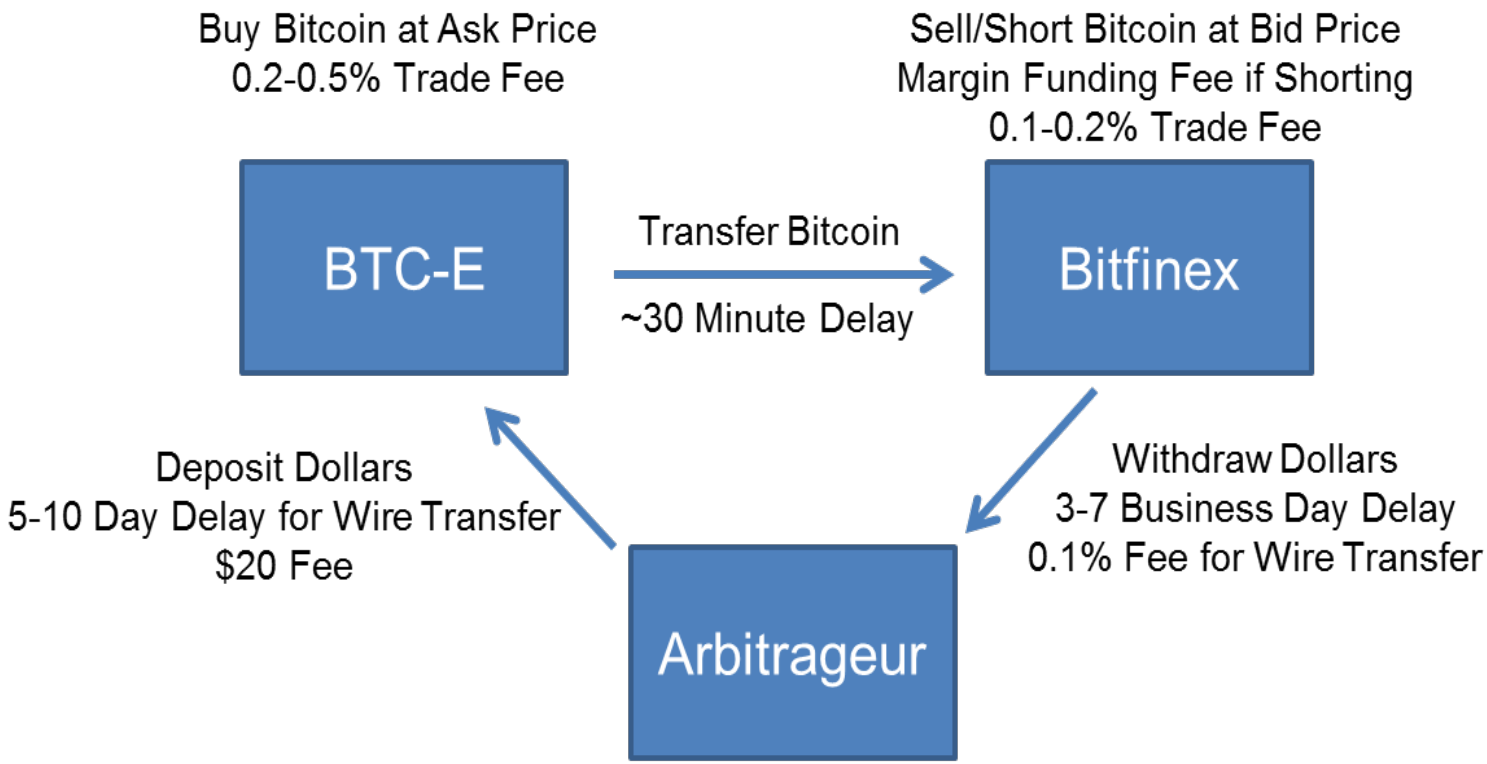


Why are Price Differences not Arbitraged?

- 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: Fees



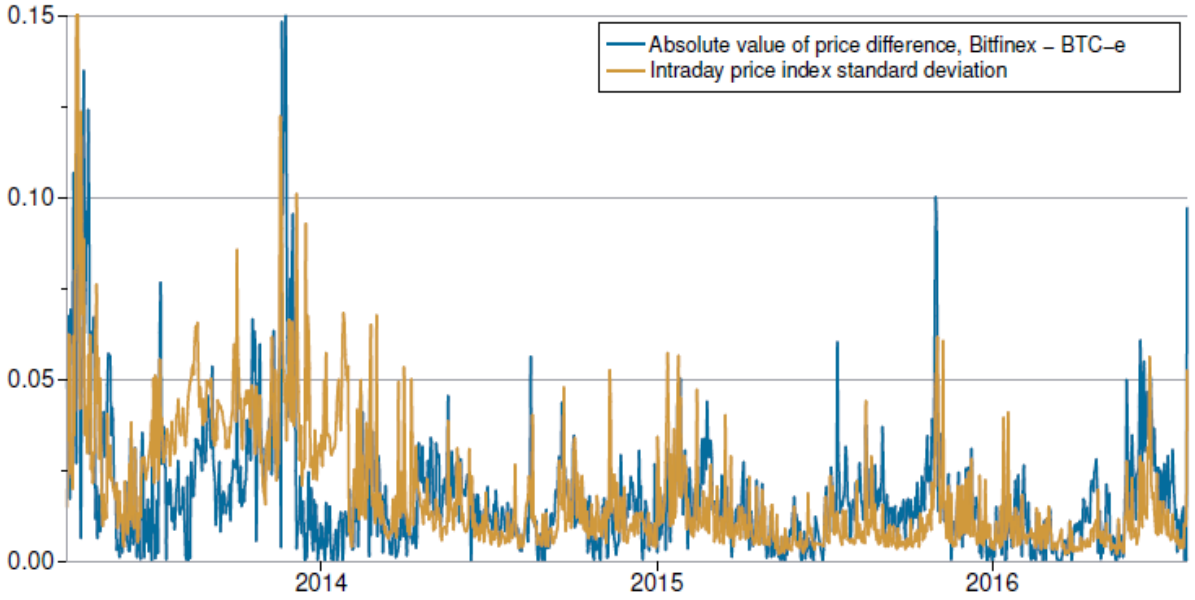
Sources: BTC-E, Bitfinex, as of December 8, 2015

- 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

Arbitrage Risk: Price Volatility

Figure 7: Intraday Volality 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
  - 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
    - consistently lower price relative to other exchanges

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

- Panel regressions for exchange pair i, time t

$$PriceDif_{i,t} = \beta_0 + \beta_1 LnAvgBAspread_{i,t} + \beta_2 LnAvgOB_{i,t} + \beta_3 LnAvgUSDVol_{i,t} + \beta_4 LnAvgNetworkFee_t + \beta_5 AvgPriceSD_{i,t} + \varepsilon_{i,t} \quad (1)$$

- 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

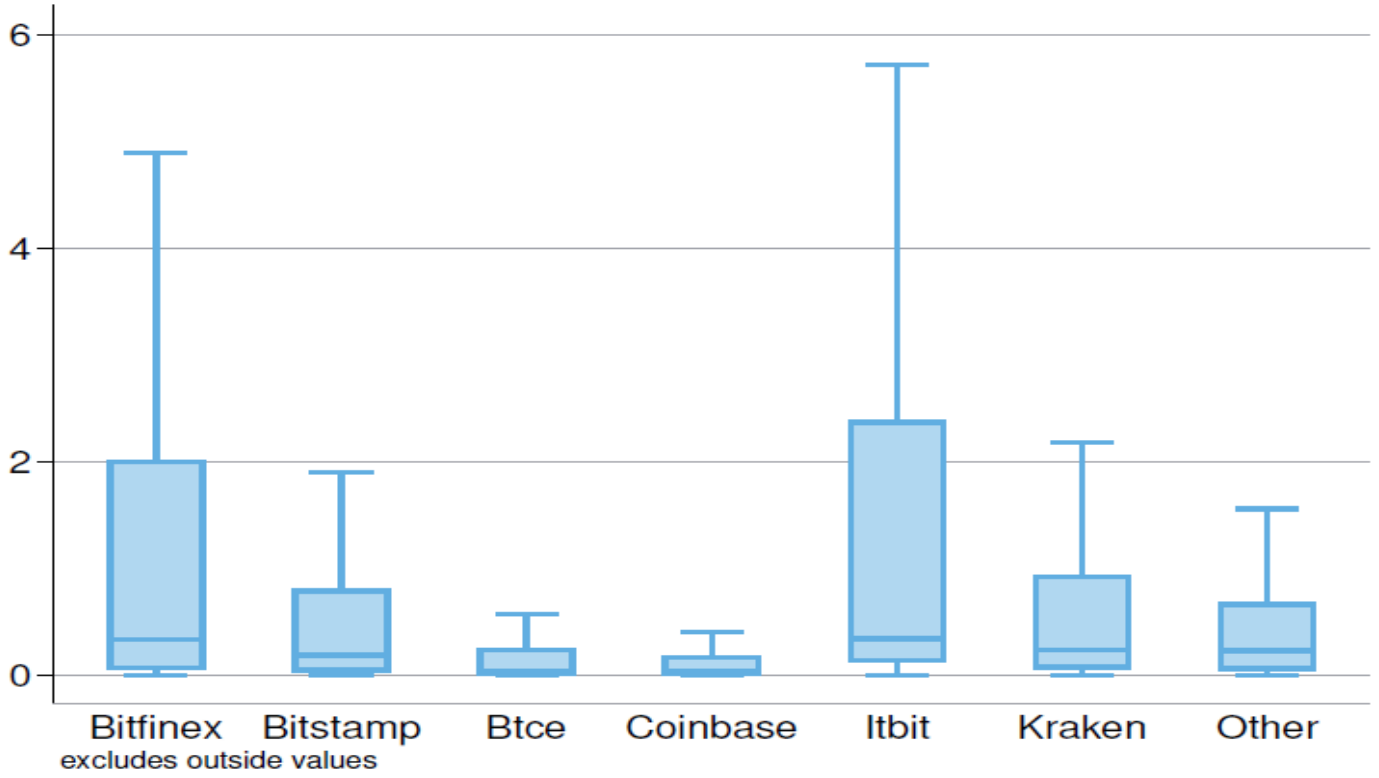
- Add indicator for retail/institutional traders:

$$PriceDif_{i,t} = \beta_0 + \beta_1 LnAvgBAspread_{i,t} + \beta_2 LnAvgOB_{i,t} + \beta_3 LnAvgUSDVol_{i,t} + \beta_4 LnAvgNetworkFee_t + \beta_5 AvgPriceSD_{i,t} + \beta_6 BothRetail_{i,t} \beta_7 OneRetail_{i,t} + \varepsilon_{i,t} \quad (3)$$

- 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

- Distribution of trades sizes (denominated in bitcoins): all bitcoin-USD exchanges in 2016



Hypothesis: Risk Premia

- Add panel and period fixed effects:

$$PriceDif_{i,t} = \beta_0 + \beta_1 LnAvgBAspread_{i,t} + \beta_2 LnAvgOB_{i,t} + \beta_3 LnAvgUSDVol_{i,t} + \beta_4 LnAvgNetworkFee_t + \beta_5 AvgPriceSD_{i,t} + \beta_6 BothRetail_{i,t} \beta_7 OneRetail_{i,t} + \varepsilon_{i,t} \quad (3)$$

- Panel FE: indirect measure of relative exchange risk due to fraud, governance etc.

Do Liquidity Differences Explain Price Differences?

	(1)	(2)	(3)	(4)	(5)
Log(Avg. spread / price	0.388***	0.222***	0.213***	0.372***	0.321***
	(0.0464)	(0.0439)	(0.0376)	(0.0389)	(0.0436)
Log(Avg. orders ±1% of price)	-0.223***	-0.176**	-0.116**	-0.0295	-0.0224
	(0.0503)	(0.0524)	(0.0330)	(0.0278)	(0.0187)
Log(Avg. USD volume (Mil. USD))	0.0224	-0.176	-0.0720	-0.120*	-0.121
	(0.0757)	(0.0895)	(0.0647)	(0.0535)	(0.0586)
Log(Avg. Network Transaction Fee)	0.226	0.268	0.325*	0.415**	1.629**
	(0.142)	(0.151)	(0.141)	(0.102)	(0.537)
Avg. intraday price std. dev.		39.59***	38.37***	42.25***	90.78***
		(6.312)	(5.893)	(5.113)	(8.263)
Both retail			0.793***	-0.0136	0.104
			(0.182)	(0.107)	(0.156)
One retail			0.409**	0.0977*	0.154*
			(0.126)	(0.0396)	(0.0621)
Constant	2.426*	1.668	1.966*	4.162***	7.604**
	(0.824)	(0.786)	(0.687)	(0.642)	(2.096)
Observations	9,396	9,380	9,380	9,380	9,380
R-Squared	0.165	0.243	0.286	0.366	0.555
Std. Errors	Clustered By Exch. Pair	Clustered By Exch. Pair	Clustered By Exch. Pair	Clustered By Exch. Pair	Clustered By Exch. Pair
Fixed Effects	None	None	None	Panel	Panel, Time

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

- 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

	(1)	(2)
Bitfinex, Bitstamp	0	0
	(.)	(.)
Bitfinex, Coinbase	0.228**	0.133
	(0.0746)	(0.0897)
Bitfinex, Itbit	0.213***	0.252***
	(0.0204)	(0.0184)
Bitfinex, Kraken	-0.193*	-0.180
	(0.0728)	(0.0877)
Bitstamp, Coinbase	-0.0411	-0.0869
	(0.0570)	(0.0915)
Bitstamp, Itbit	-0.107*	-0.0408
	(0.0363)	(0.0377)
Bitstamp, Kraken	-0.418***	-0.396***
	(0.0755)	(0.0772)
Btce, Bitfinex	0.920***	0.872***
	(0.0413)	(0.0604)
Btce, Bitstamp	0.530***	0.509***
	(0.0381)	(0.0674)
Btce, Coinbase	1.148***	1.046***
	(0.111)	(0.178)
Btce, Itbit	0.711***	0.727***
	(0.0585)	(0.0945)
Btce, Kraken	0.296***	0.270
	(0.0574)	(0.128)
Itbit, Coinbase	0.0322	0.0142
	(0.0722)	(0.114)
Kraken, Coinbase	-0.431***	-0.445**
	(0.0530)	(0.130)
Kraken, Itbit	-0.420**	-0.350**
	(0.106)	(0.0986)
Constant	4.162***	7.604**
	(0.642)	(2.096)
Observations	9,380	9,380
R-Squared	0.366	0.555
Std. Errors	Clustered By Exch. Pair	Clustered By Exch. Pair
Time Fixed Effects?	No	Yes

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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- FE estimates for BTC-E related Pairs larger, Consistent with Greater exchange Risk premia Due to governance Issues
- Separate Regressions support Idea that BTC-E has Higher risk premia Associated with its trading

Dynamics of Price Differences and Illiquidity

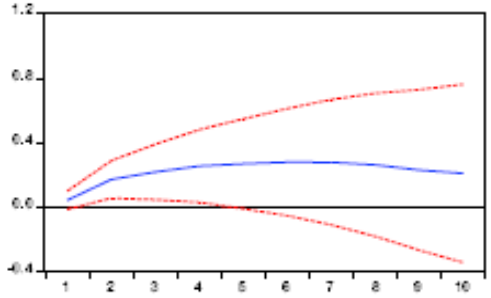
- Time series show short-term reversals for some exchange pairs and more persistent behavior for others
- How persistent are effects of illiquidity and volatility on the price differences?
- Estimate VARs by exchange pair with Network fee, Volatility, Volume, Depth, Bid/Ask Spread and absolute price differences
  - Generalized IR functions

Impulse Responses: BTC-E vs Bitfinex

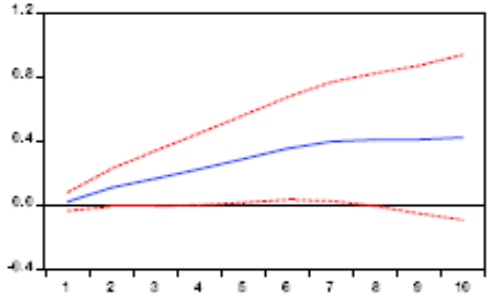
Panel B Column 1: Btce Coinbase pair

Accumulated Response to Generalized One S.D. Innovations ± 2 S.E.

Accumulated Response of PRICEDIF to AVGPRICESD



Accumulated Response of PRICEDIF to LNAVGUSDVOL



Panel B Column 2: Bitfinex Coinbase pair

Accumulated Response to Generalized One S.D. Innovations ± 2 S.E.

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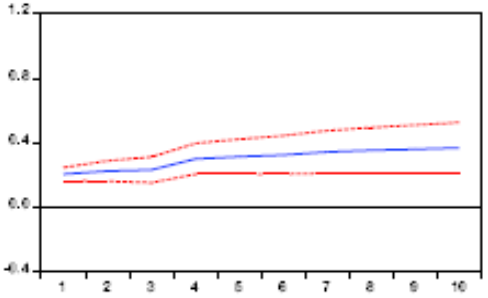

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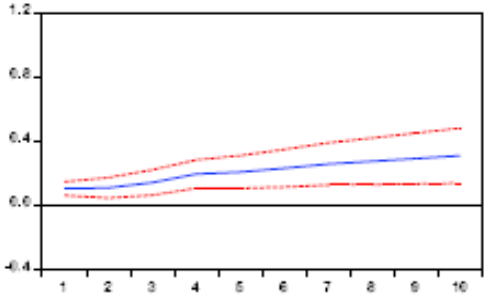

Speed of Adjustment and Price Discover: BTC-E vs Bitfinex

(a) Panel A: BTC-e relative to other exchanges

	Exchange 1			
	Bitstamp	Coinbase	ItBit	Kraken
Cointegrated of Order 1?	YES	YES	YES	YES
Cointegration coefficient α_{11}				
Estimate	-0.03	-0.07	-0.21	-0.38
T-statistics	-0.30	-0.69	-2.10	-4.04
Speed of adjustment, exchange 1 to BTC-e	NS	NS	6.59	3.65
Cointegration coefficient α_{12}				
Estimate	0.14	0.06	0.08	0.08
T-stat	1.40	0.61	0.80	0.89
Information share (%) of BTC-e				
After day 1	0.00	1.49	1.98	5.26
S.E.	0.04	0.04	0.04	0.03
After day 100	0.18	2.22	7.00	18.04
S.E.	0.29	0.22	0.29	0.30

	Exchange 1			
	Bitstamp	Coinbase	ItBit	Kraken
Cointegrated of Order 1?	YES	YES	YES	YES
Cointegration coefficient α_{11}				
Estimate	-0.93	-0.61	-0.90	-0.56
T-statistics	-3.45	-1.99	-4.43	-4.76
Speed of adjustment, exchange 1 to Bitfinex	1.49	2.29	1.54	2.46
Cointegration coefficient α_{12}				
Estimate	-0.33	0.01	-0.09	-0.03
T-stat	-1.18	0.03	-0.41	-0.21
Information share (%) of Bitfinex				
After day 1	6.35	0.88	10.48	12.17
S.E.	0.04	0.04	0.04	0.04
After day 100	13.23	5.05	14.45	28.12
S.E.	0.33	0.27	0.32	0.33

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Conclusions

- Intra-exchange bitcoin price differences explained in part by microstructure frictions
- What explains remainder?
- Bitcoin unlikely to disrupt banking:
  - Need to exchange bitcoin with fiat currency leads to price risk
  - Price uncertainty inhibits use of bitcoin as store of value