Blockchain Market Microstructure

Perm Summer School 2018

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Who we are

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What are we interested in?

Central question of our research:

- **What are the implications of blockchain technology for financial markets?**

Answers are useful for

- **Academics:** to understand how financial markets work
- **Regulators:** to identify risks/ benefits of the new technology
- **Blockchain Architects:** to build powerful applications addressing the needs of market participants
- **Practitioners:** to understand how to construct satisfying trading platforms
- **Investors:** to evaluate the value of start-ups, ICOs, etc.

Outline of my talk

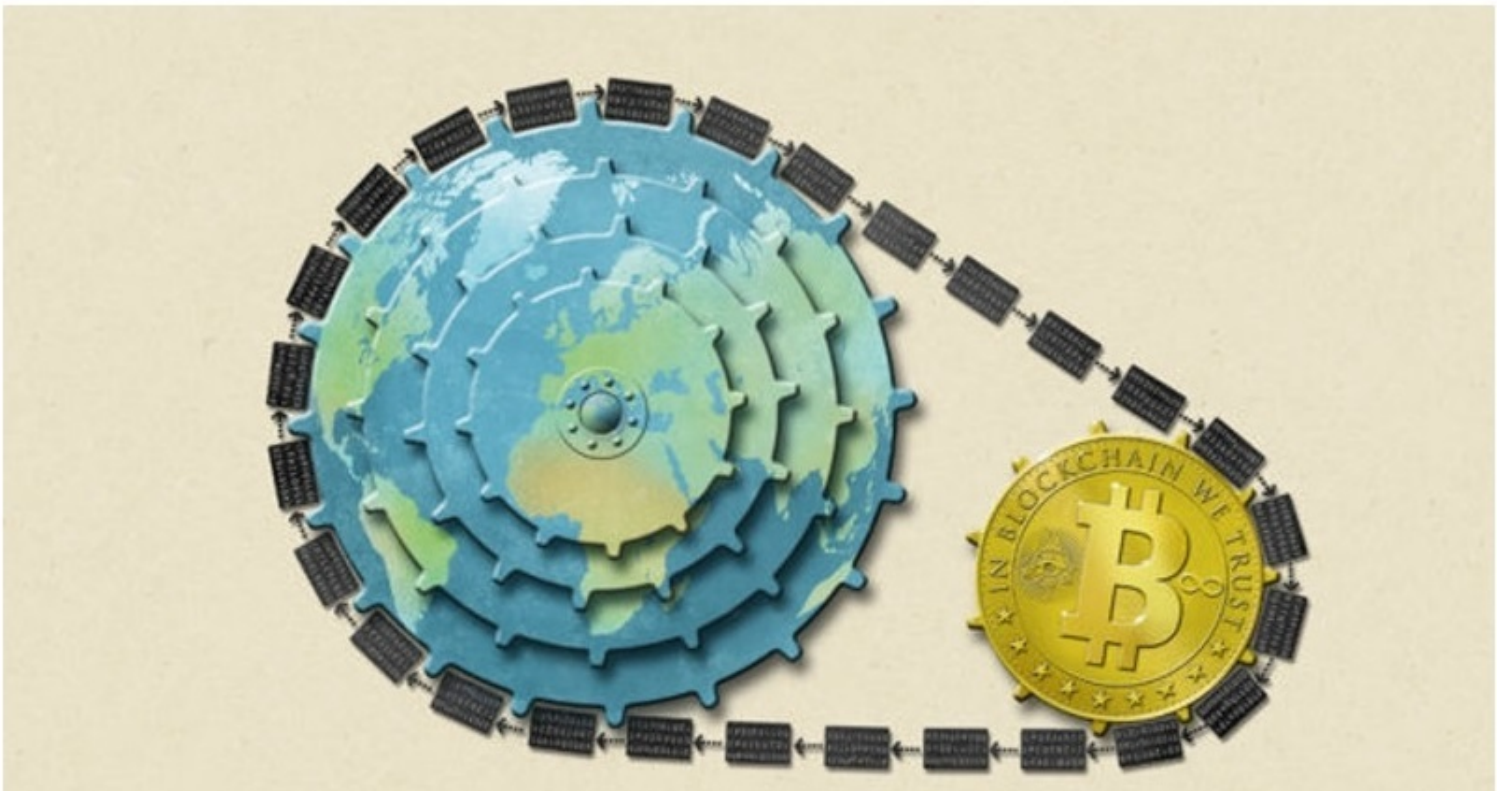
1. Hype, revolution or just a new technology? (Current state of blockchain adoption in financial markets)
2. What makes "traditional" trading different from a blockchain market? (And why is this interesting for academia?)
3. Example: Trading on the most famous blockchain
4. Limits to Arbitrage in Crypto-Trading
5. Transparency, Speed Bumps, ... many more venues for blockchain market microstructure

Hype, revolution or just a new technology?

The promise of the blockchain

The trust machine

The technology behind bitcoin could transform how the economy works



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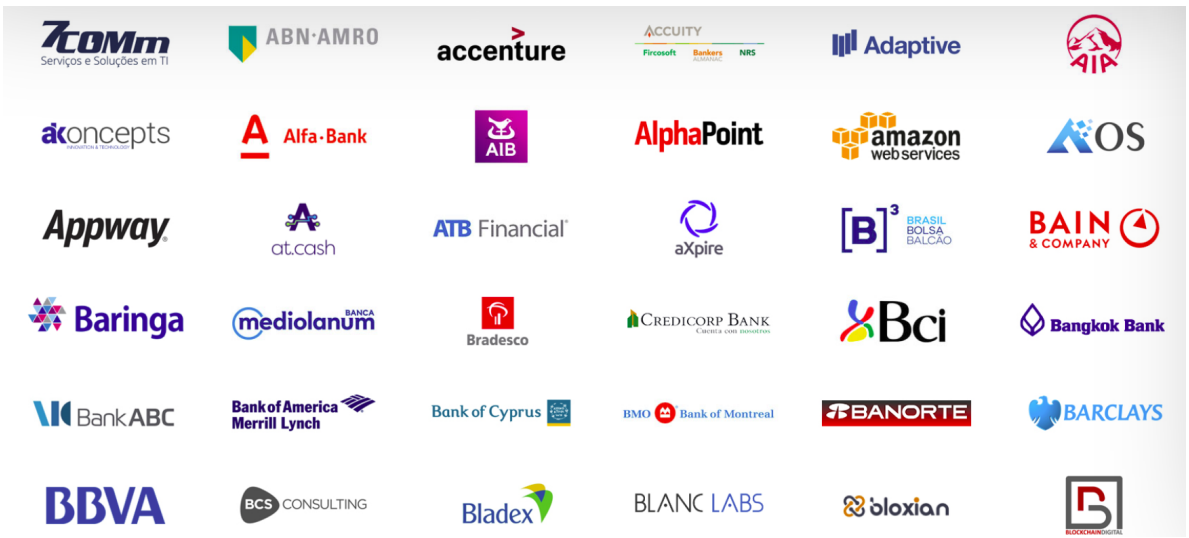
Hype, revolution or just a new technology?

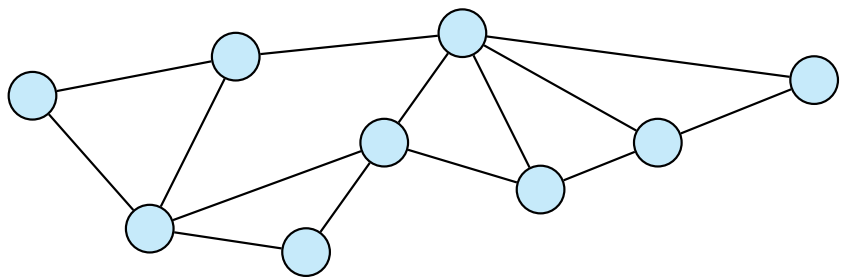
- Funding for Blockchain and Bitcoin startups grows to >$900 M in 2017
- More than 40 companies are engaged in the joint consortium *R3* to investigate potential for blockchain in the banking sector



What is going to change?

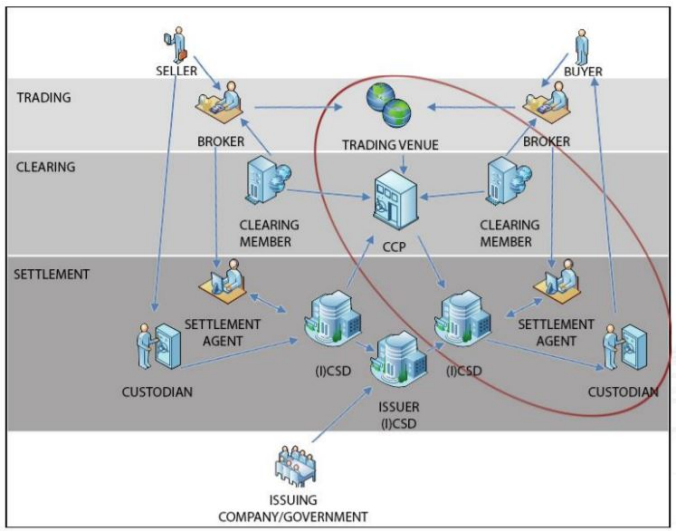
- (Even) faster Markets?
- Higher/cheaper security? (less need for clearing houses?)
- Greater transparency of ownership?

Traditional Markets



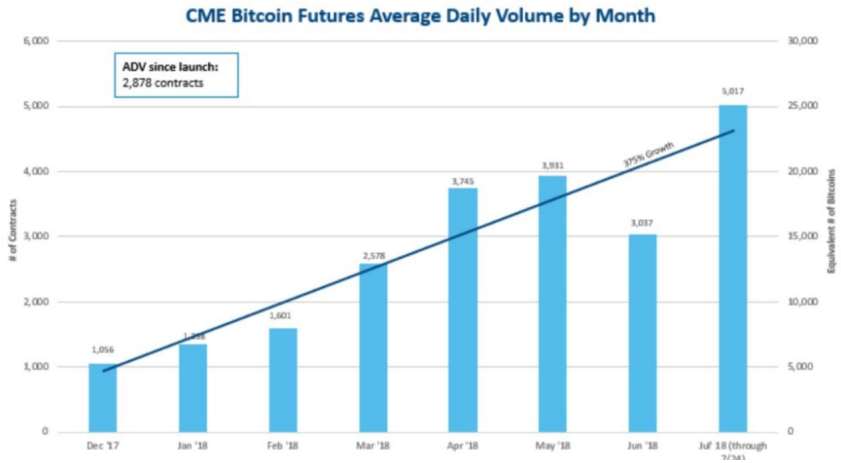
Blockchain-Based Markets

What makes "traditional" trading different from a blockchain market?



+ Security without intermediaries
+ (Legal) settlement process much faster
- With PoW no instantaneous transfer of assets
? On a public blockchain, transactions are (semi-)transparent
? ... (probably many more things)

What does the coexistence of different market structures imply?



- (Cash-settled) Bitcoin Future Trading at CBOE and CME
- Different regulation
- Access for institutional investors
- Shorting of Bitcoin is possible

Questions relevant for academia (but also for practitioners)

- Speed of trading (or settlement) may attract new groups of traders (such as HF-traders)
- Market architecture may also discourage groups of traders (such as Arbitrageurs)

Does presence/absence of these investors improve or decrease market quality?

- High-Frequency traders can be harmful (or beneficial) for market makers
- Without arbitrageurs, prices at exchanges may be less meaningful (the market is not efficient)

Do overall benefits of blockchain trading outweigh the implicit costs?

Example: Trading on the most famous blockchain

Bitcoin as laboratory for markets with stochastic latency

- Bitcoin can be traded on more than 400 exchanges
- Daily trading volume for Bitcoin/Dollar exceeds 1 billion Dollar

#	Name	Market Cap	Price	Volume (24h)	Circulating Supply	Change (24h)
1	Bitcoin	$141.115.053.084	$8.217,58	$5.025.410.000	17.172.337 BTC	0,74%
2	Ethereum	$48.188.350.778	$477,43	$1.618.370.000	100.932.386 ETH	1,59%
3	XRP	$18.104.400.453	$0,460488	$213.594.000	39.315.683.476 XRP *	0,99%
4	Bitcoin Cash	$14.417.907.661	$835,42	$600.389.000	17.258.213 BCH	0,54%
5	EOS	$7.725.651.003	$8,62	$657.541.000	896.149.492 EOS *	2,12%
6	Stellar	$6.038.174.586	$0,321738	$205.631.000	18.767.365.329 XLM *	6,48%
7	Litecoin	$5.004.521.868	$86,92	$278.328.000	57.577.707 LTC	0,68%
8	Cardano	$4.434.229.093	$0,171027	$83.627.200	25.927.070.538 ADA *	1,72%
9	IOTA	$2.879.232.034	$1,04	$39.203.200	2.779.530.283 MIOTA *	6,24%

Bitcoin/USD Prices

- Volatility of Bitcoin is/was huge
- Sharpe Ratio of Bitcoin in 2017 is worse than corresponding measure for SP500 index returns

The Bitcoin Market

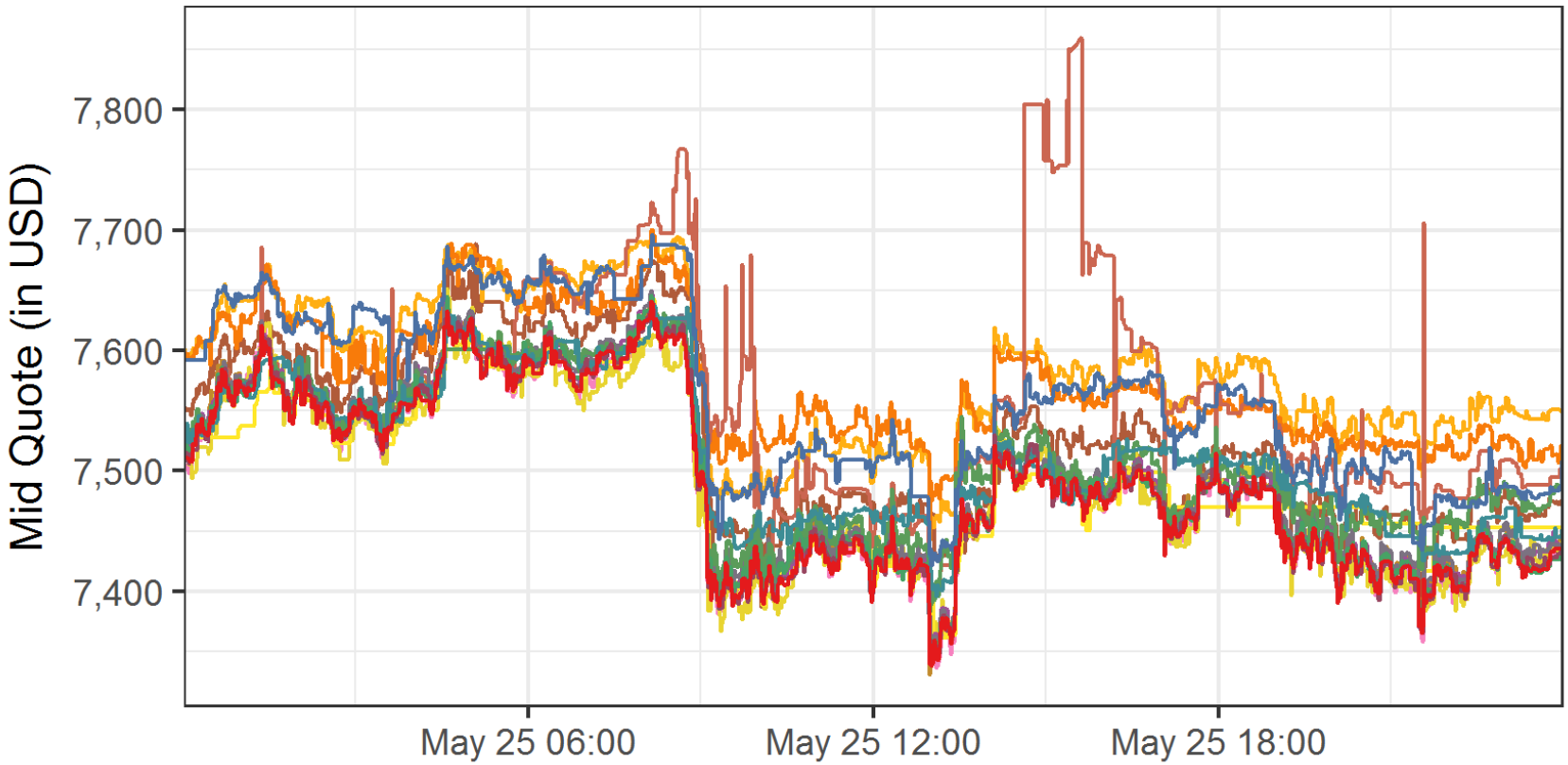
- We collect minute-level Bitcoin/Dollar orderbooks from 18 exchanges since December 2017 ($\approx$ 95% of trading volume)
- We provide an R package on Github: https://github.com/ckscheuch/CryptoX (Feel free to download and analyze orderbooks on your own =))

	Only Crypto	Taker Fee	Margin Trading	US Citizens	Confirmations	Company location
Binance	✓	0.10	✓	✓	2	Tokyo, Japan
Bitfinex	✗	0.20	✓	✗	3	Central, Hong Kong
bitFlyer	✗	0.15	✓	✓		Tokyo, Japan
Bitstamp	✗	0.25	✗	✓	3	London, United Kingdom
Bittrex	✓	0.25	✗	✓	2	Las Vegas NV, United States
BTCC	✗	0.10	✗		2	Shanghai, China
CEX.IO	✗	0.16	✓	✓	3	London, United Kingdom
Gatecoin	✗	0.35	✗		6	Wanchai, Hong Kong
Gate	✓	0.20	✗		2	Sparta NJ, United States
Gemini	✗	0.25	✗	✓	3	New York NY, United States
GDAX	✗	0.25	✓	✓	3	San Francisco CA, United States
HitBTC	✓	0.10	✗	✓	2	Hong Kong
Kraken	✗	0.26	✓	✓	6	San Francisco CA, United States
Liqui	✓	0.25	✓	✗		Kiev, Ukraine
Lykke	✗	0.14	✗	✗	10	Zug, Switzerland
Poloniex	✓	0.25	✓	✓	1	Wilmington DE, USA
xBTCe	✗	0.25	✓	✗	3	Charlestown, Nevis

Bitcoin market structure - Summary statistics

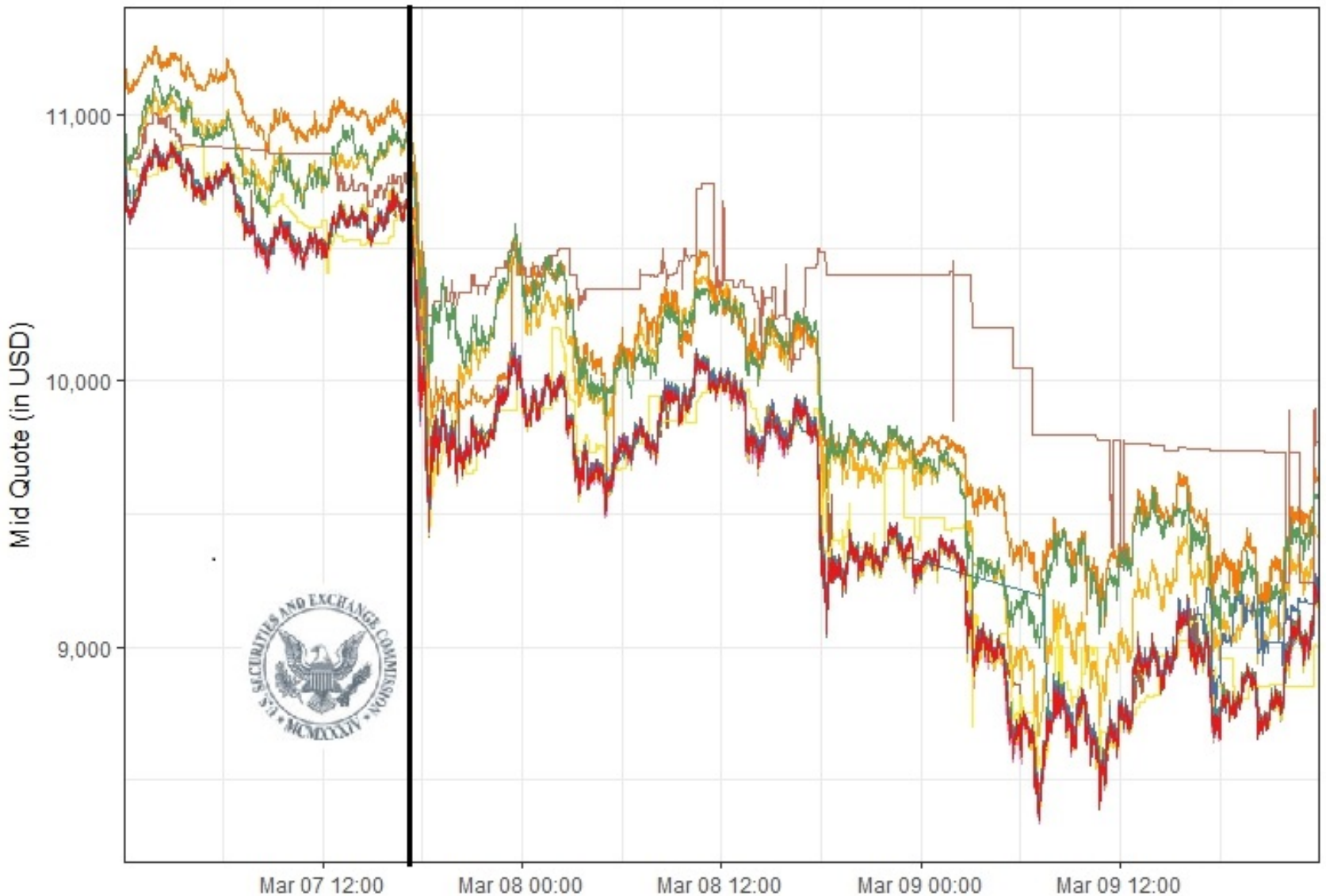
	N	Spread (USD)	Spread (%)	Depth (Ask)	Depth (Bid)
Binance	122,872	2.98	0.04	186,153	186,193
Bitfinex	122,560	0.28	0.00	431,910	459,571
bitFlyer	122,639	18.86	0.24	385,788	258,952
Bitstamp	122,217	5.58	0.07	487,181	517,634
Bittrex	122,878	13.37	0.17	159,462	162,656
BTCC	108,871	110.87	1.46	133,869	75,811
CEX.IO	122,275	13.75	0.18	406,944	426,745
Gate	122,685	219.79	2.84	123,234	129,820
Gatecoin	121,539	163.41	1.92	61,722	67,358
GDAX	122,672	0.04	0.00	249,977	259,122
Gemini	121,678	2.12	0.03	441,173	486,447
HitBTC	122,497	4.22	0.05	128,729	110,010
Kraken	122,929	3.00	0.04	420,540	399,207
Liqui	122,211	34.47	0.45	131,535	182,248
Lykke	124,355	51.52	0.65	110,695	128,994
Poloniex	123,910	8.65	0.11	200,314	183,140
xBTCe	119,808	7.56	0.10	451,848	473,457

What is the price of one Bitcoin?

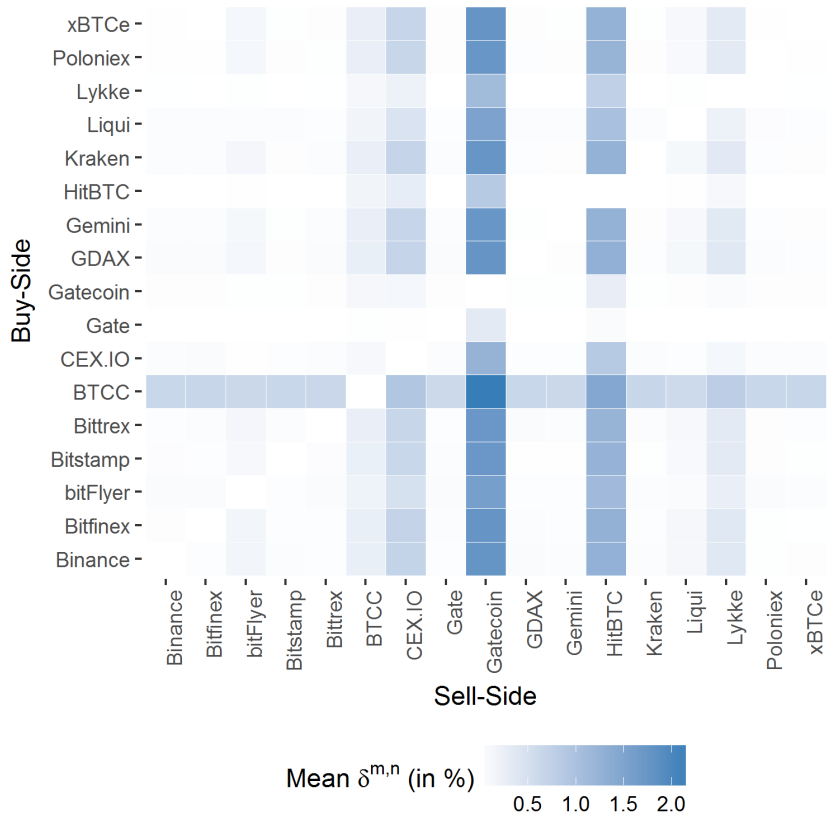


Bitcoin-Dollar Mid Quotes on May 25, 2018.
One Bitcoin in US Dollar on a particular day for 17 different exchanges. We gather high-frequency orderbook information of these exchanges by accessing their public application programming interfaces (APIs) on a minute level.

What happens if news arrive?



Price differences are substantial



Average Price Differences between Exchanges.
Mean price differences $\delta_t^{m,n}$ (in %) across time for each exchange pair in our sample.

Stochastic latency and blockchain technology

Real-world application of blockchain

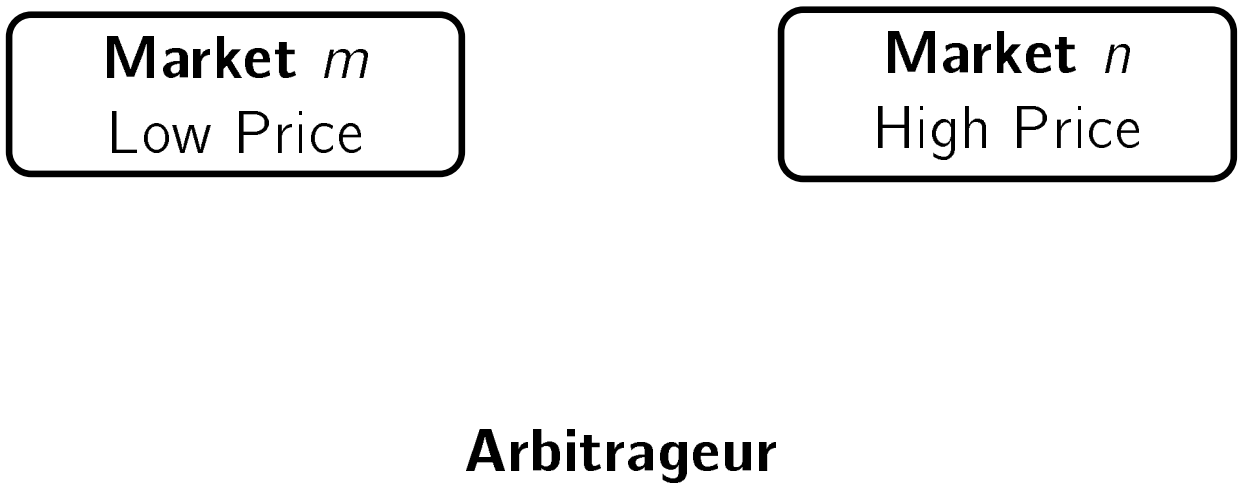
- Substantial price differences
- Persistence of price differences
- Are there inefficiencies?

Blockchain-based settlement

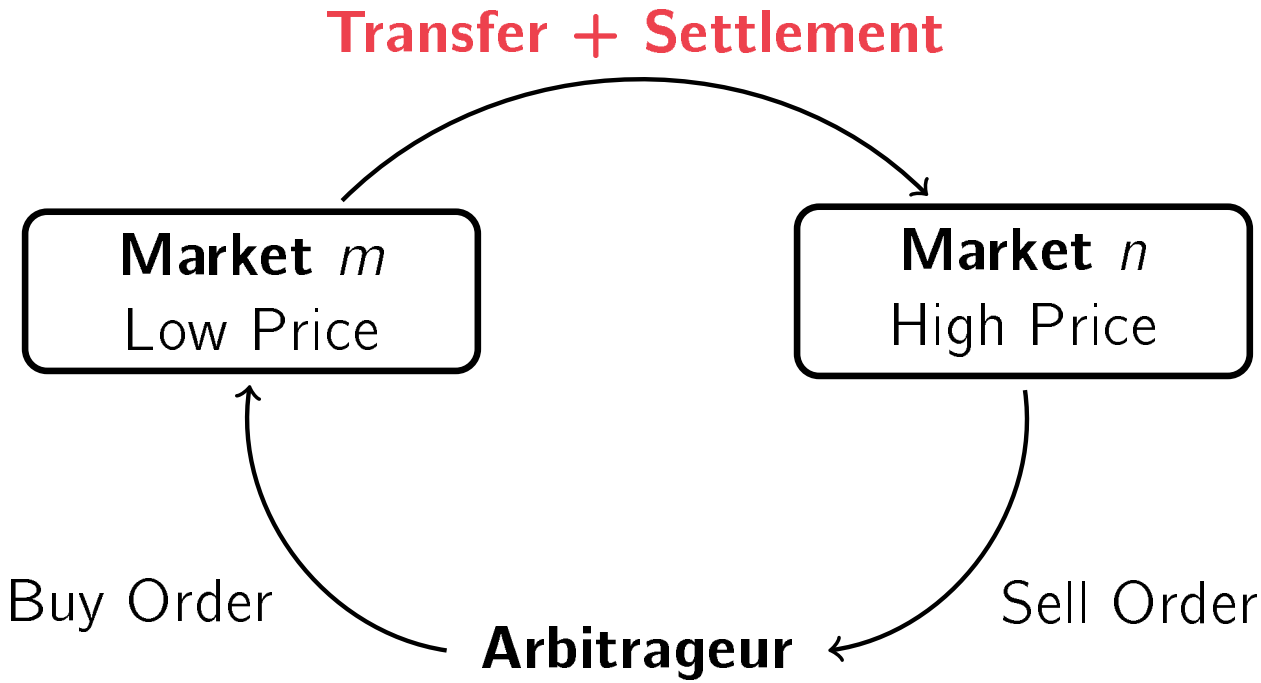
- Consensus algorithms introduce *stochastic latency*
- E.g. how long does it miners take to append a new block?

- **What are the implications of stochastic latency for price efficiency?**
- How inefficient are (current) blockchain-based markets?

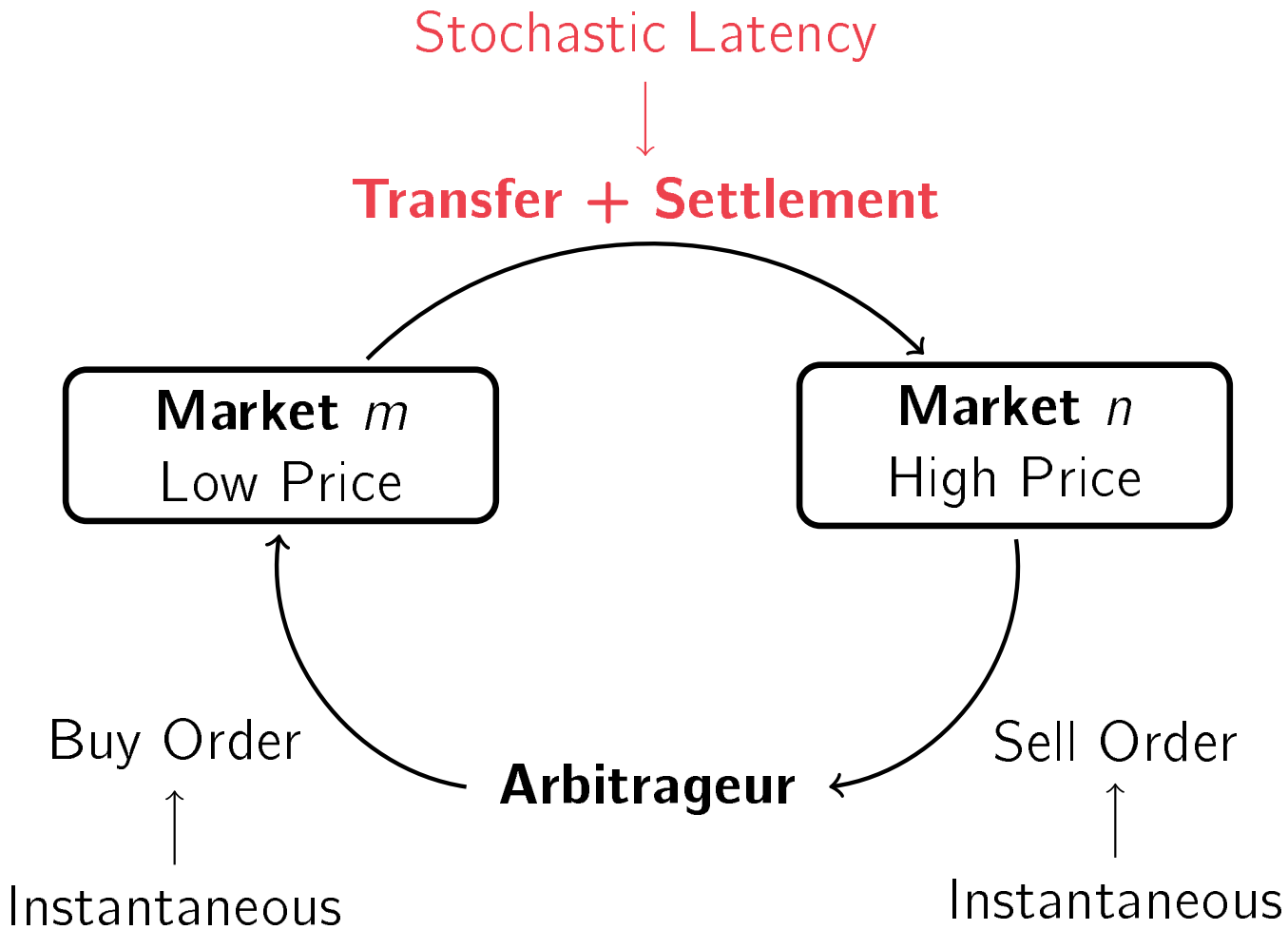
How does blockchain introduce stochastic latency?



How does blockchain introduce stochastic latency?

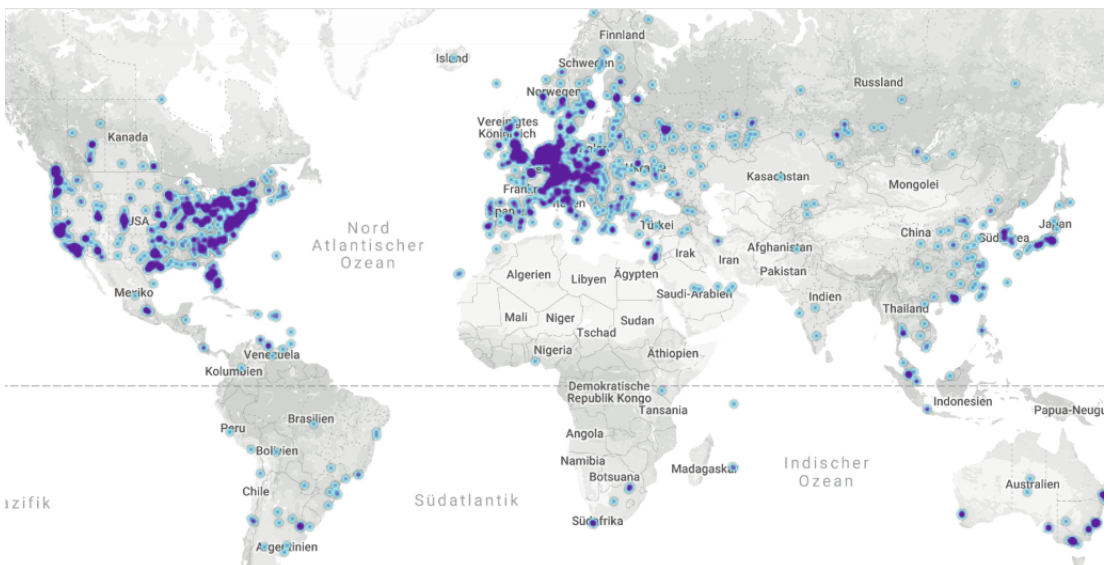


How does blockchain introduce stochastic latency?



How long is the waiting time in the Blockchain network?

- We run a full Bitcoin Node on our server in Vienna
- We provide an R package to access data easily from server
- For every transaction we collect
  - Unique ID, size, fee, waiting time until included in a block
- In total, we tracked $> 50.000.000$ transactions since December

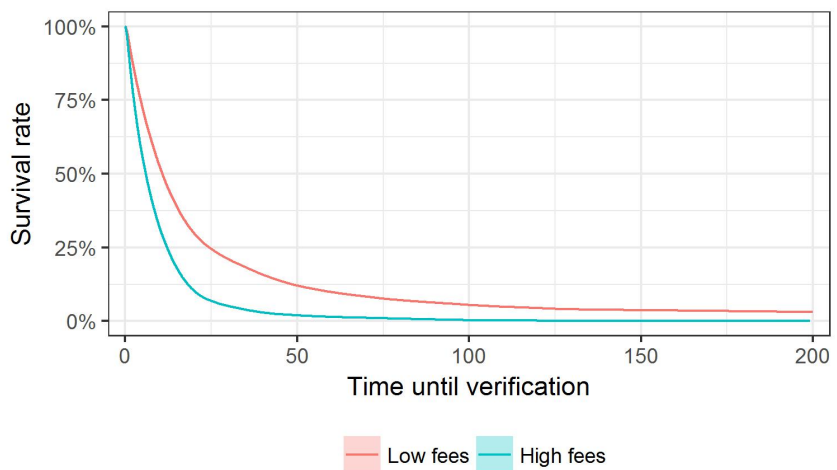


Waiting times in the Bitcoin Blockchain

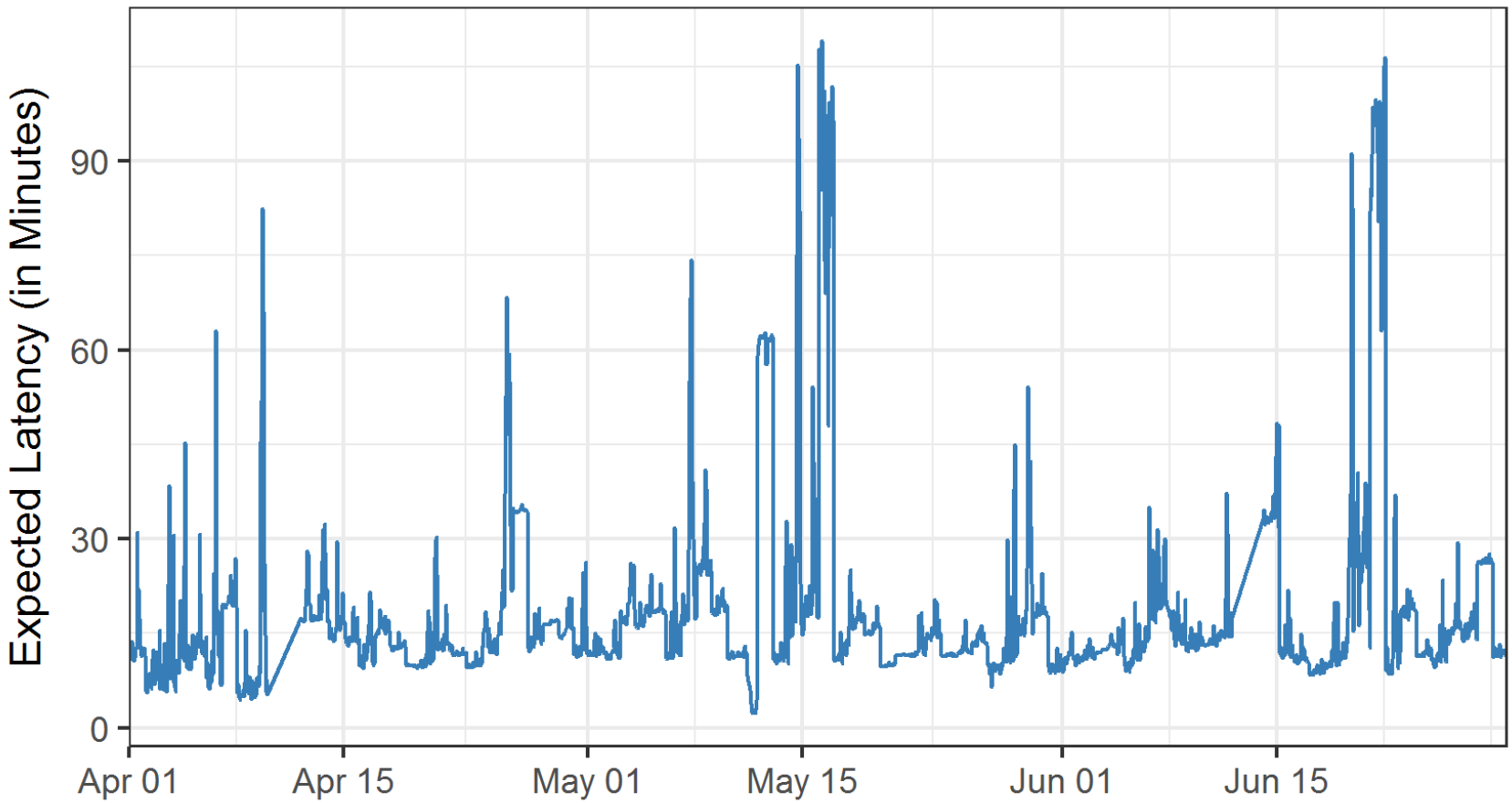
Latency of a transaction depends on

- Current state of the system (i.e. no. of unconfirmed transactions)
- Transaction fee relative to other transactions

Variable	Mean	SD	5 %	25 %	Median	75 %	95 %
Fee per Byte (Satoshi)	31.27	106.58	2.80	5.07	10.07	25.56	133.14
Fee per Transaction (USD)	1.01	10.02	0.05	0.09	0.20	0.62	3.63
Waiting Time (Minutes)	17.57	41.68	0.85	3.45	8.08	17.08	55.93
Mempool Size	2703.01	3322.76	171.00	687.00	1571.00	3320.50	9305.10



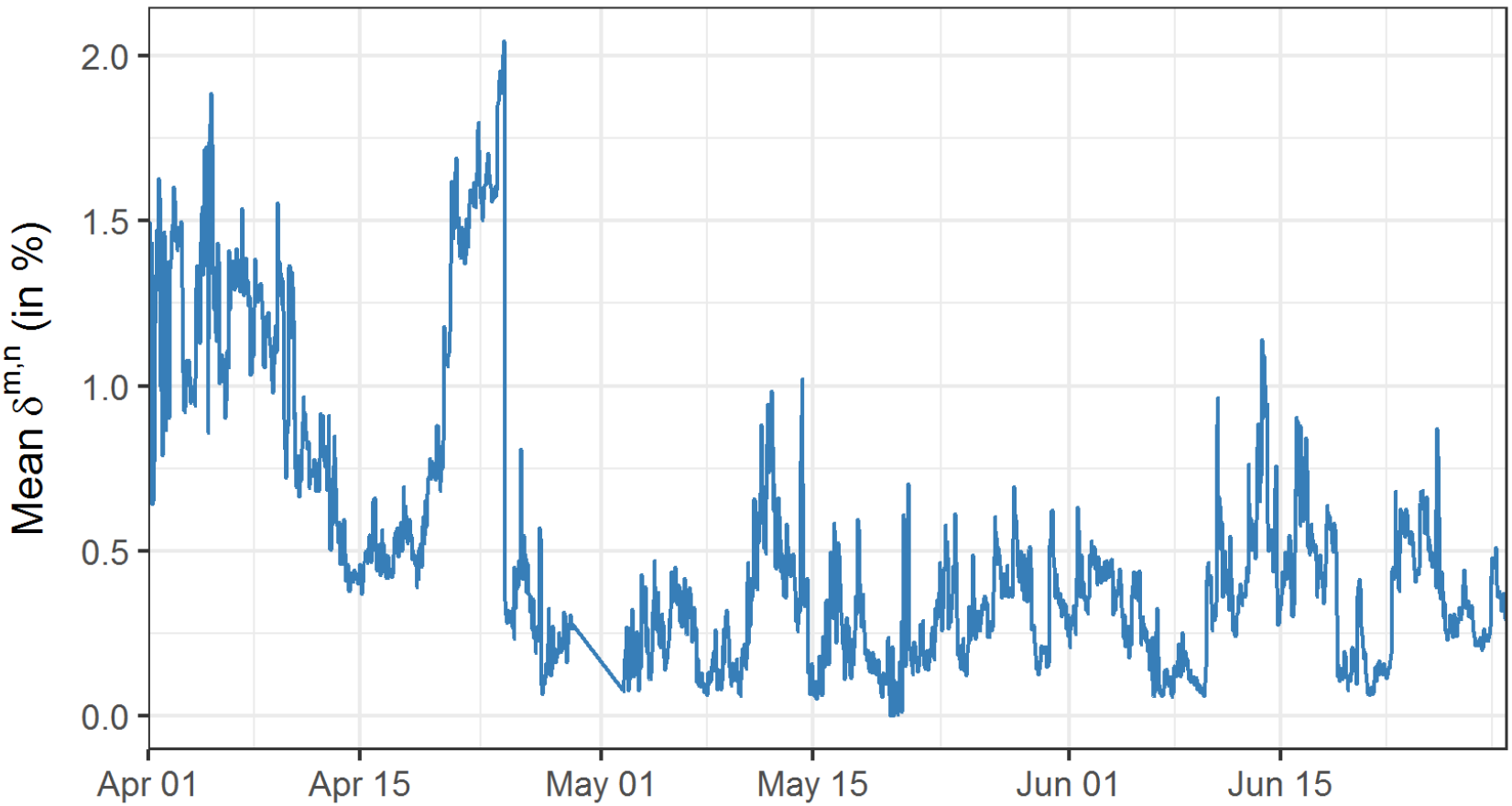
(Predicted) Latency of Bitcoin transactions



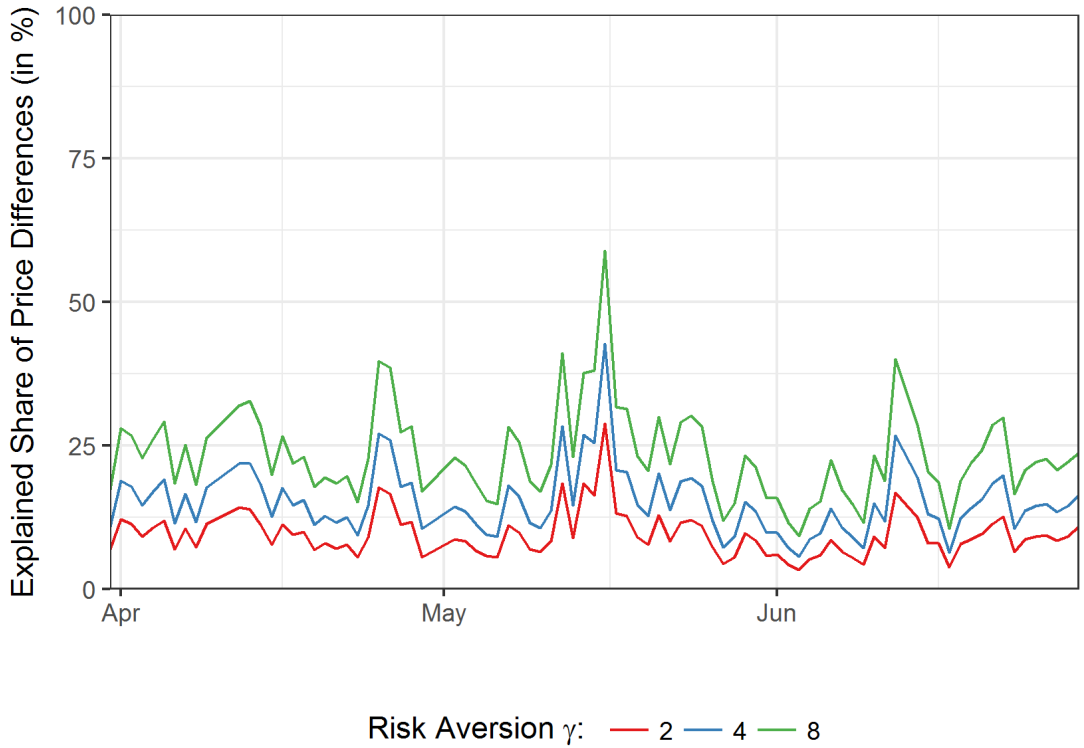
Putting the evidence together: Is the Bitcoin market inefficient?

- We derive analytical efficiency boundaries for markets with stochastic latency
- **Intuition:** If an arbitrageur expects long waiting times, a trade may be too risky. Therefore, trades are unattractive if
  - Price differences are small
  - Risk (volatility) is high
  - (Predicted) waiting time is high
- We estimate limits to arbitrage for every exchange pair (156) and every minute.
- Finally, we compare observed price differences and risks due to verification process

Average Price Differences over Time

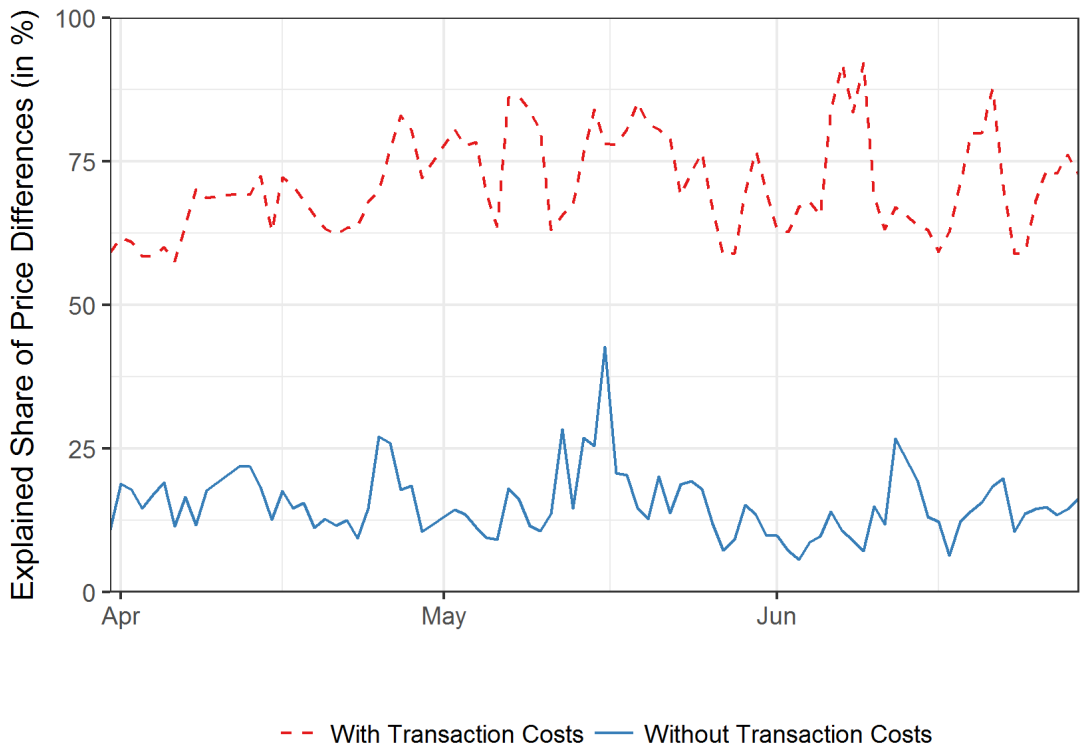


How much do efficiency boundaries explain?



- **Main finding 1:** Limits to Arbitrage explain 20 percent of variation in quoted price differences (for conservative $\gamma = 4$)
- **Main finding 2:** Bitcoin prices exhibit substantial price differences beyond our derived boundaries to price efficiency

How much do efficiency boundaries explain?



- Trading is costly: Taker fees, withdrawal fees, ...
- **Main finding 3:** If we adjust for transaction costs, stochastic latency explains on average 75 % of all price differences

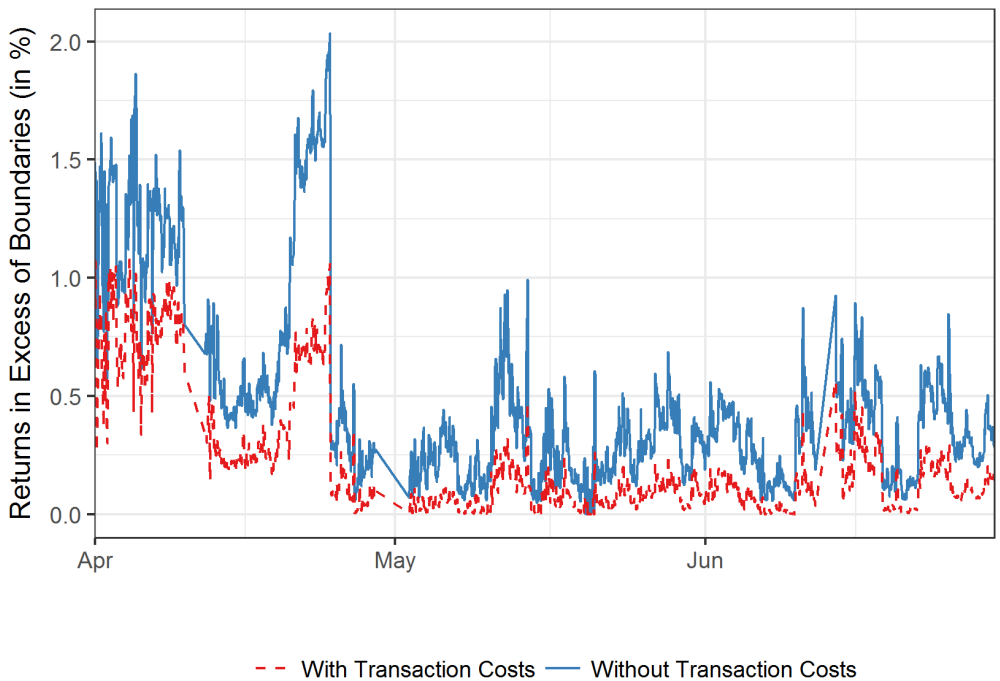
Exchange Characteristics and Excess Price Differences

- Price differences seem to persist even after adjusting for derived boundaries stochastic latency
- Remaining frictions include exchange-specific constraints, withdrawal restrictions, country regulations, HFT-access, ...

	$\pi(\delta_t^{m,n}(q^*) > d_t^n)$		
	(1)	(2)	(3)
Both Margin Trading	-0.365***	-0.356***	-0.058***
	(-27.49)	(-26.99)	(-7.48)
Both Only Crypto	0.138***	0.138***	-0.012*
	(10.17)	(9.70)	(-1.90)
Both US Citizens	-0.182***	-0.172***	-0.059***
	(-14.59)	(-13.28)	(-7.94)
Constant	Yes	No	No
Timestamp FE	No	Yes	Yes
Buy-Side FE	No	No	Yes
Sell Side FE	No	No	Yes
N	11,158,476	11,158,476	11,158,476
Adjusted R^2	0.13	0.20	0.50

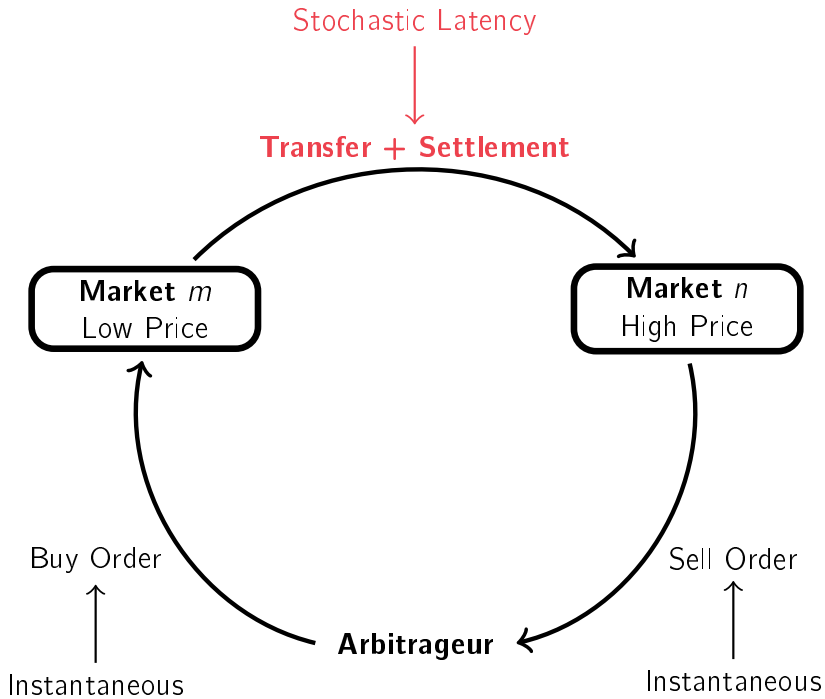
Is Bitcoin arbitrage profitable in practice?

All we can say by now is: Not everything can be explained by "common" measures - the remainder may be money left on the table



Takeaway: Latency in the verification process may limit the activity of arbitrageurs. The PoW-protocol thus has a direct effect on one of the fundamental pillars of financial markets!

Market making and stochastic latency

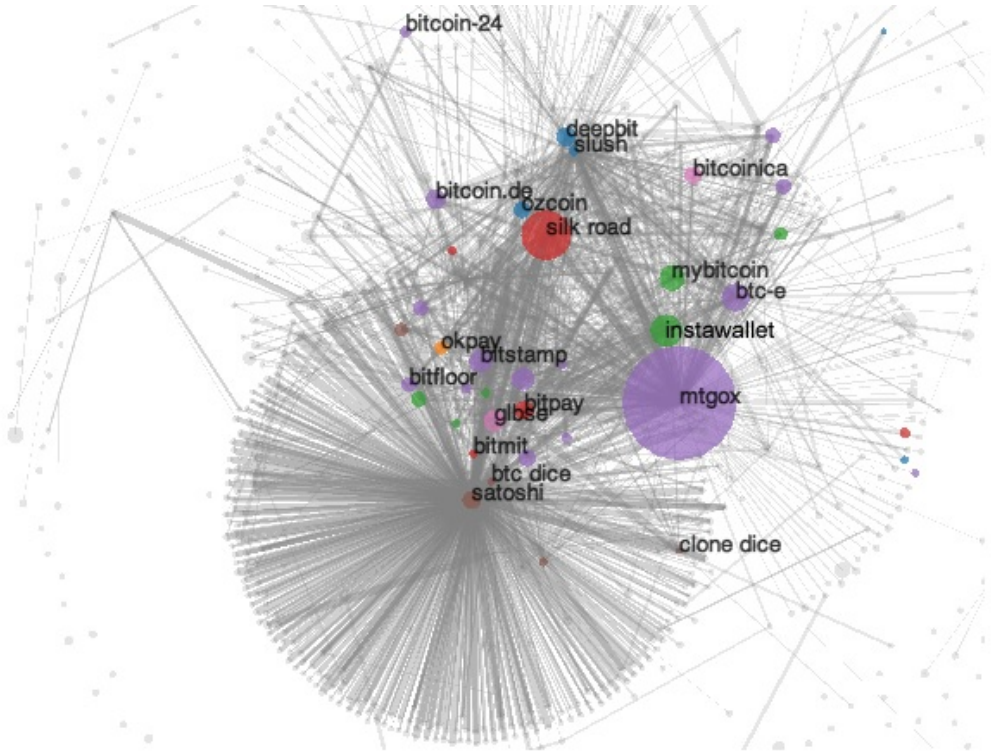


- Market maker want to avoid to get ripped of by arbitrageur
- Usually they get compensated for that risk by earning a spread
- Stochastic latency is a natural speed bump: Quotes can be updated before an arbitrageur arrives $\Rightarrow$ Market making becomes less risky!

Wallet transparency is used by market participants

- Supposedly, the first generated blocks of bitcoins are still controlled by the (unkown) founder Satoshi Nakamoto.
- On August 4th 2015, a debate started after an (invalid) transaction originated by one of these 'genesis' wallets was recorded.
- Blockchain wallet and block explorer service *blockchain.info* (and some exchanges, investors, etc.) felt forced to avoid panicking:

Wallet transparency is used by market participants (Meiklejohn et al (2013))



- Bitcoin transaction history is used to trace back drug dealers active on *silk road*
- Network analysis allow (and is used) to resemble asset flows even when *mixing* services are used.

Final Take-aways

- Financial markets in the presence of Blockchain technology may change with respect to many dimensions - there is much more work to do.
- Stochastic latency is embedded in the DNA of every PoW concept and affects the fundamental law of price.
- Crypto-markets exhibit persistent price differences in excess of documented frictions which do not seem to be exploited entirely.
- **Communication is key! Contact us, discuss with us, help us improving our R packages or perform your own analysis - many things are not explored yet!**