Looking under the hood: Investigating the blockchain with R

Bernhard Pfaff
bernhard_pfaff@fra.invesco.com

Invesco Asset Management GmbH
Frankfurt am Main

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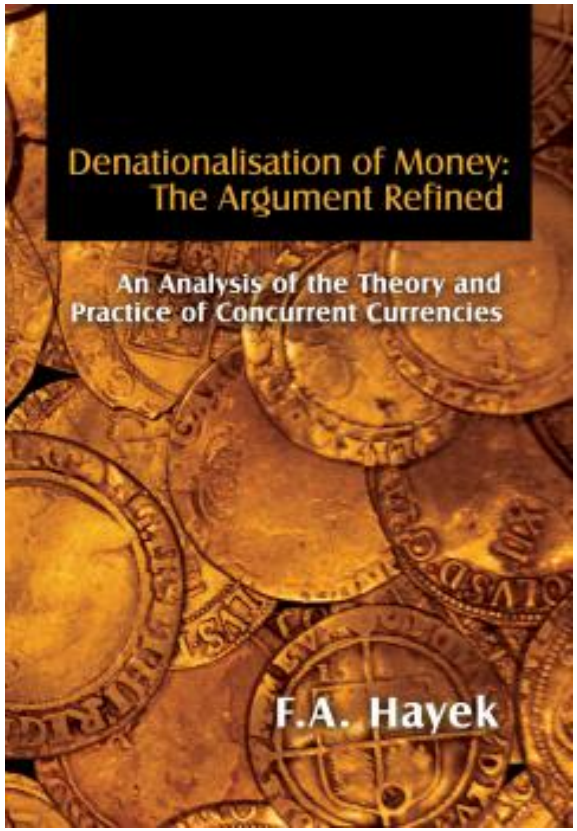
Prologue

Who knows, who this person is?

Source: Wikipedia, license Wikimedia Commons.

Prologue

A reminiscence to Vienna & the Austrian School



Friedrich August von Hayek
(* 8 May 1899 in Vienna; † 23 March 1992 in Freiburg im Breisgau).

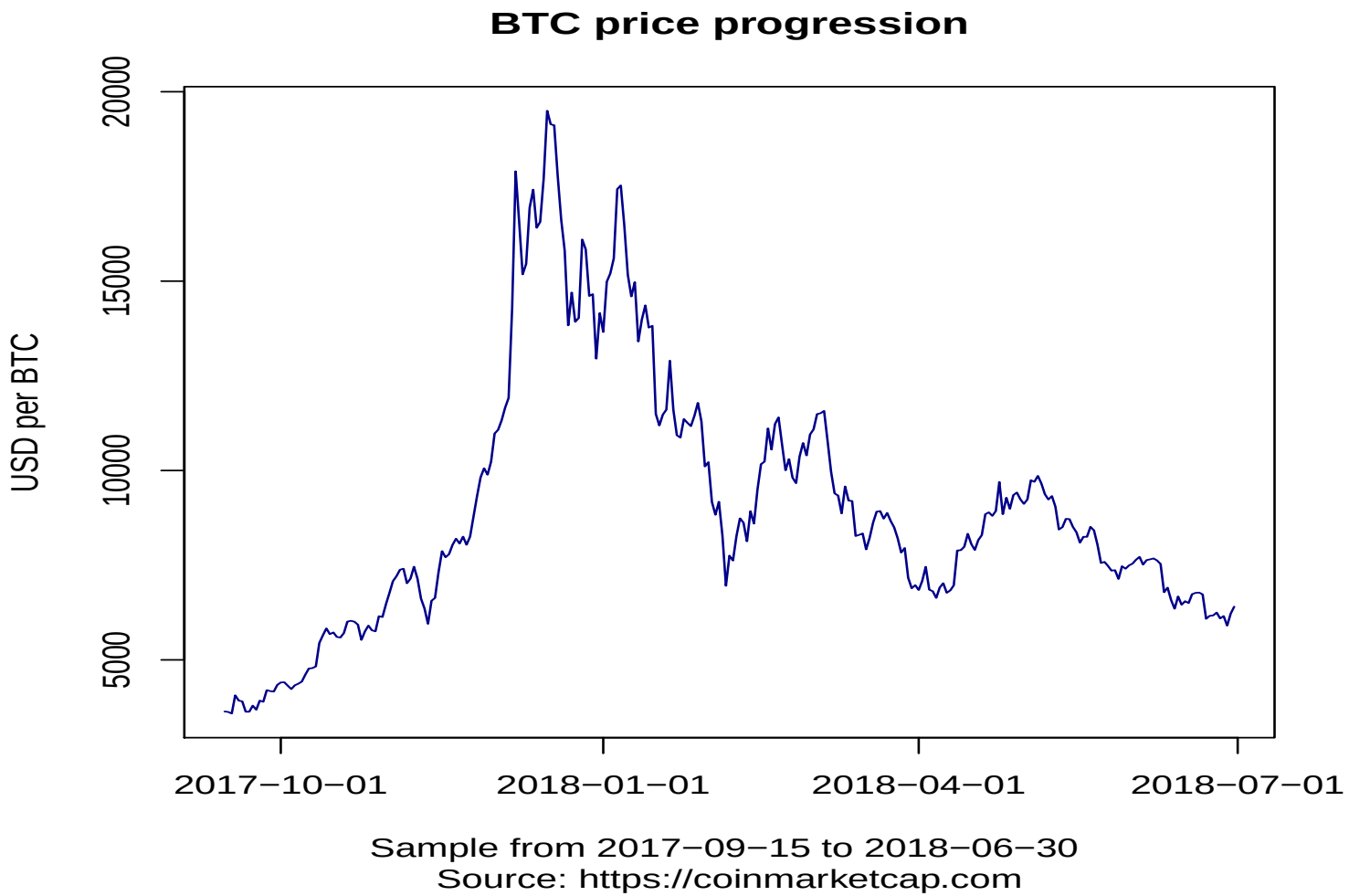
Source: Wikepedia, licence Wikimedia Commons; Hayek (1977).

Overview

- BTC: Charts & Statistics
- BTC: Blockchain Primer
- R package **rbtc**
- Block Analysis
- Summary
  item Appendix

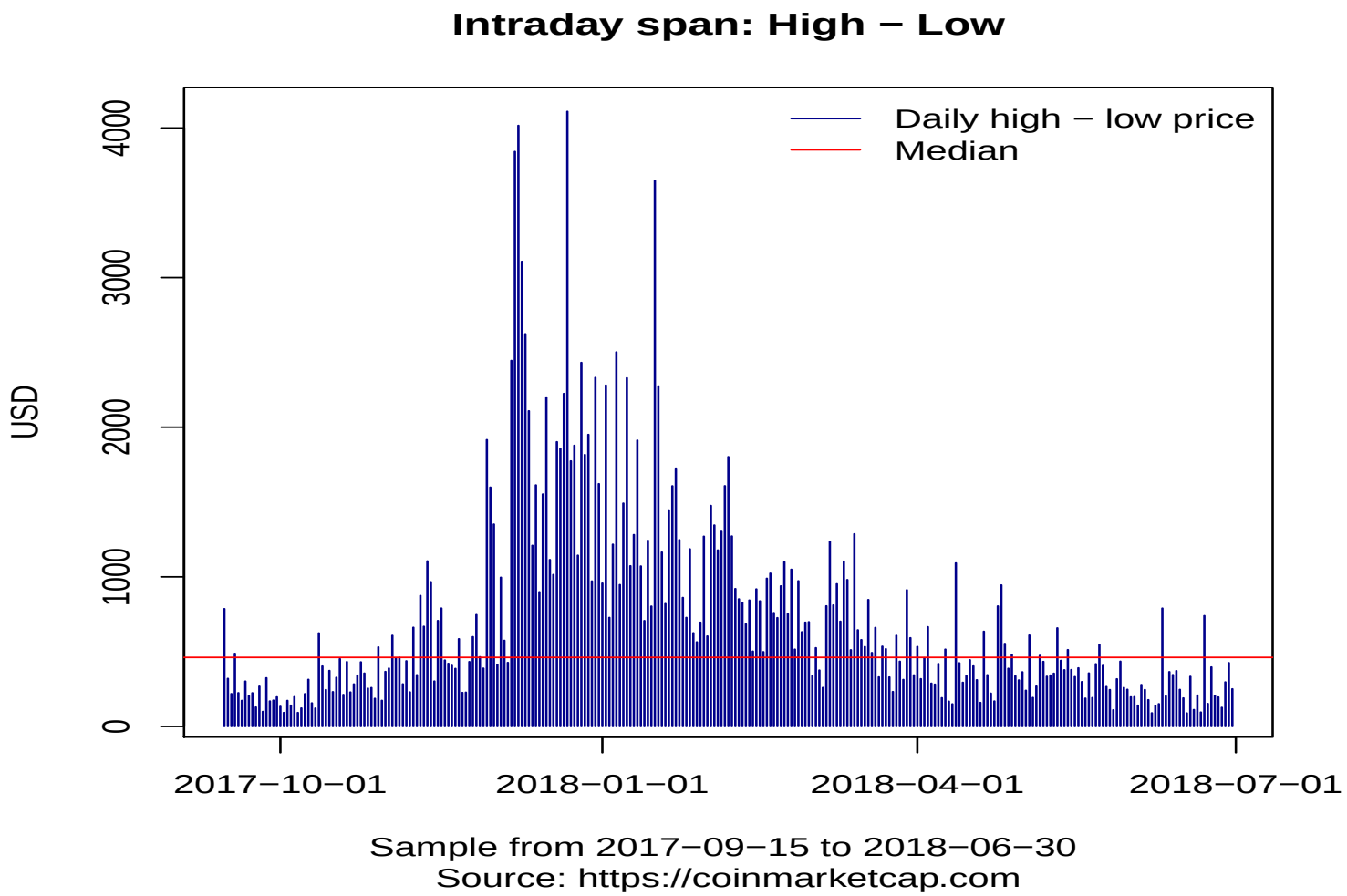
BTC: Charts & Statistics

Fade away of a frenzy?



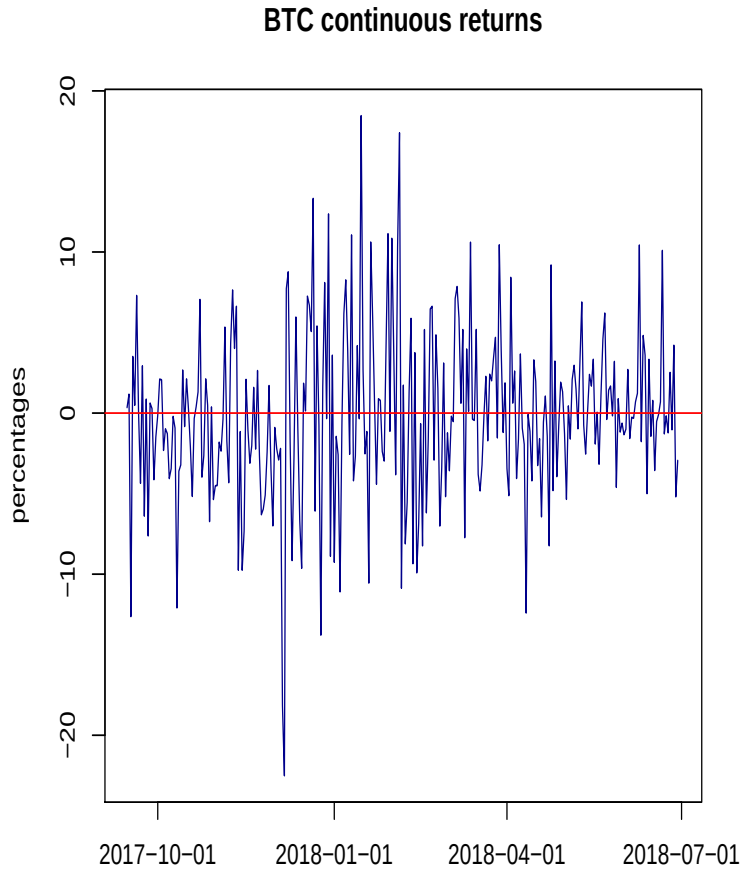
BTC: Charts & Statistics

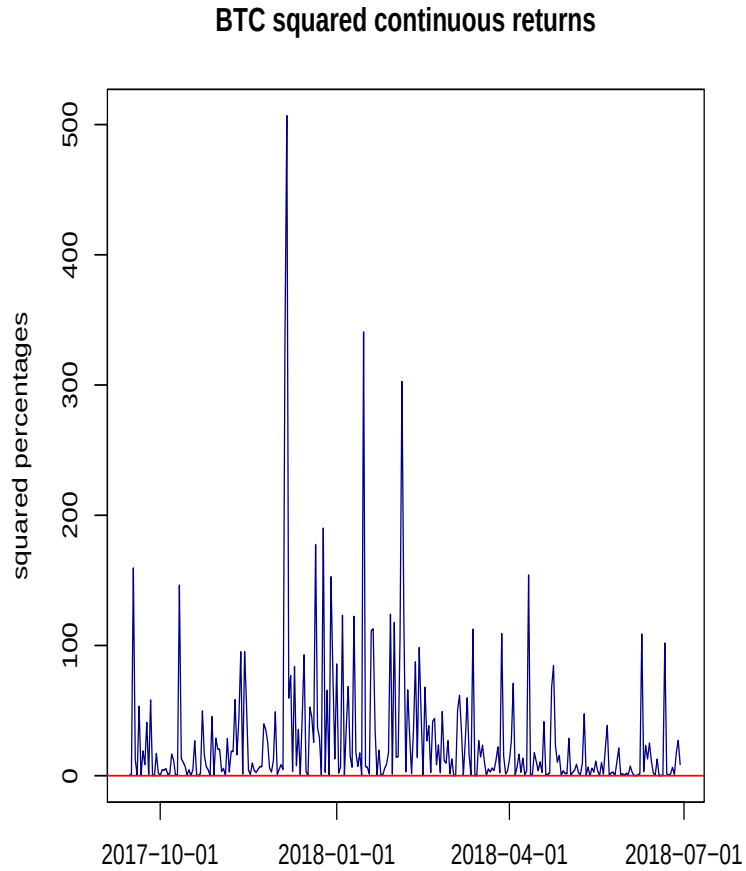
Nerve bundles should better stay away . . .



BTC: Charts & Statistics

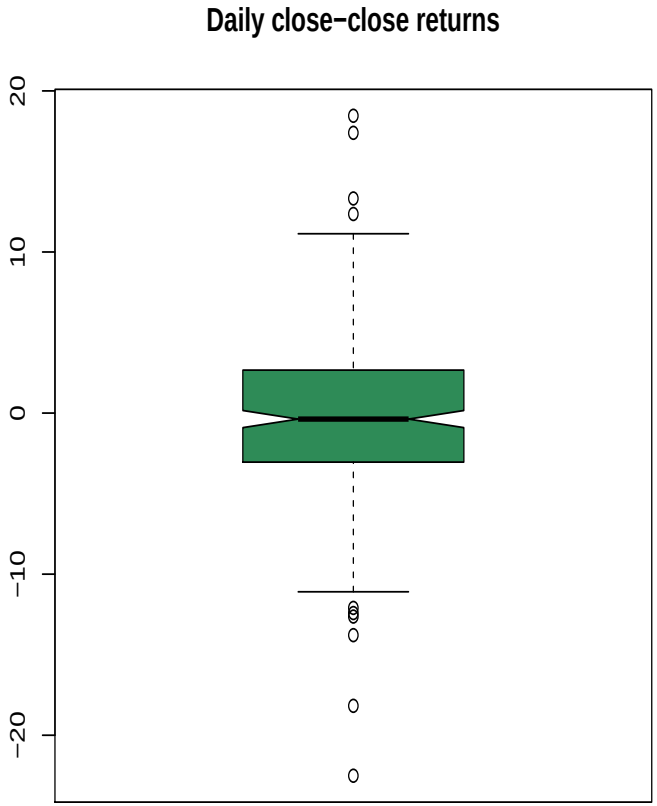
Returns and Volatility





BTC: Charts & Statistics

Daily Returns: Descriptive Statistics



Statistic	
Minimum	−22.512
Maximum	18.458
Mean	−0.196
Median	−0.373
StdDev	5.341
Skewness	−0.067
Kurtosis (excess)	1.644

BTC: Blockchain Primer

Key Items

- A distributed (P2P) ledger (double-entry bookkeeping) system.
- Bitcoin is an open source project, MIT license.
- Network started in 2009 (*genesis block*).
- Three net environments: `mainnet`, `testnet`, `regtest`.
- Three broad transaction types: `P2PKH` (`P2PK`), `P2SH` & `SegWit` (`P2WPKH`).
- Transactions are validated, collected in blocks and are confirmed by solving a cryptographic puzzle (Proof-of-Work).
- First transaction in a block is termed *coinbase*: the miner's revenue (transaction fees plus mining reward).
- Common bitcoin denomination (units):
  1. 1 cBTC $=$ 0.01 BTC (a hundreth),
  2. 1 mBTC $=$ 0.001 BTC (a thousandth),
  3. 1 (μ)uBTC $=$ 0.000001 BTC (one millionth),
  4. 1 Satoshi $=$ 1 sat $=$ 0.00000001 BTC (one hundred millionth).

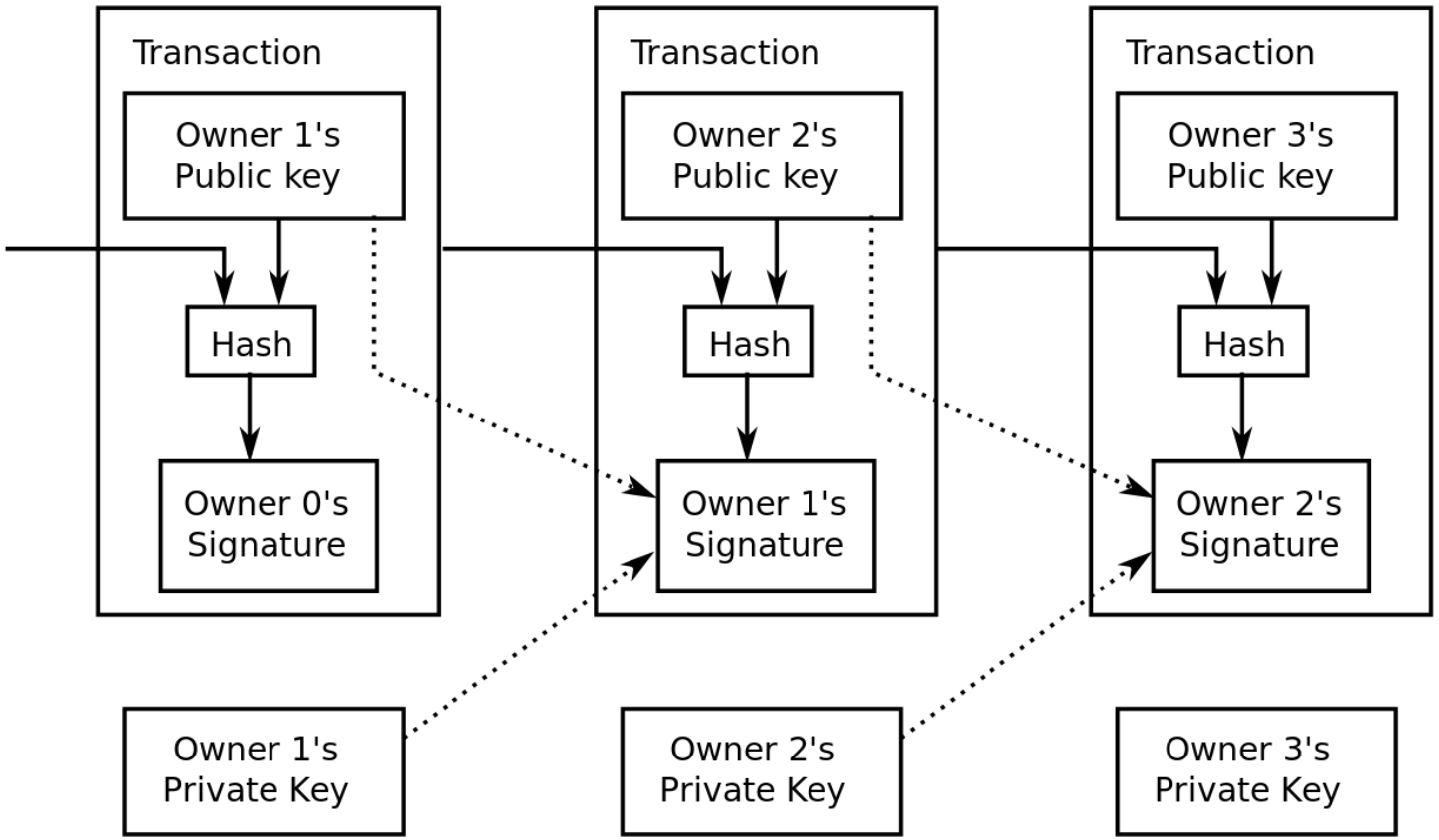
BTC: Blockchain Primer

Transactions in Detail

- Double-entry bookkeeping: Sum of input values (*debits*) equals sum of output values (*credits*) plus a transaction fee.
- Transactions are chained: only outputs from a previous transaction (UTXOs) can be used as inputs in a new transaction (discrete and indivisible units of value).
- Content of transaction output: a) amount of bitcoin, b) length script in bytes and c) locking script itself (witness script / `scriptPubKey`.
- Content of transaction input: a) transaction hash, b) index number of the UTXO in the former transaction, c) length script in bytes, d) unlocking script (`scriptSig`) and e) sequence number (locktime).
- Transactions are broadcasted as serialized byte-streams.

BTC: Blockchain Primer

Transactions in progress



Source: https://en.wikipedia.org/wiki/Bitcoin_network, licence Wikimedia Commons, Author: Satoshi Nakamoto.

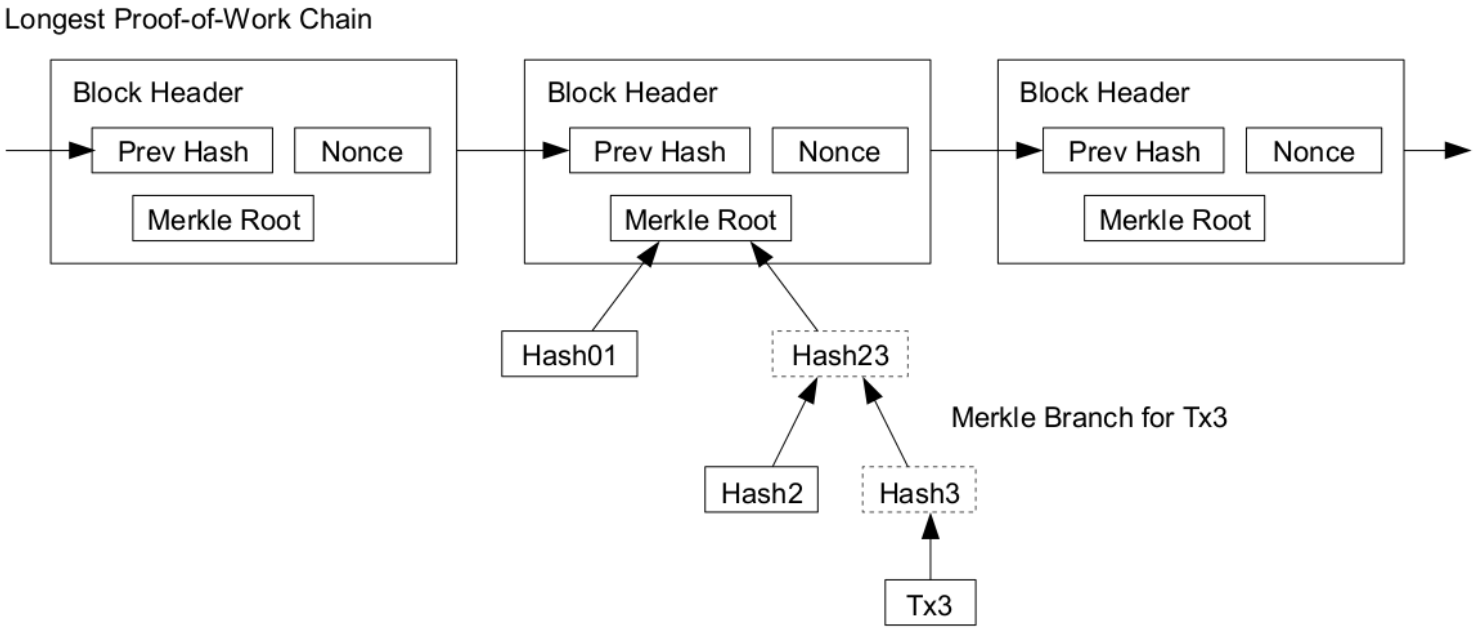
BTC: Blockchain Primer

Blocks in Detail

- Content of a block: a) size of block (bytes), b) block header, c) count of transactions and d) transactions in the block.
- Content of a block header: a) version of the software protocol, b) previous block hash, c) the Merkle Root, d) timestamp, e) difficulty target and f) the nonce.
- Approximately every 10 minutes a block is mined.
- Every $2,016$ blocks the difficulty target is adjusted to meet this mining time goal.

BTC: Blockchain Primer

Blocks: Content and Chain



Source: https://en.wikipedia.org/wiki/Bitcoin_network, licence Wikimedia Commons, Author: Satoshi Nakamoto.

R package **rbtc**

Structure

- A (partial) implementation of the BitCoin API and related utility functions. (see Antonopoulos (2017) and `https://bitcoin.org/en/developer-reference`).
- Purely written in R and utilizes S4-classes and methods.
- Dependencies to the packages **httr** (see Wickham, 2017) and **rjson** (see Couture-Beil, 2014) for conducting calls to and receiving responses from the RPC-JSON API.
- Dependencies to **openssl** (see Ooms, 2018) and **gmp** (see Lucas et al., 2017) for creating BTC addresses.
- Requirement(s): bitcoin-core/bitcoind; configuration file (see `https://en.bitcoin.it/wiki/Running_Bitcoin`).
- Hosted on GitHub: https://github.com/bpfaff/rbtc/

R package **rbtc**

Key Functions

- `startbtc()` and `stopbtc()`:
  `bitcoind` can also be started/stopped from the shell, supports TOR.
- `conrpc()`:
  creating a connection object, used in http posts.
- `getblockhash()`:
  hash of a block for a provided height.
- `getblock()`:
  block's content (three levels of verbosity).
- `getrawtransaction()` & `decoderawtransaction()`:
  retrieving & decoding of a transaction (two levels of verbosity).
- `decodescript()`:
  decoding of a P2SH (UTXO address starts with a '3').

R package **rbtc**

Key S4-Classes

- `CONRPC`:
  object for establishing calls to JSON-RPC.
- `ANSRPC`:
  objects returned by calls to JSON-RPC.
- `ECPARAM` and `ECPOINT`:
  elliptic curve computations.
- `BTCADR`:
  object containing private & public keys, WIF, public hash and BTC address – should not be used on `mainnet`, only for exemplary purposes.

R package **rbtc**

Utility Functions

- Functions for coercing integer to date times and *vice versa*: `int2date()`, `date2int()`, `intMinDay()`, `intMaxDay()`, `intRangeDay()`, `intRangePeriod()`.
- Functions for aggregating/retrieving information contained in blocks/transactions: `blockstats()`, `txstats()`, `txfee()`, `txids()`, `txinids()`, `utxoage()`, `utxovalue()`, `timeofblock()`, `blockattime()`.
- Functions/methods & operators related to cryptographic algorithms: `ecpoint()`, `doubleUp()`, `+`, `*`, `AND`, `leftmostBit()`, `createPrivateKey()`, `PrivKey2Wif()`, `Wif2PrivKey()`, `PrivKey2PubKey()`, `PubKey2PubHash()`, `PubHash2BtcAdr()`, `createBtcAdr()`, `concatHex()`, `hash256()`, `hash160()`, `base58CheckEncode()`, `base58CheckDecode()`, `decodeHex()`.

Block Analysis

Setting the Scene . . .

- Sample period from 09/15/2017 until 06/30/2018.
- This corresponds to the block heights from 485, 295 until 529, 950; a total of 44, 6656 blocks.
- Empty blocks and coinbase transactions are excluded from the analysis (see https://news.bitcoin.com).
- For saving/retrieval of intermediate results the Rpackages **RSQLite** (see Müller et al., 2018) and **DBI** (see R Special Interest Group on Databases (R-SIG-DB) et al., 2018) are utilized.
- Time series aggregation with R package **timeSeries** (see Würtz et al., 2017, in memoriam Diethelm!).

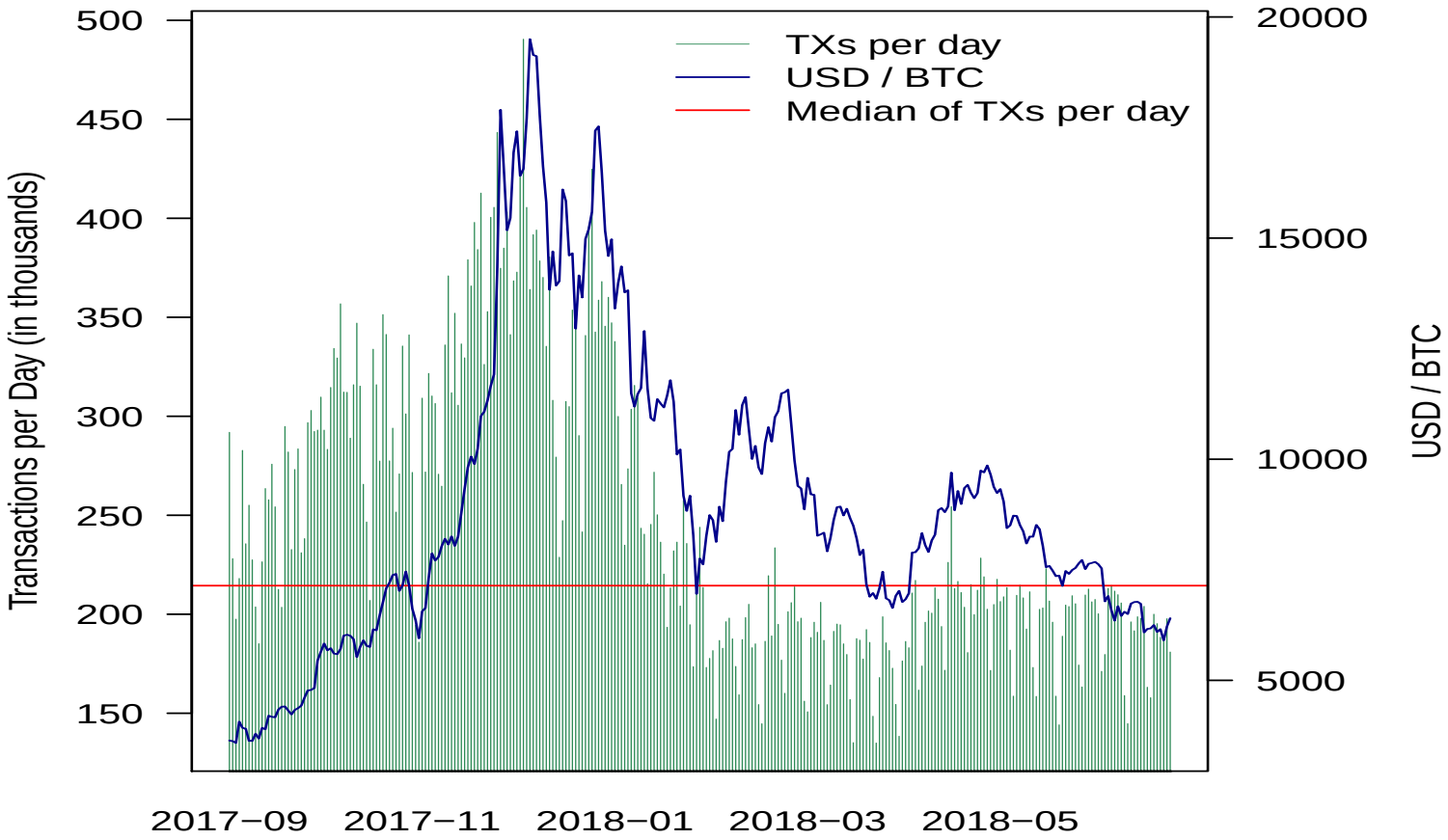
Block Analysis

Gearing up . . .

```
> ## Code to show on slide: retrieving blockstats (DBI)
```

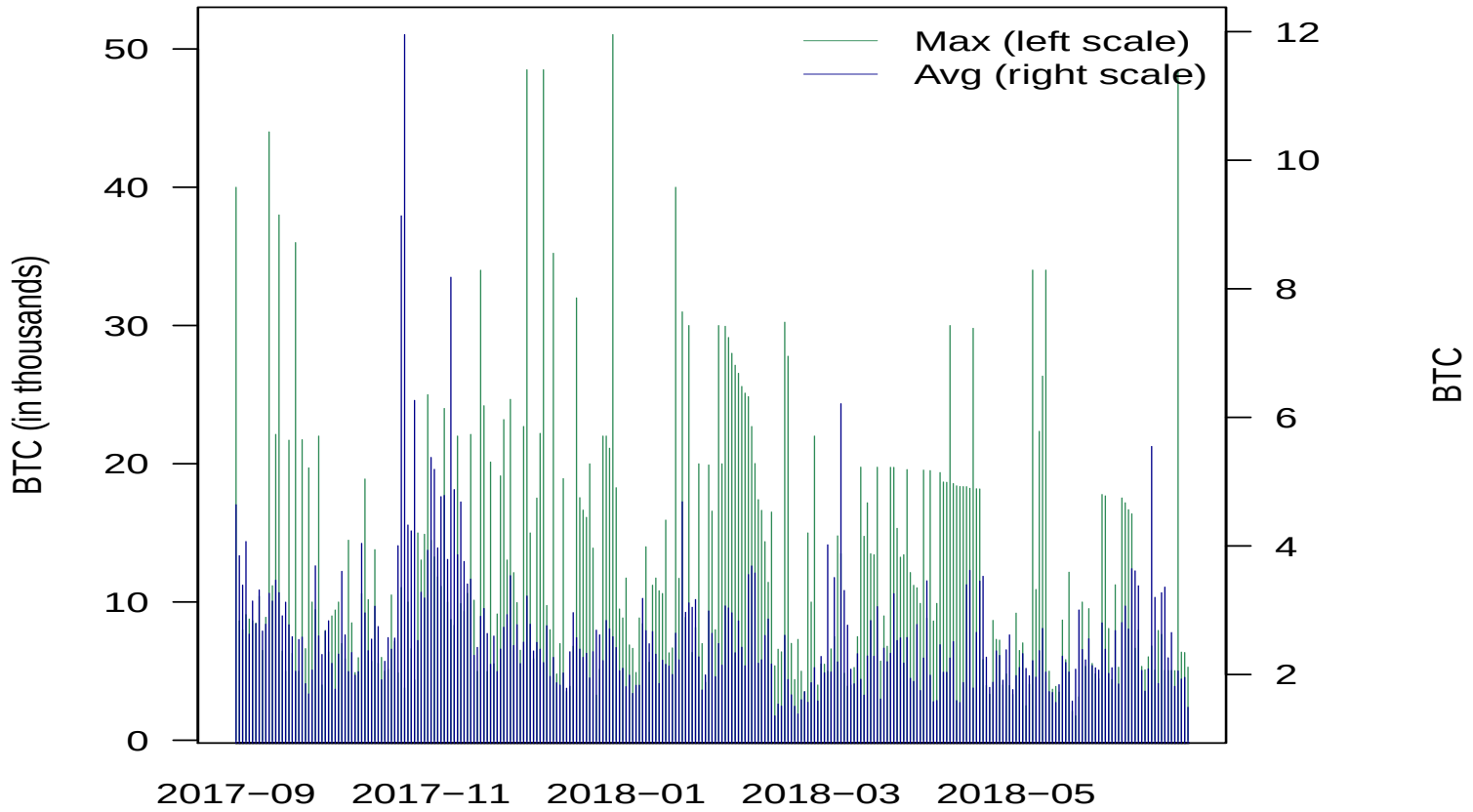
Block Analysis

When the crowd kicked in . . .



Block Analysis

UTXO: Cameron & Tyler, was that you?



Block Analysis

Chasing the Coins: BTC's Black Friday was on 22nd December 2017

- Biggest price swing intra-day ever since.
- Market commentary, for instance:
  https://money.cnn.com, https://www.theguardian.com
- Analysing the vintage of the traded `UTXOs` in the blocks on that day.
- Can trading patterns/behaviour be detected?
- A data science field experiment for behavioral finance?

Block Analysis

Chasing the Coins: BTCs Black Friday 2017/12/22

```
> sblock <- blockattime("2017-12-22 00:00:00")[2, 1]
> eblock <- blockattime("2017-12-22 23:59:59")[1, 1]
> bseq <- sblock:eblock
> n <- length(bseq)
> ## Creating SQLite-table
> coinage <- data.frame("Height" = integer(),
+                       "Time" = integer(),
+                       "AgeMin" = numeric(),
+                       "AgeMax" = numeric(),
+                       "AgeMean" = numeric(),
+                       "AgeMedian" = numeric()
+                       )
> dbCreateTable(conlite,
+               name = "coinage",
+               fields = coinage)
> ## Looping through the blocks
> for (i in 1:n){
+     h <- slot(getblockhash(con, bseq[i]),
+               "result")
+     b <- slot(getblock(con, h),
+               "result")
+     btime <- b[["time"]]
+     txsinblock <- unlist(b[["tx"]])[-1] # ex coinbase
+     k <- length(txsinblock)
+     if (k > 0){ # mind the empty blocks
+         vage <- c()
+         for (j in 1:k){
```

Block Analysis (contd.)

Chasing the Coins: BTCs Black Friday 2017/12/22

```
+             inputage <- uxtoage(con, txsinblock[j])
+             vage <- c(vage, inputage[["AgeInput"]])
+         }
+         ans <- data.frame("Height" = bseq[i],
+                           "Time" = btime,
+                           "AgeMin" = min(vage),
+                           "AgeMax" = max(vage),
+                           "AgeMean" = mean(vage),
+                           "AgeMedian" = stats::median(vage),
+                           )
+         dbAppendTable(conlite,
+                       name = "coinage",
+                       value = ans)
+     }
+ }
```

Block Analysis

Hidden Content in the Blocks?

- Have a look at this transaction:

```
> txid <- ""
> (tx <- slot(getrawTransaction(con, ),
+             "result"))
```

- Something suspicious with `utxo` address `17EGi2sxaBtfceqANacKkeHVvoKXgAbnjc`?
- Let's check:
  1. Apply base 58 check decoding
  2. Drop last four bytes, *i.e.*, take first 20 bytes
  3. Convert from raw to character format ...

Block Analysis

Unveiling the Miracle

```
> y <- "17EGi2sxaBtfceqANacKkeHVvoKXgAbnjc"
> (r1 <- base58CheckDecode(y)[1:20])
 [1] 44 53 46 2d 52 20 56 69 65 6e 6e 61 3a 20 47 72 65 61 74 21
> (r2 <- rawToChar(r1))
[1] "DSF-R Vienna: Great!"
> ## ... and in the opposite direction
> x <- "DSF-R Vienna: Great!" # must be 20 characters long
> (s <- paste(charToRaw(x), collapse = ""))
[1] "4453462d52205669656e6e613a20477265617421"
> (se <- c(decodeHex("00"), decodeHex(s)))
 [1] 00 44 53 46 2d 52 20 56 69 65 6e 6e 61 3a 20 47 72 65 61 74 21
> (cs <- hash256(se)[1:4])
[1] 6b dc 1b bb
> (pkh <- c(se, cs))
 [1] 00 44 53 46 2d 52 20 56 69 65 6e 6e 61 3a 20 47 72 65 61 74 21 6b dc 1b bb
> (y <- base58CheckEncode(pkh))
[1] "17EGi2sxaBtfceqANacKkeHVvoKXgAbnjc"
```

Wahrschau! The amount send to this address is lost, unless you find the corresponding private key, good luck!

See Ken Shiriff's blog for more examples.

Summary

- A tool for investigating the blockchain and deriving descriptive statistics.
- The package can be utilized for data science research in finance (viewed as a field experiment: *e.g.*, market micro structure analysis and/or behavioral finance).
- Complementary to the R packages **rbitcoin** (see Gorecki, 2014) and **coindeskr** (see AbdulMajedRaja, 2018), *i.e.* linking summary statistics derived from the block chain with BTC price history.
- Package is hosted on CRAN, R-Forge & GitHub — your choice.

Thank You!

Appendix

Glossary

- `BIP`: Bitcoin improvement proposal.
- `ECDSA`: Elliptic Curve Digital Signature Algorithm.
- `P2P`: Peer-to-Peer Network Architecture.
- `P2PK` & `P2PKH`: Pay-to-Public-Key(-Hash).
- `P2SH`: Pay-to-Script-Hash.
- `P2WPKH`: Pay-to-Witness-Public-Key-Hash.
- `satoshi`: smallest bitcoin unit.
- `TOR`: The Onion Router.
- `TXID`: Transaction identifier.
- `UTXO`: unspent transaction outputs (`vout` field JSON output from RPC-API).
- `WIF`: Wallet Import Format.

Appendix

Session Information

```
> sessionInfo()
R version 3.5.1 (2018-07-02)
Platform: x86_64-pc-linux-gnu (64-bit)
Running under: Ubuntu 18.04.1 LTS

Matrix products: default
BLAS: /usr/lib/x86_64-linux-gnu/blas/libblas.so.3.7.1
LAPACK: /usr/lib/x86_64-linux-gnu/lapack/liblapack.so.3.7.1

locale:
  [1] LC_CTYPE=de_DE.UTF-8       LC_NUMERIC=C
  [3] LC_TIME=de_DE.UTF-8        LC_COLLATE=de_DE.UTF-8
  [5] LC_MONETARY=de_DE.UTF-8    LC_MESSAGES=de_DE.UTF-8
  [7] LC_PAPER=de_DE.UTF-8       LC_NAME=C
  [9] LC_ADDRESS=C               LC_TELEPHONE=C [11] LC_MEASUREMENT=de_DE.UTF-8 LC_IDENTIFICATION=C

attached base packages:
[1] stats     graphics  grDevices utils     datasets  methods base

other attached packages:
[1] timeSeries_3042.102 timeDate_3043.102   DBI_1.0.0 [4] rbtc_0.1-4

loaded via a namespace (and not attached):
[1] httr_1.3.1     compiler_3.5.1 rjson_0.2.20   R6_2.2.2 gmp_0.5-13.2 [6] openssl_1.0.2
```

Appendix

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Appendix (contd.)

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