CRIX or evaluating blockchain based currencies

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Currencies - Cigarettes, USD, Cryptos

- Anything can be a currency

Figure 1: Cigarette trading in postwar Germany (42)

- Anyone can offer a currency

Figure 2: Friedrich A. Hayek (42)

Digital Economy

- Amazon
- Paypal
- Google Wallet
- Cryptocurrencies
- Ripple

Cryptocurrencies

- Decentralized, virtual, low transaction costs

- NYSE, Andreesen Horowitz, DFJ: Coinbase funding (75 M$)
- Nasdaq: company-wide utilization of blockchain technology
- Citigroup: own coin development
- PBOC: working on digital currency
- Switzerland: first city accepts Bitcoin payments

Cryptocurrencies - Facts

- As of 20160531, CoinMarketCap.com
  - 632 cryptos
  - 2,034 exchange pairs
  - Market Cap 10.6 billion USD
- Barely derivatives
- Commodity Futures Trading Commission (USA)
  - Cryptos are commodities

Challenges

- What is the benchmark?
- How does the market evolve?
- Market index necessary to compare cryptos

What is the benchmark?

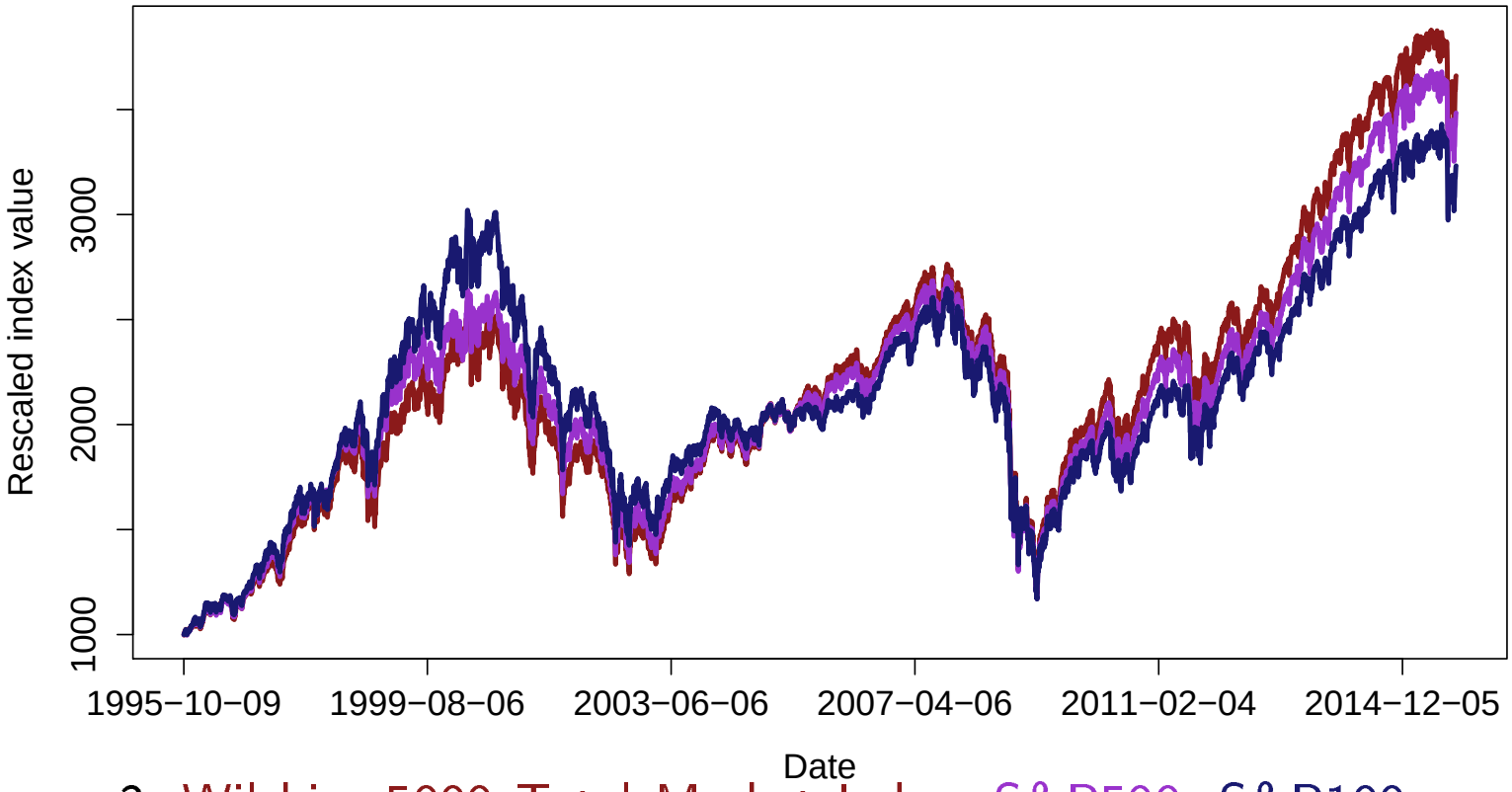

Figure 3: Wilshire 5000 Total Market Index, S&P500, S&P100, rescaled to a starting value of 1000 ▸ CRIX rules

CRIX - the benchmark

Figure 4: Screenshot: crix.hu-berlin.de

Outline

1. Motivation ✓
2. Market Index - CRIX
3. CRIX family comparison
4. Application to German stock market
5. Application to Mexican stock market
6. Conclusion
7. Appendix

Data

- 290 cryptos
- Time period: 20140401 - 20160406
- Prices, capitalization, volumes
- CoinGecko

▸ Bitcoin

CRIX - Rules I

- Laspeyres' idea:

$$\text{CRIX}(k)_t = \frac{\sum_{j=1}^{k} MV_{jt}}{Divisor}$$

- MV_{jt}: market capitalization of crypto j
- k: number of constituents
- Liquidity rule:
  - Eligible if higher rank than 0.25 percentile
  - Measure regarding daily volume in USD and coins

▸ Liquidity Rule ▸ Unused Bitcoins

CRIX - Rules II

- Spine
  - Index members
  - Crucial for benchmark fit

$$CRIX(k)_t \overset{\min(k)}{\rightarrow} \text{total market}_t$$

  - $\text{total market}_t = \frac{\sum_{j=1}^{J} MV_{jt}}{Divisor}$
- Quadratic loss function
- Sparse benchmark

CRIX - Rules III

1. Construct total market index: $\text{total market}_t = \frac{\sum_{j=1}^{J} MV_{jt}}{Divisor}$
2. Set $i = 1$
3. Construct $CRIX(k_i),\ i = 1, 2, 3, \ldots,\ k_1 < k_2 < k_3 < \cdots$
4. Compute $\varepsilon(k_i)_t = \text{total market}_t - CRIX(k_i)_t$
5. Kernel density estimation for density $f(\varepsilon(k_i)_t)$ with leave-one-out cross validation
6. Derive $AIC(k_i) = -2 \log \prod_{t=1}^{n} f(\varepsilon(k_i)_t) + 2k_i$
7. If $i = 1$: Jump to 3., else 8.
8. If $AIC(k_{i-1}) < AIC(k_i)$: stop, else jump to 3. and $i = i + 1$

▸ KDE ▸ US indices

CRIX - Rules IV

- AIC asymp. optimal - Benchmark
  - Best model out of model set
  - Minimization of K-L information loss by approximating full reality

CRIX family

- CRIX - AIC
  - $k_1 = 5$
  - Step width: 5 constituents
  - Local optimum
- ECRIX - AIC
  - $k_1 = 1$
  - Step width: 1 constituents
  - Local optimum
- EFCRIX - AIC
  - $k_1 = 1$
  - Step width: 1 constituents
  - Optimum

Index members

- Compare last 3 M
- Amount used for next 3 M

Period	CRIX	ECRIX	EFCRIX	Maximum achievable
1	5	3	40	41
2	25	8	119	119
3	5	12	170	170
4	30	10	190	190
5	15	2	204	205
6	30	8	215	215
7	55	4	214	214

Table 1: Number of constituents in respective periods

CRIX performance

Figure 5: CRIX CRIXindex CRIXcode

Loss comparison I

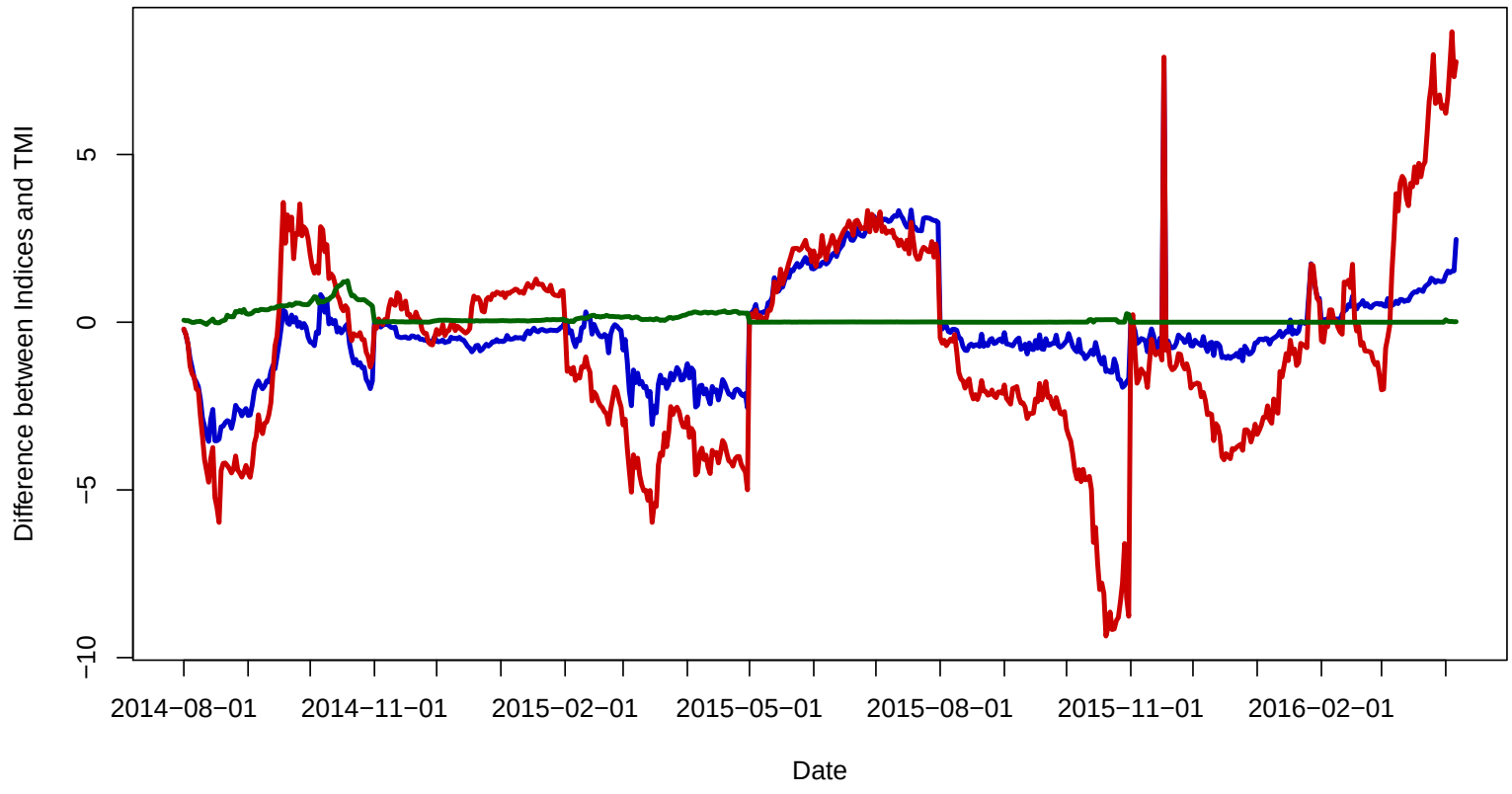

Figure 6: Realized difference between total market and CRIX, ECRIX, EFCRIX CRIXfamdiff CRIXcode

Loss comparison II

	MSE	MDA
CRIX vs. Total Market	2.0687	0.9935
ECRIX vs. Total Market	9.2370	0.9870
EFCRIX vs. Total Market	0.0503	1.0000

Table 2: Comparison of CRIX, ECRIX, EFCRIX against total market

CRIXfamdiffloss CRIXcode

CRIX methodology & German stock market

- German Prime Standard
- Basis for DAX, MDAX, SDAX, TecDAX
- DAX often interpreted as market indicator
- DAXCRIX
  - CRIX methodology applied to German companies
  - Initialization with 30 members
  - Time period: 20000616 - 20151218
  - AIC computation quarterly
  - Index members exchange quarterly

Index members FDAX

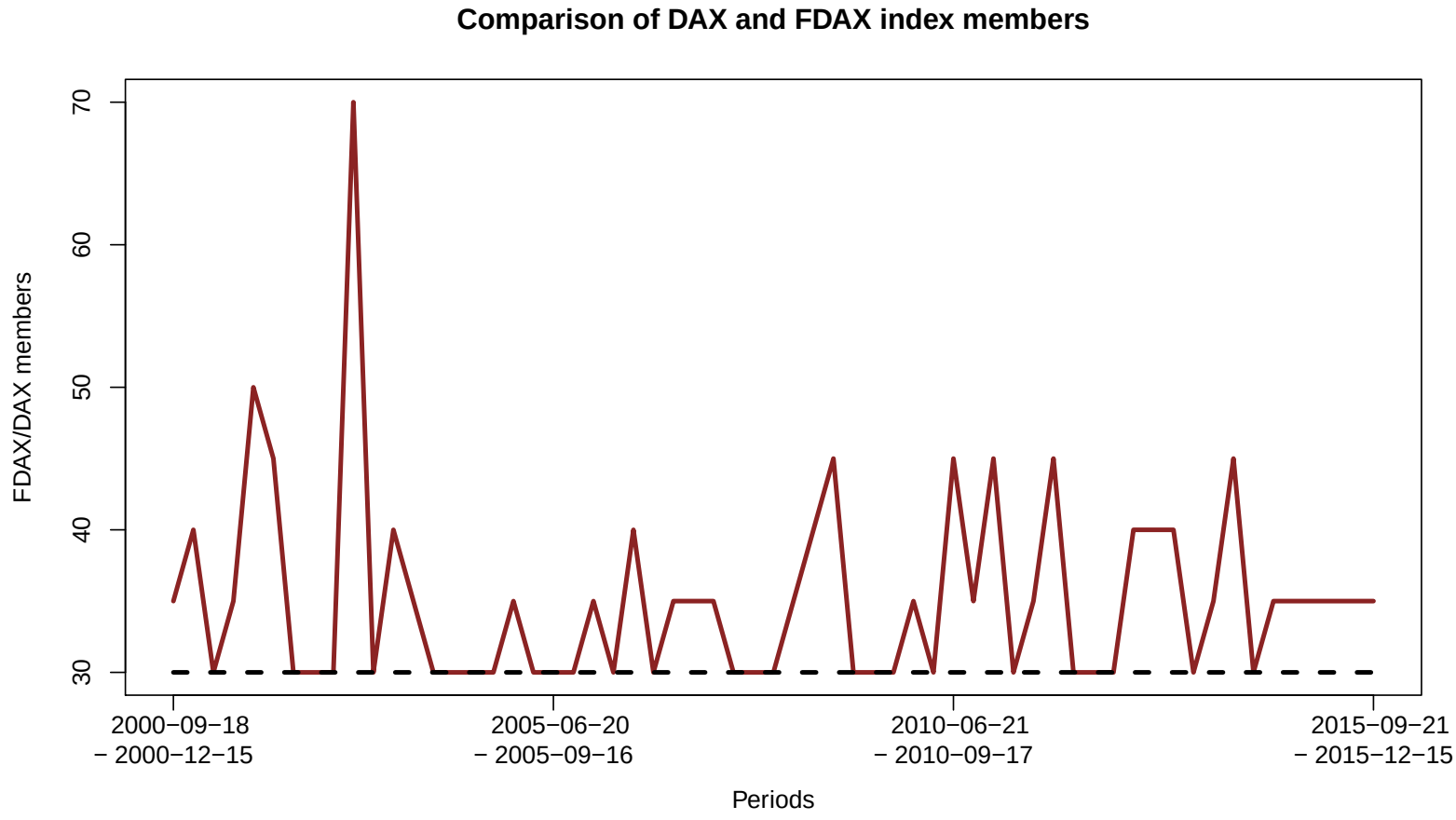

Figure 7: Number of constituents in respective periods for DAX and FDAX

Loss comparison DAX & FDAX

	MSE	MDA
FDAX vs. TMI	347.20	0.95
DAX vs. TMI	756.47	0.91

Table 3: Comparison of DAX with CRIX methodology (FDAX) and rescaled DAX against total market FDAXloss CRIXcode

CRIX methodology & Mexican stock market

- Unique condition: Telecommunication sector dominant
- Carlos Slim Helu
- IPC35 meant as market indicator
- FIPC
  - CRIX methodology applied to Mexican stock market
  - Initialization with 35 members
  - Time period: 19960601 - 20150529
  - All Mexican companies in Datastream
  - AIC computation quarterly
  - Index members exchange quarterly

Loss comparison IPC & FIPC

	MSE	MDA
FIPC vs. TMI	242.07	0.97
IPC vs. TMI	151113.43	0.91

Table 4: Comparison of IPC with CRIX methodology (FIPC) and rescaled IPC against total market

Conclusion

- CRIX represents market very well
- EFCRIX best but too many index constituents
- CRIX good choice in terms of MSE and MDA
- Methodology enhances fit to German stock market
  - But strategy may cause high transaction costs
  - Use analysis to identify lower bound of index members
- Methodology performs even better applied to Mexican stock market

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Bibliography

 Simon Trimborn and Wolfgang Karl Härdle (2016)
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SFB Discussion Paper

 Simon Trimborn and Wolfgang Karl Härdle (2015)
CRIX or evaluating Blockchain based currencies
Oberwolfach Report No. 42/2015 "The Mathematics and Statistics of Quantitative Risk"
DOI: 10.4171/OWR/2015/42

Bitcoin

- Counteract inflation
  - Fixed max amount
- Anonymity
- Needs of users
  - Decision on structure

▸ Movie: Bitcoin - Made simple

Anonymity - Black market

- Wallets are anonym
- Transactions are anonym
- Blockchain core feature
- Causes problems

Figure 8: US government warning

Source: www.wikipedia.org

The Blockchain - Spine of Bitcoin

- Transaction list
- Transaction processors called miners
- Miners collect & publish transactions
- Order is invariable

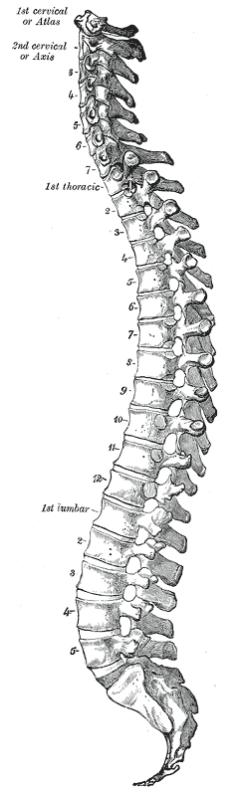

Figure 9: Spine

The Blockchain

- Sometimes parallel chains
  - Due to e.g. internet lag
- Green block: first block (Genesisblock)
- Black blocks: main chain
- Purple blocks: parallel chains

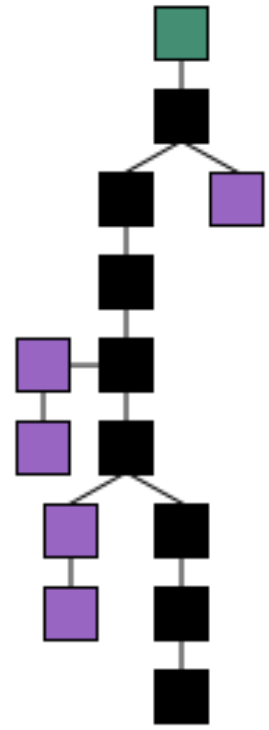

Figure 10: Blockchain

Source: www.wikipedia.de

The Blockchain - Lag

- Assume: 2 blocks mined simultaneously
  - Miner 1: Australia
  - Miner 2: Germany
- Effect of lag:
  - Some receive Australian block
  - Some receive German block
- Parallel chain
- For next block:
  - Check which chain contains the most difficult to find blocks
  - Becomes main chain

Process of Transactions

- Users organize process
- Some users (miners) create a transaction list
  - Next block of blockchain
- Blocks has a strict order, ensured by signature
- Miners search for signature
- Signature encrypted by cryptography

▸ Transaction example

Who accepts Bitcoin?

- Overstock - Retailer
- Dell
- University of Cumbria
- Expedia - Travel Agency
- Republican Party of Louisiana

back: Index Construction

Bitcoin - The System I

- Take 4 people
  - Alice, Bob
  - Gary, Grace
- 2 special users (miners)
  - Gary
  - Grace
- Alice buys a rare book from Bob and pays with Bitcoin
- Gary and Grace process this transaction

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Bitcoin - The System II

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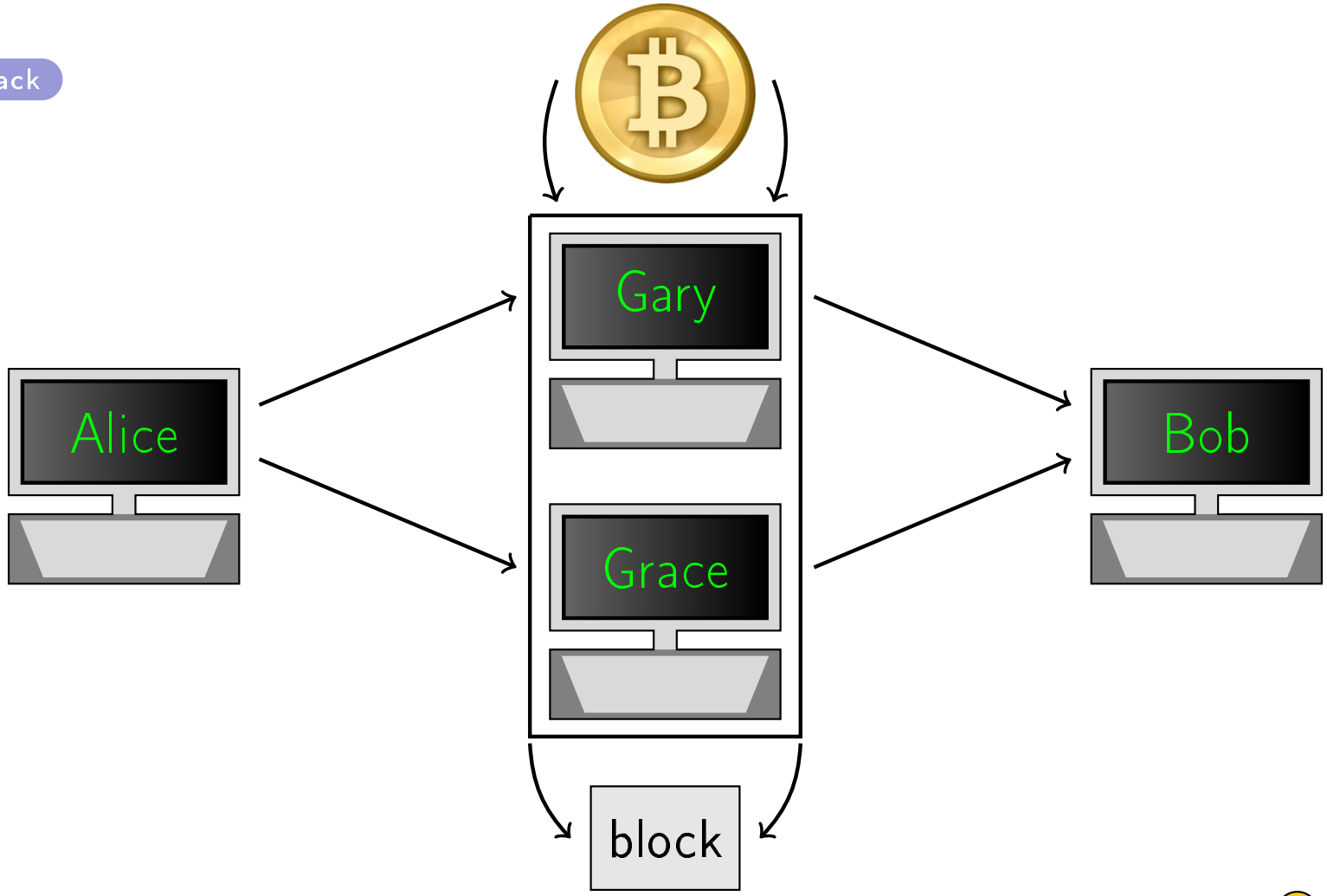

Bitcoin - The System III

- Gary OR Grace receives Bitcoins for service
- BOTH add transaction to list
- BOTH compute hash value (trial and error)
- Click for online hash generator
- List: one block of the blockchain
- Hash value: gives position of block in blockchain
- Contains part of hash value of last block

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Liquidity Rule I

- Rely often on turnover

$$Turnover = \frac{Volume}{Floating\ \ Coins}$$

- Floating Coins for cryptos unclear
- Rule motivated by STOXX Japan 600 and AEX Family
- Measure relative to asset universe
- Small trading volume in USD but high traded coins taken into account

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Liquidity Rule II

- Liquidity rule (one of these):
  1. 0.25 percentile of ADTV (Average Daily Trading Volume):

$$ADTV_i \geq ADTV_{0.25}$$

  2. 0.25 percentile of ADRTC (Average Daily Relative Traded Coins):

$$ADRTC_i \geq ADRTC_{0.25}$$

- Checked monthly
- Crypto made insensitive if trading stops

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Usage of Bitcoins

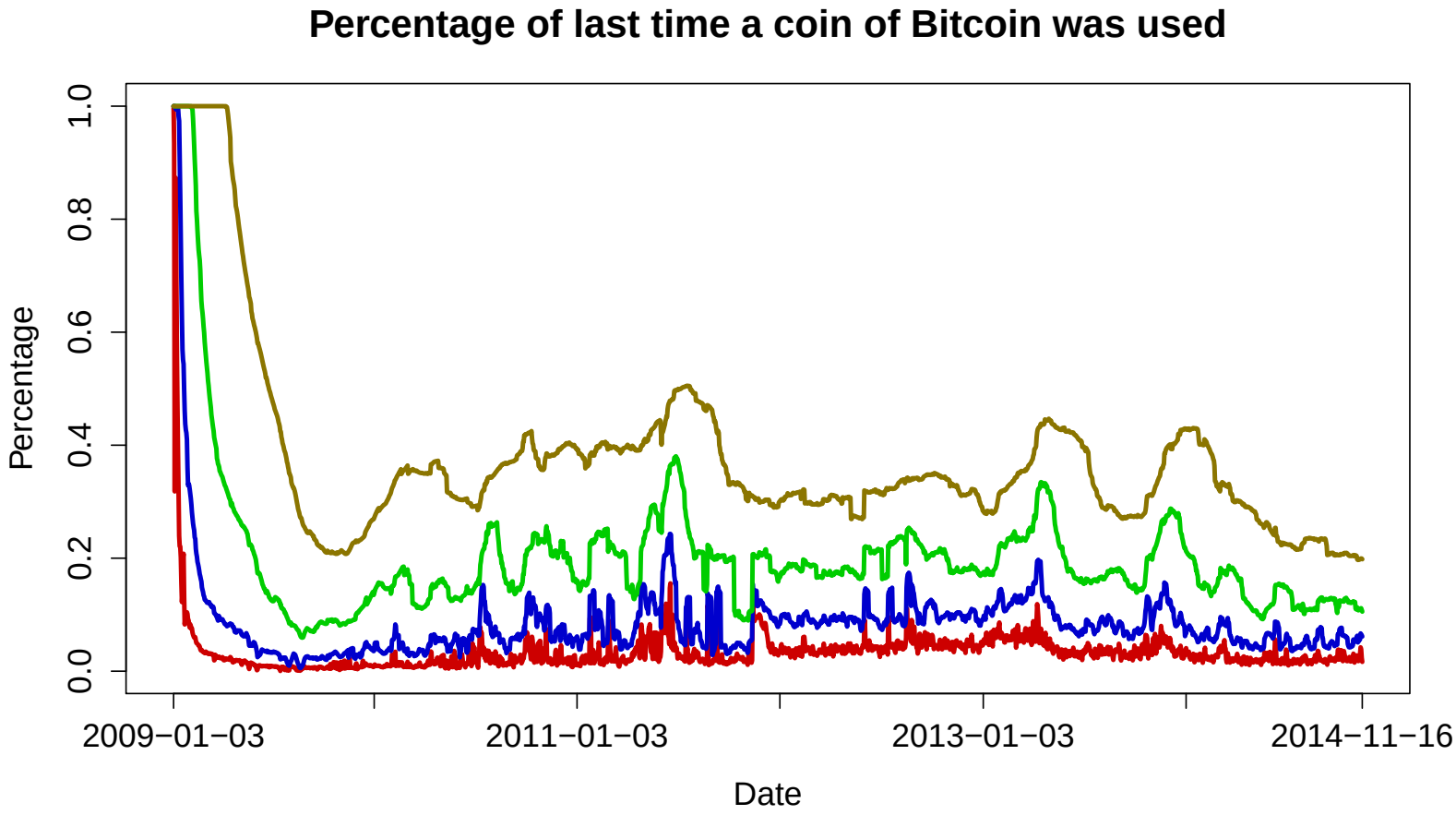

Figure 11: one day, one week, one month, 1-3 month source: John Radcliff

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Kernel Density Estimation (KDE)

- Compute pdf with KDE

$$\hat{f}_h(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right)$$

  with $K(u)$ Epanechnikov kernel, h bandwidth

- Bandwidth selection with Wand & Jones plug-in estimator

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References

- Cigarette trading in postwar Germany, Bundesarchiv, Bild 183-R79014 / CC-BY-SA
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