

Trading and social signals in the Bitcoin ecosystem

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Signals of the Bitcoin ecosystem

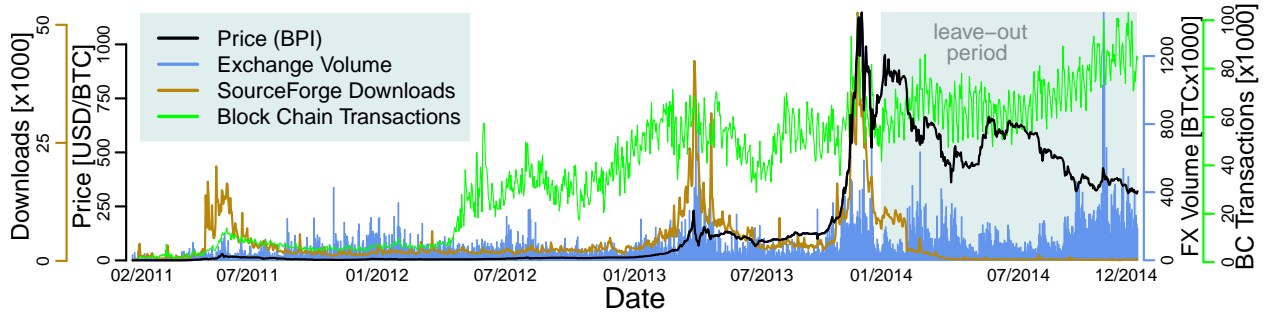


Figure 1: Time series of Bitcoin Price Index, FX Volume, amount of transactions in the Block Chain, and Bitcoin client downloads.

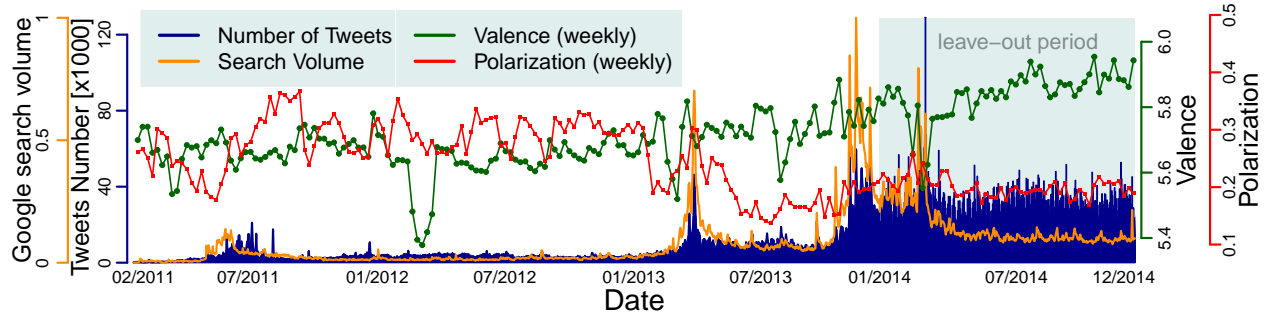


Figure 2: Time series of Bitcoin-related tweets, polarization, valence, and Google search volume.

FXVolume	BC Transactions	Downloads	Tweets
152439477	55210262	5449105	19578671

Table 1: Summary of dataset sizes.

Stationarity tests

signal	ADF	ADFpval	PP	PPpval	KSP	KSPpval	AR
Tweets	-7.7559748	0.0000000	-101.9368658	0.0100000	5.5212865	0.0100000	0.9135424
Polarization	-7.9836833	0.0000000	-158.1479700	0.0100000	4.6718462	0.0100000	0.8584331
Valence	-12.1639828	0.0000000	-493.8340651	0.0100000	2.8230069	0.0100000	0.6489829
Transactions	-8.2131394	0.0000000	-125.7243099	0.0100000	12.0026714	0.0100000	0.9999990
ExchangeVolume	-11.9483558	0.0000000	-475.7609587	0.0100000	2.6769065	0.0100000	0.6586341
Downloads	-5.8322548	0.0000037	-43.3071791	0.0100000	2.6960804	0.0100000	0.9992237
Search	-6.7051727	0.0000000	-41.1135810	0.0100000	3.9321100	0.0100000	0.9994038
BPI	-0.8243950	0.9619119	-3.5448747	0.9096929	4.3478948	0.0100000	0.9979938
Return	-22.6856583	0.0000000	-1044.5997512	0.0100000	0.1824587	0.1000000	0.0721432

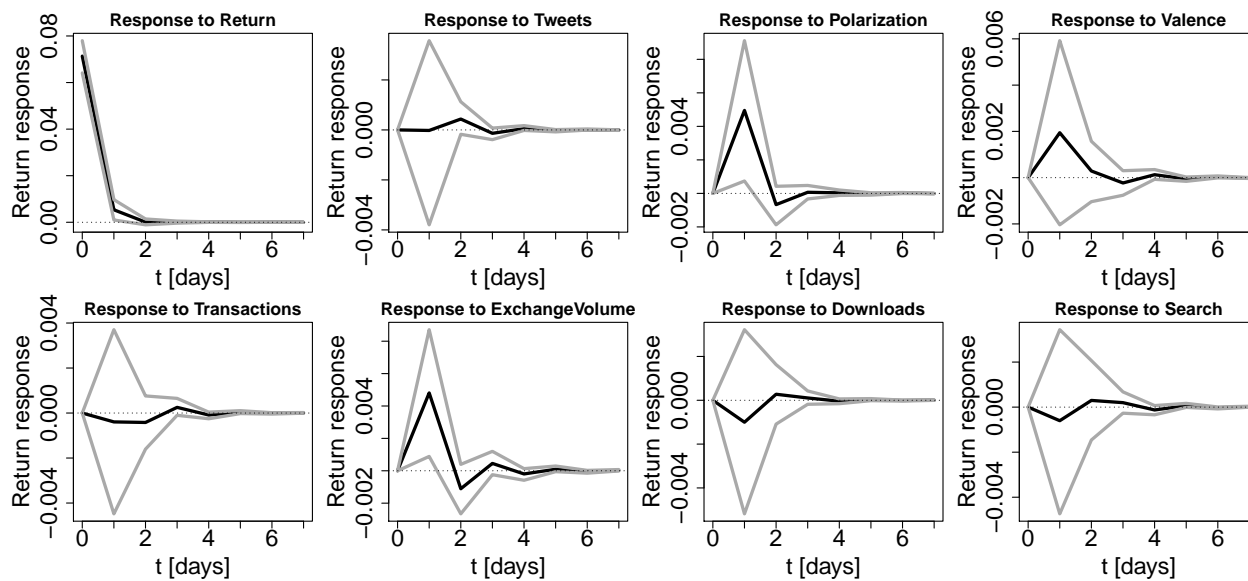
Table 2: Stationarity tests for time series of levels and Return

signal	ADF	ADFpval	PP	PPpval	KSP	KSPpval	AR
Δ Tweets	-30.9634468	0.0000000	-833.1857606	0.0100000	0.0430182	0.1000000	-0.1391233
Δ Polarization	-31.5239392	0.0000000	-1023.3434173	0.0100000	0.0146565	0.1000000	-0.2593133
Δ Valence	-38.7433909	0.0000000	-1091.8257832	0.0100000	0.0107607	0.1000000	-0.3310941
Δ Transactions	-31.0196706	0.0000000	-883.7768285	0.0100000	0.0155640	0.1000000	-0.1592976
Δ ExchangeVolume	-32.3629574	0.0000000	-1109.4614927	0.0100000	0.0082475	0.1000000	-0.3398761
Δ Downloads	-25.7994780	0.0000000	-735.7927756	0.0100000	0.0154578	0.1000000	0.0783164
Δ Search	-27.9643026	0.0000000	-569.5286792	0.0100000	0.0265053	0.1000000	0.1654444

Table 3: Stationarity tests for time series of first order differences

Vector Auto-Regression

Response of Return

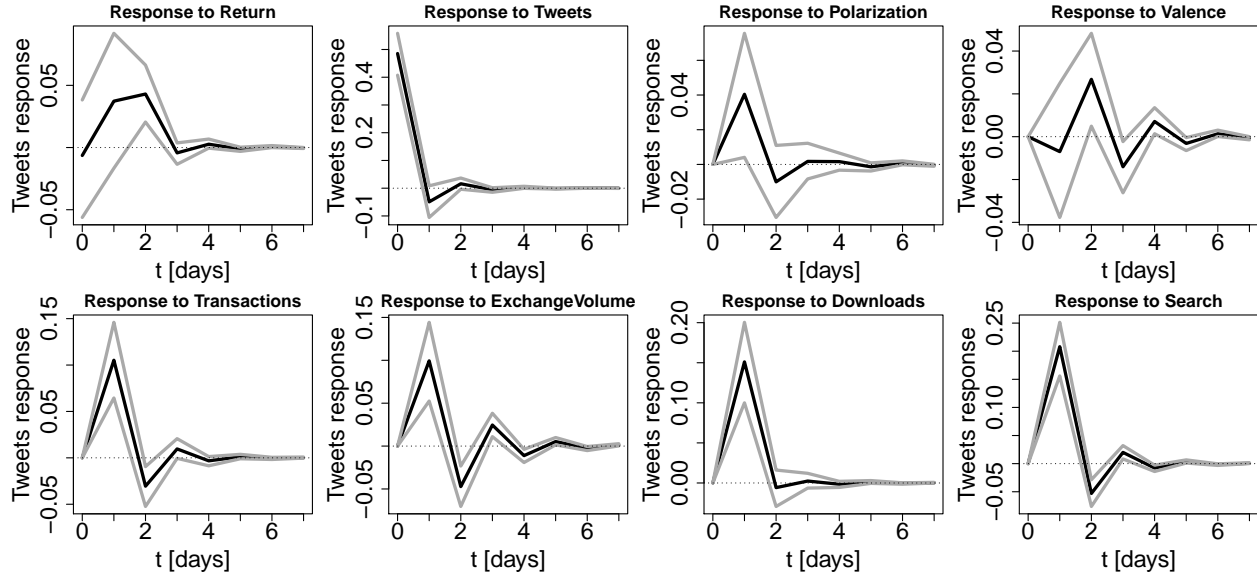


	VAR(1)	VAR(opt)
Return.l1	0.09 (0.03)**	0.09 (0.03)**
Tweets.l1	0.00 (0.00)	0.00 (0.01)
Polarization.l1	0.00 (0.00)*	0.00 (0.00)*
Valence.l1	0.00 (0.00)	0.00 (0.00)
Transactions.l1	-0.00 (0.00)	-0.00 (0.00)
ExchangeVolume.l1	0.01 (0.00)*	0.01 (0.00)**
Downloads.l1	-0.00 (0.00)	-0.00 (0.00)
Search.l1	-0.00 (0.00)	-0.00 (0.00)
const	0.01 (0.00)	0.01 (0.00)
trend	0.00 (0.00)	0.00 (0.00)
Return.l2		-0.01 (0.03)
Tweets.l2		0.00 (0.01)
Polarization.l2		-0.00 (0.00)
Valence.l2		0.00 (0.00)
Transactions.l2		-0.00 (0.00)
ExchangeVolume.l2		0.00 (0.00)
Downloads.l2		0.00 (0.00)
Search.l2		-0.00 (0.00)
R ²	0.02	0.02
Adj. R ²	0.01	0.00
Num. obs.	1065	1064
RMSE	0.07	0.07

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 4: Results for Return equation

Response of Number of tweets

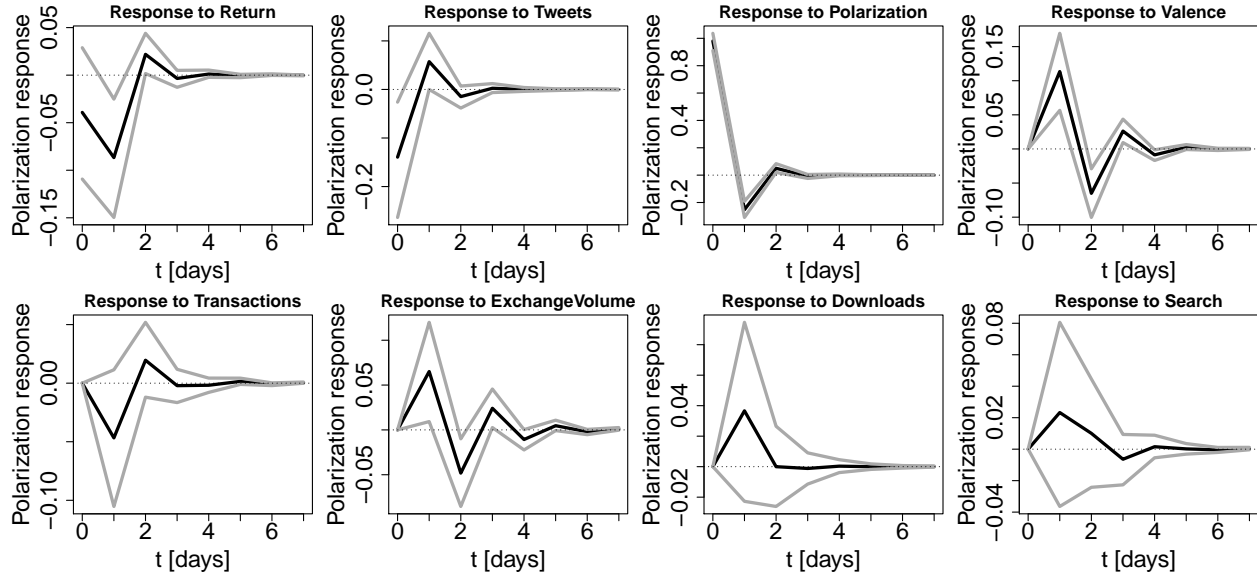


	VAR(1)	VAR(opt)
Return.l1	0.64 (0.21)**	0.66 (0.20)**
Tweets.l1	-0.50 (0.03)***	-0.55 (0.04)***
Polarization.l1	-0.01 (0.01)	-0.01 (0.01)
Valence.l1	-0.01 (0.01)	-0.01 (0.01)
Transactions.l1	0.07 (0.02)***	0.06 (0.02)***
ExchangeVolume.l1	0.03 (0.02)	0.07 (0.02)***
Downloads.l1	0.02 (0.02)	0.02 (0.02)
Search.l1	0.36 (0.03)***	0.36 (0.02)***
const	-0.01 (0.03)	-0.01 (0.03)
trend	0.00 (0.00)	0.00 (0.00)
Return.l2		0.09 (0.21)
Tweets.l2		-0.26 (0.03)***
Polarization.l2		0.01 (0.01)
Valence.l2		0.01 (0.01)
Transactions.l2		0.01 (0.02)
ExchangeVolume.l2		0.08 (0.02)***
Downloads.l2		0.01 (0.02)
Search.l2		-0.04 (0.03)
R ²	0.30	0.38
Adj. R ²	0.30	0.37
Num. obs.	1065	1064
RMSE	0.49	0.46

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 5: Results for Tweets equation

Response of Polarization

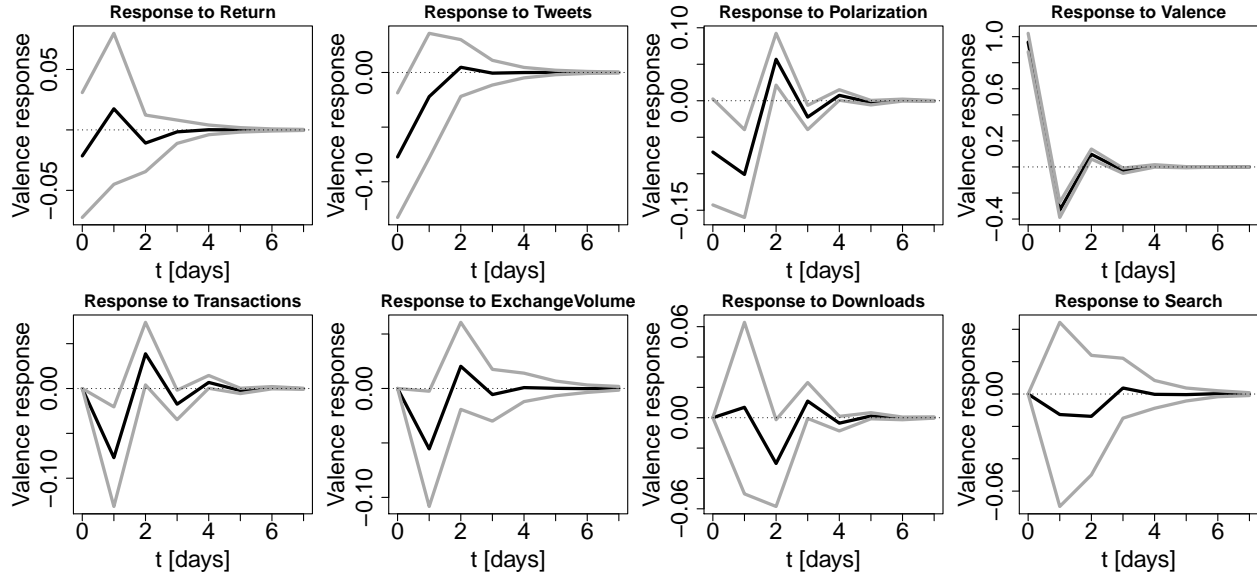


	VAR(1)	VAR(opt)
Return.l1	-1.17 (0.44)**	-1.06 (0.43)*
Tweets.l1	0.03 (0.07)	0.06 (0.08)
Polarization.l1	-0.26 (0.03)***	-0.30 (0.03)***
Valence.l1	0.12 (0.03)***	0.12 (0.03)***
Transactions.l1	-0.08 (0.04)*	-0.07 (0.04)
ExchangeVolume.l1	0.07 (0.04)	0.06 (0.04)
Downloads.l1	0.02 (0.03)	0.02 (0.03)
Search.l1	0.04 (0.05)	0.02 (0.05)
const	0.01 (0.06)	0.01 (0.06)
trend	0.00 (0.00)	-0.00 (0.00)
Return.l2		0.30 (0.44)
Tweets.l2		-0.02 (0.07)
Polarization.l2		-0.18 (0.03)***
Valence.l2		0.08 (0.03)**
Transactions.l2		0.02 (0.04)
ExchangeVolume.l2		-0.07 (0.04)
Downloads.l2		0.00 (0.03)
Search.l2		0.04 (0.06)
R ²	0.10	0.14
Adj. R ²	0.09	0.13
Num. obs.	1065	1064
RMSE	0.99	0.97

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 6: Results for Polarization equation

Response of Valence

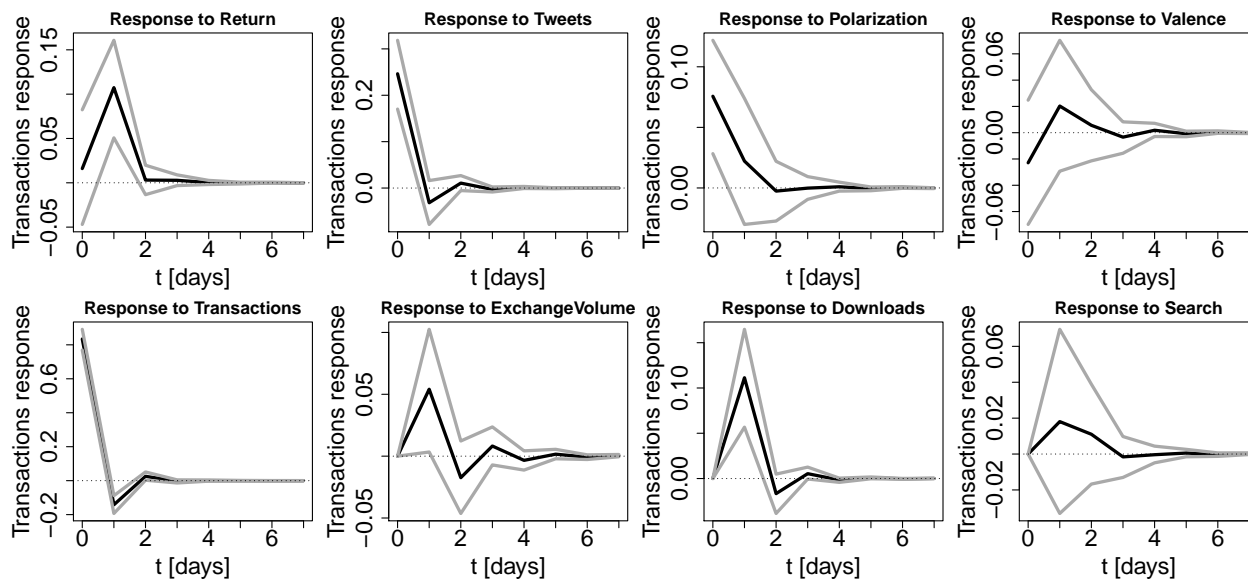


	VAR(1)	VAR(opt)
Return.l1	-0.09 (0.43)	0.04 (0.40)
Tweets.l1	-0.06 (0.06)	-0.09 (0.07)
Polarization.l1	-0.11 (0.03) ^{***}	-0.09 (0.03) ^{**}
Valence.l1	-0.35 (0.03) ^{***}	-0.47 (0.03) ^{***}
Transactions.l1	-0.08 (0.04) [*]	-0.08 (0.03) [*]
ExchangeVolume.l1	-0.07 (0.04)	-0.05 (0.04)
Downloads.l1	0.01 (0.03)	0.02 (0.03)
Search.l1	-0.02 (0.05)	-0.02 (0.05)
const	-0.01 (0.06)	-0.02 (0.06)
trend	0.00 (0.00)	0.00 (0.00)
Return.l2		-0.17 (0.41)
Tweets.l2		-0.03 (0.07)
Polarization.l2		-0.04 (0.03)
Valence.l2		-0.36 (0.03) ^{***}
Transactions.l2		0.03 (0.03)
ExchangeVolume.l2		-0.02 (0.04)
Downloads.l2		0.02 (0.03)
Search.l2		-0.03 (0.05)
R ²	0.14	0.25
Adj. R ²	0.13	0.24
Num. obs.	1065	1064
RMSE	0.96	0.90

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 7: Results for Valence equation

Response of BC Transactions

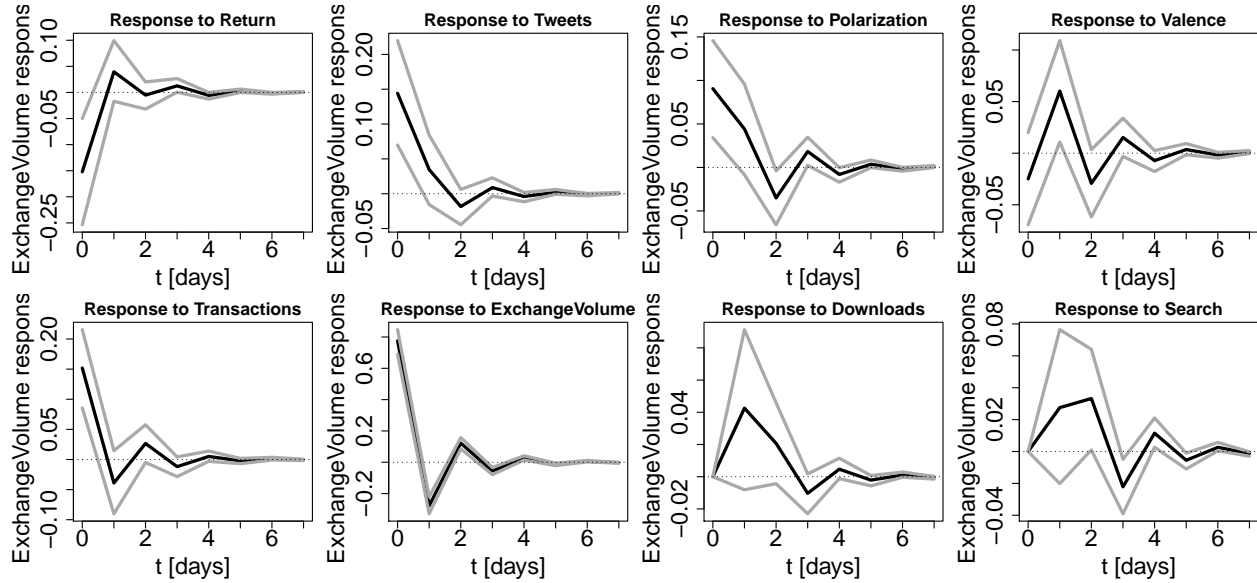


	VAR(1)	VAR(opt)
Return.l1	1.52 (0.39) ^{***}	1.51 (0.38) ^{***}
Tweets.l1	-0.06 (0.06)	-0.02 (0.07)
Polarization.l1	0.02 (0.03)	0.02 (0.03)
Valence.l1	0.01 (0.03)	0.01 (0.03)
Transactions.l1	-0.19 (0.03) ^{***}	-0.24 (0.03) ^{***}
ExchangeVolume.l1	0.04 (0.03)	0.05 (0.04)
Downloads.l1	0.10 (0.03) ^{**}	0.09 (0.03) ^{**}
Search.l1	0.03 (0.05)	0.05 (0.05)
const	-0.01 (0.05)	-0.01 (0.05)
trend	-0.00 (0.00)	-0.00 (0.00)
Return.l2		0.32 (0.38)
Tweets.l2		-0.08 (0.06)
Polarization.l2		0.02 (0.03)
Valence.l2		0.02 (0.03)
Transactions.l2		-0.23 (0.03) ^{***}
ExchangeVolume.l2		0.03 (0.04)
Downloads.l2		-0.04 (0.03)
Search.l2		0.03 (0.05)
R ²	0.06	0.12
Adj. R ²	0.05	0.11
Num. obs.	1065	1064
RMSE	0.87	0.85

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 8: Results for Transactions equation

Response of FX Volume

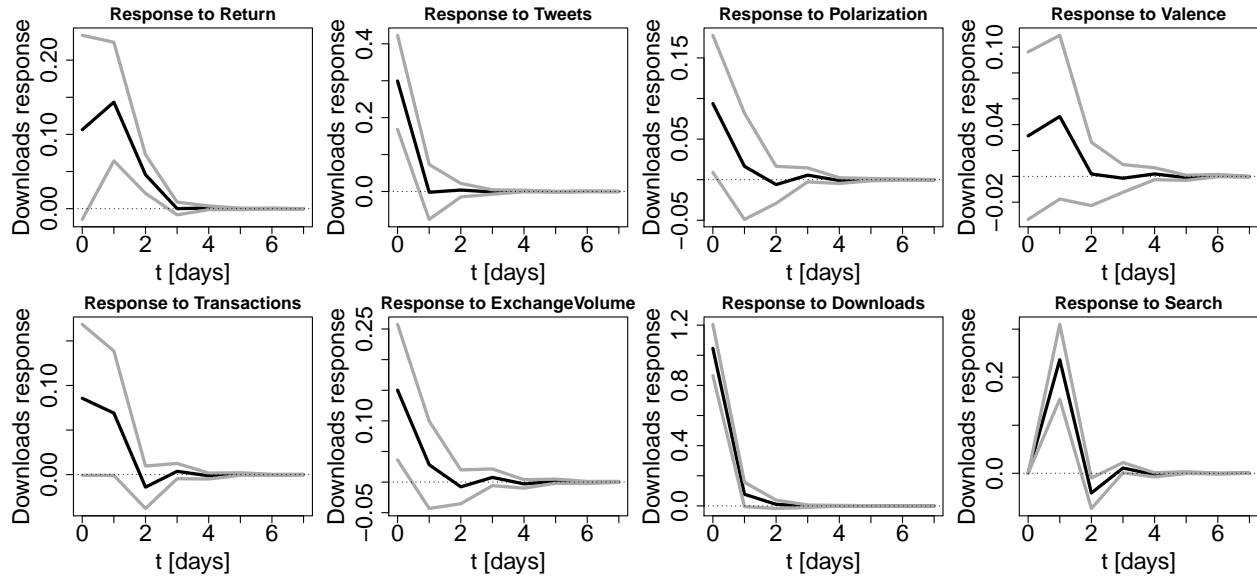


	VAR(1)	VAR(opt)
Return.l1	-0.19 (0.36)	-0.23 (0.35)
Tweets.l1	0.15 (0.05)**	0.17 (0.06)**
Polarization.l1	0.08 (0.02)**	0.09 (0.03)**
Valence.l1	0.05 (0.02)*	0.06 (0.03)*
Transactions.l1	0.01 (0.03)	0.03 (0.03)
ExchangeVolume.l1	-0.38 (0.03)**	-0.46 (0.03)**
Downloads.l1	0.02 (0.03)	0.02 (0.03)
Search.l1	0.05 (0.04)	0.04 (0.04)
const	0.01 (0.05)	0.01 (0.05)
trend	-0.00 (0.00)	-0.00 (0.00)
Return.l2		-0.12 (0.36)
Tweets.l2		-0.16 (0.06)**
Polarization.l2		0.01 (0.03)
Valence.l2		0.05 (0.03)*
Transactions.l2		0.03 (0.03)
ExchangeVolume.l2		-0.26 (0.03)**
Downloads.l2		0.03 (0.03)
Search.l2		0.05 (0.05)
R ²	0.15	0.21
Adj. R ²	0.14	0.20
Num. obs.	1065	1064
RMSE	0.82	0.80

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 9: Results for ExchangeVolume equation

Response of Downloads

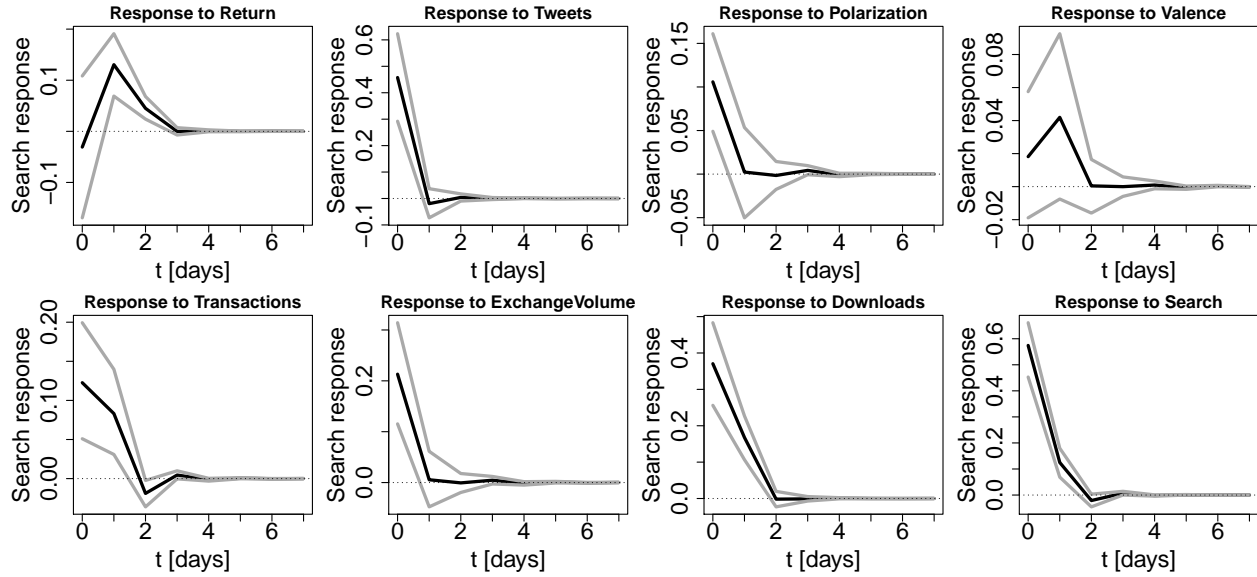


	VAR(1)	VAR(opt)
Return.l1	2.13 (0.49) ^{***}	2.30 (0.49) ^{***}
Tweets.l1	-0.35 (0.07) ^{***}	-0.35 (0.08) ^{***}
Polarization.l1	-0.02 (0.03)	-0.03 (0.03)
Valence.l1	0.04 (0.03)	0.03 (0.04)
Transactions.l1	0.04 (0.04)	0.06 (0.04)
ExchangeVolume.l1	-0.06 (0.04)	-0.02 (0.05)
Downloads.l1	-0.07 (0.04)	-0.08 (0.04) [*]
Search.l1	0.41 (0.06) ^{***}	0.43 (0.06) ^{***}
const	-0.01 (0.07)	-0.01 (0.07)
trend	-0.00 (0.00)	-0.00 (0.00)
Return.l2		-0.43 (0.49)
Tweets.l2		-0.17 (0.08) [*]
Polarization.l2		-0.08 (0.03) [*]
Valence.l2		-0.02 (0.04)
Transactions.l2		0.07 (0.04)
ExchangeVolume.l2		0.07 (0.05)
Downloads.l2		-0.15 (0.04) ^{***}
Search.l2		-0.01 (0.06)
R ²	0.07	0.11
Adj. R ²	0.06	0.10
Num. obs.	1065	1064
RMSE	1.11	1.09

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 10: Results for Downloads equation

Response of Search



	VAR(1)	VAR(opt)
Return.l1	1.60 (0.38) ^{***}	1.65 (0.37) ^{***}
Tweets.l1	-0.31 (0.06) ^{***}	-0.19 (0.06) ^{**}
Polarization.l1	-0.03 (0.03)	-0.02 (0.03)
Valence.l1	0.04 (0.03)	0.03 (0.03)
Transactions.l1	0.07 (0.03) [*]	0.06 (0.03)
ExchangeVolume.l1	-0.07 (0.03) [*]	-0.03 (0.03)
Downloads.l1	0.08 (0.03) ^{**}	0.12 (0.03) ^{***}
Search.l1	0.22 (0.05) ^{***}	0.17 (0.04) ^{***}
const	-0.02 (0.05)	-0.02 (0.05)
trend	0.00 (0.00)	0.00 (0.00)
Return.l2		-0.12 (0.38)
Tweets.l2		-0.06 (0.06)
Polarization.l2		-0.04 (0.03)
Valence.l2		-0.00 (0.03)
Transactions.l2		0.05 (0.03)
ExchangeVolume.l2		0.10 (0.03) ^{**}
Downloads.l2		0.06 (0.03) [*]
Search.l2		-0.33 (0.05) ^{***}
R ²	0.09	0.16
Adj. R ²	0.08	0.15
Num. obs.	1065	1064
RMSE	0.87	0.83

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 11: Results for Search equation

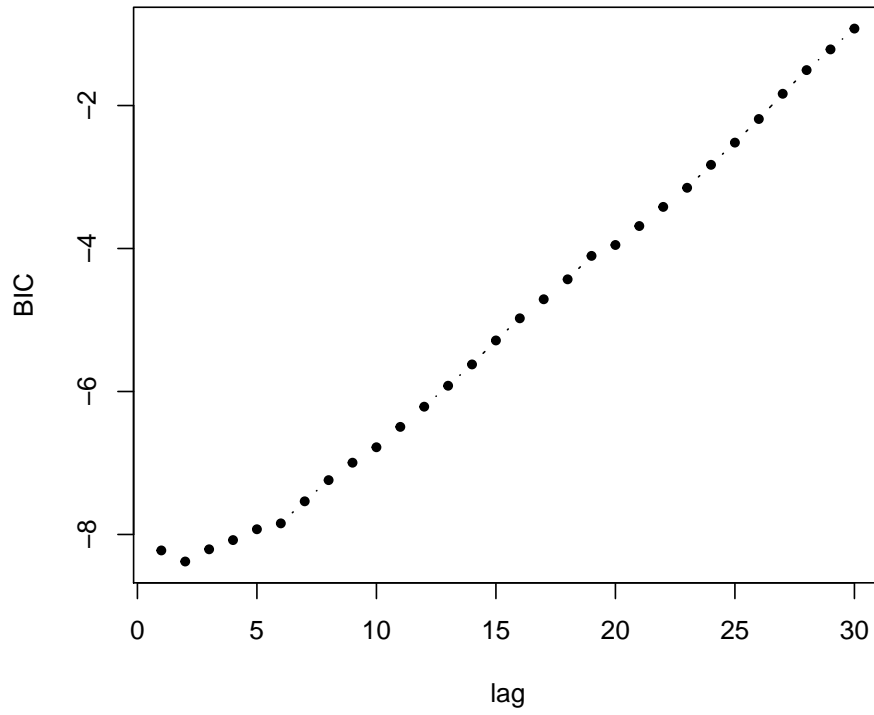


Figure 3: Bayesian Information Criterion for VAR fits of increasing lags.

Impulse Response Functions

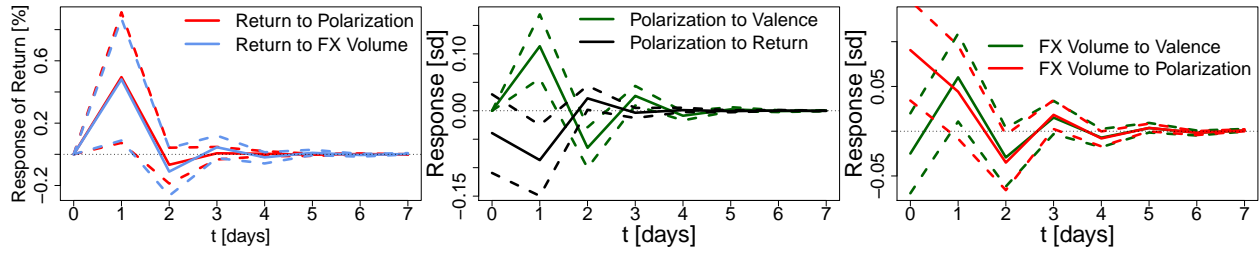


Figure 4: Significant impulse response functions of Return (left), Polarization (center) and FX Volume (right). Solid lines show HAC corrected estimates, dashed lines show bootstrapping 95% confidence intervals.

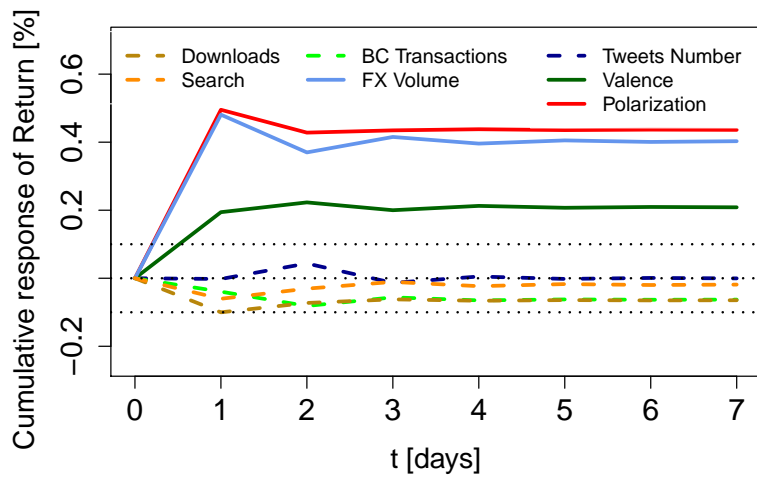


Figure 5: Cumulative impulse response functions of Return. Solid lines show sizable responses beyond $\pm 0.1\%$.

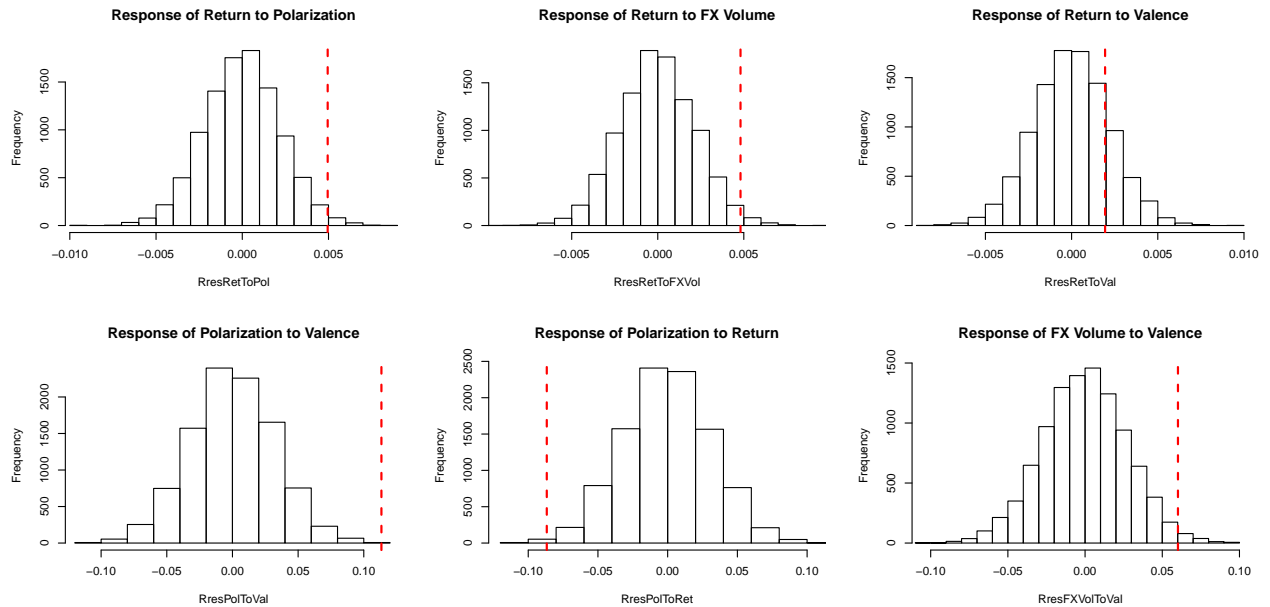


Figure 6: Results of Monte Carlo tests for the identified responses.

Trading Strategies Time Series

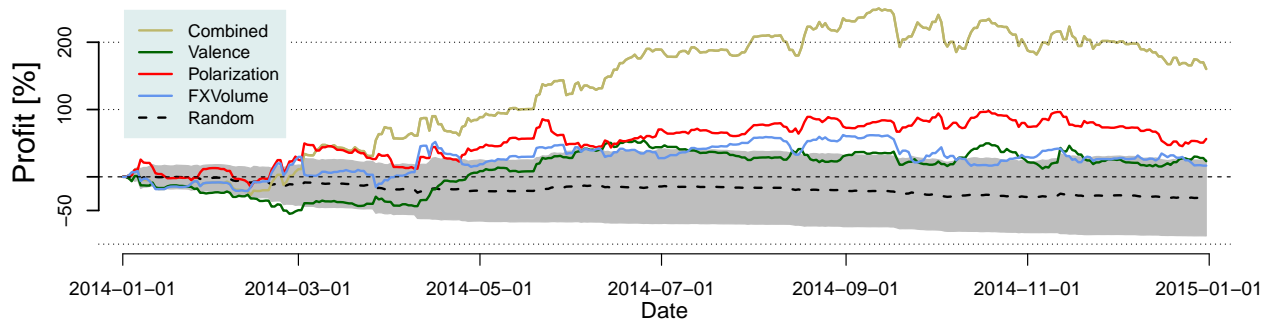


Figure 7: Time series of strategy cumulative returns. Shaded area shows one standard deviation around the random strategy.

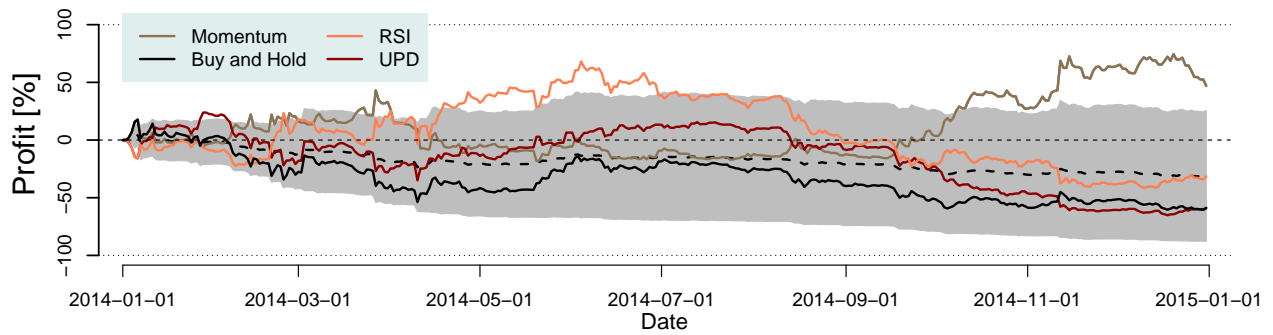


Figure 8: Time series of technical analysis cumulative returns.

Strategy Evaluation

	Combined	Buy&Hold	Pol	Val	FX Vol	MOM	UPD	RSI	DJIA	Rnd
SR	1.7653	-0.7741	1.0120	0.6410	0.5738	0.9146	-0.8990	-0.1772	0.7995	-1.6590
μ_R	0.3229	-0.1635	0.1779	0.1183	0.1082	0.1625	-0.1736	-0.0346	0.0345	-0.0963

Table 12: Sharpe Ratios and mean daily returns of strategies (%)

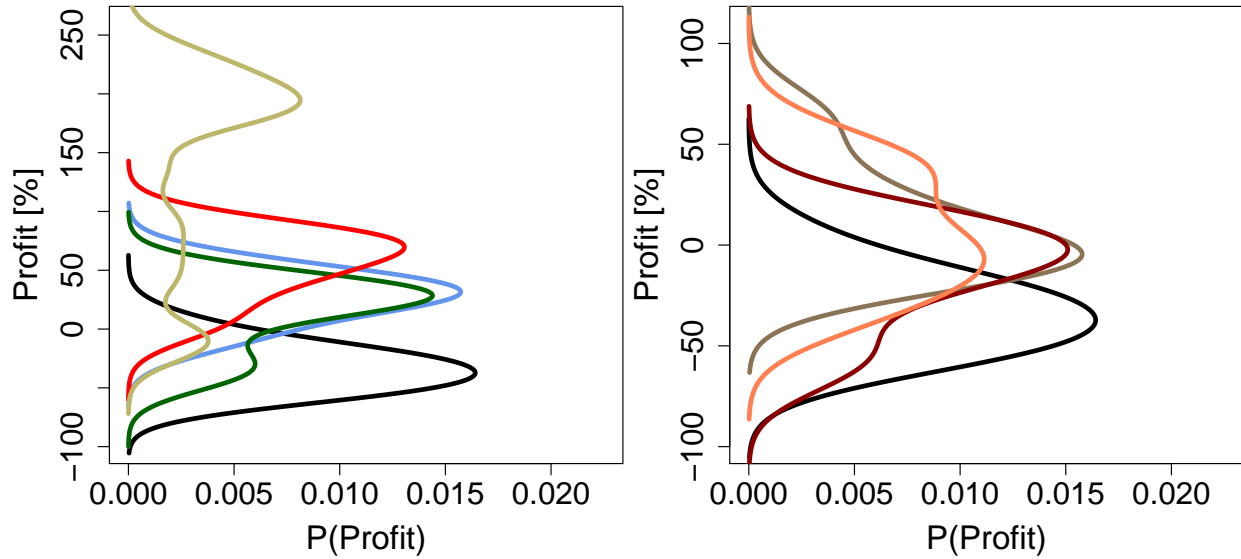


Figure 9: Kernel Density Plot of cumulative returns of data-driven and technical analysis strategies.

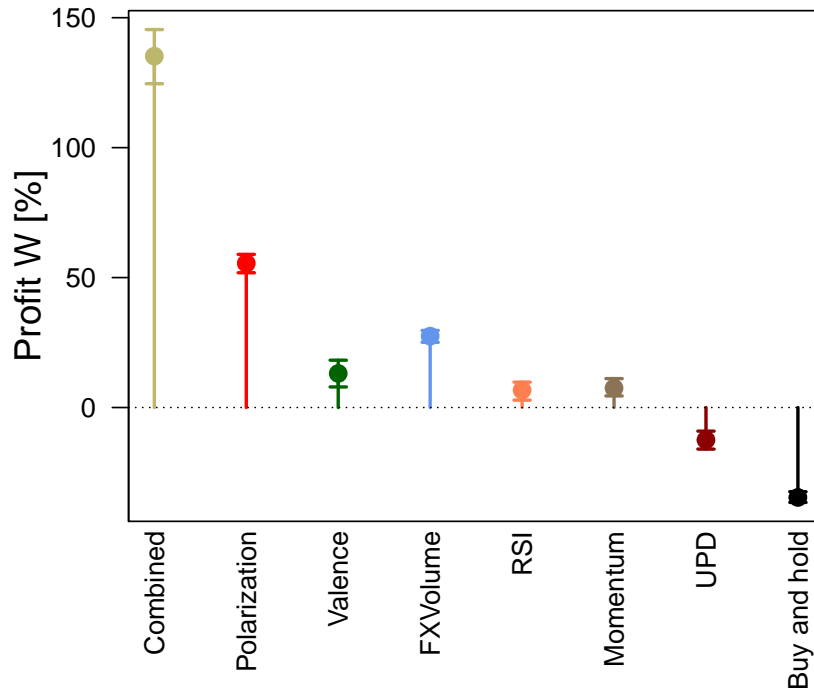


Figure 10: Wilcoxon estimates of cumulative returns.

Costs analysis

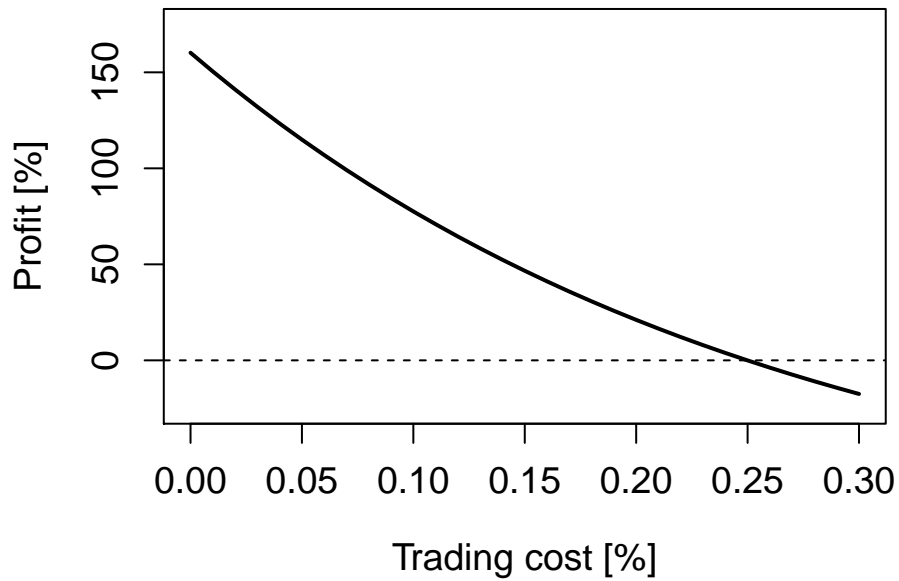


Figure 11: Final cumulative returns depending on transaction costs.

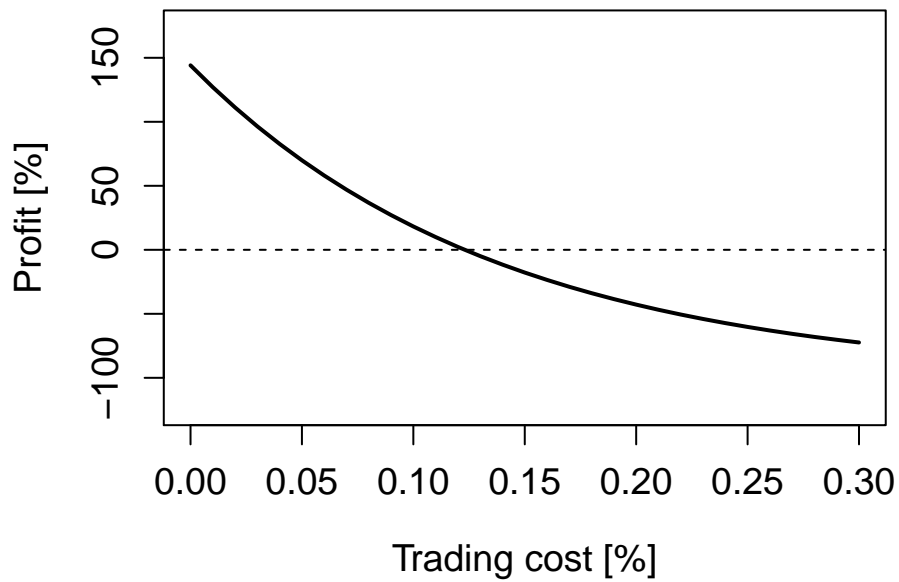


Figure 12: Final cumulative returns depending on transaction costs, for daily closing positions.

Risk Analysis

signal	ADF	ADFpval	PP	PPpval	KSP	KSPpval	AR
Returns	-14.87932971	0.00000000	-391.64898133	0.01000000	0.28793772	0.10000000	-0.07966048

Table 13: Stationarity tests for instantaneous returns of Combined

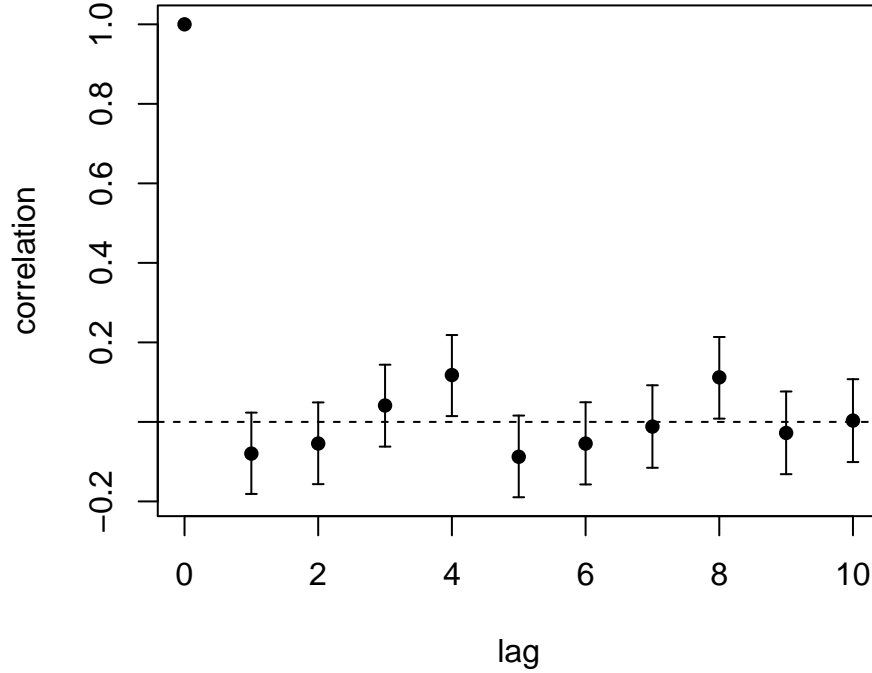


Figure 13: Autocorrelation function of Combined strategy returns

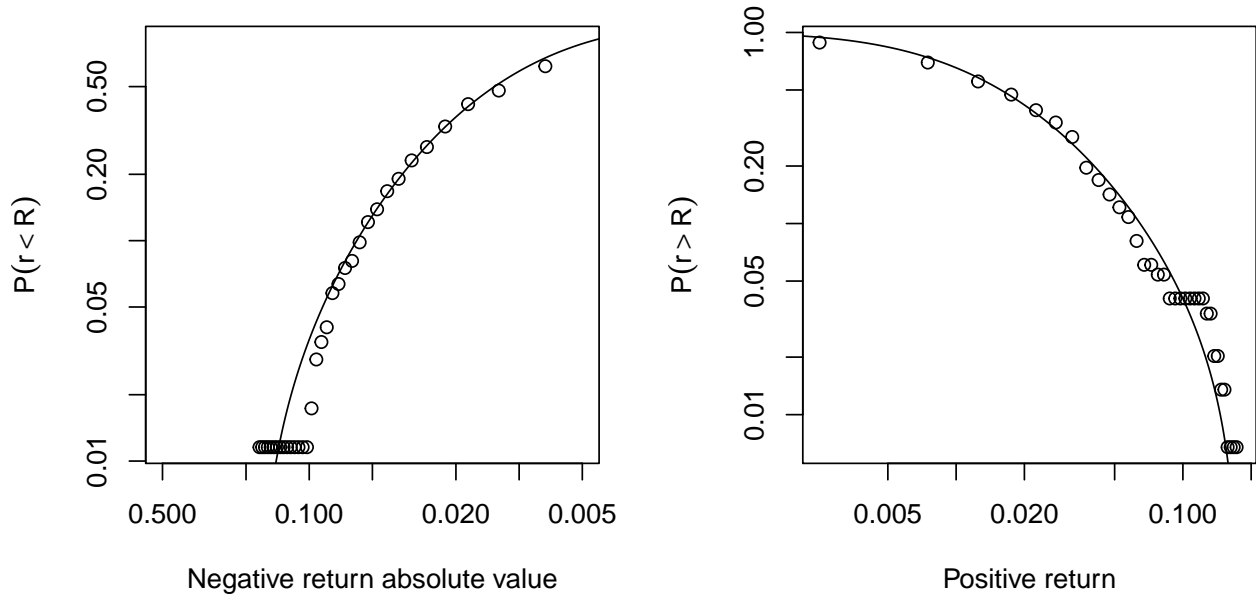


Figure 14: Distribution of Returns of Combined Strategy. The line shows the ML estimate of a lognormal fit.

- Negative Returns
 - meanlog: -4.30209144 (0.09442549)
 - sdlog: 1.24197346 (0.06676891)
 - KS Distance: 0.066764 (p-value = 0.4236)
- Positive Returns
 - meanlog: -4.11858870 (0.09595619)
 - sdlog: 1.16735747 (0.06785127)
 - KS Distance: 0.070967 (p-value = 0.4453)

Only short/long combined strategy evaluation

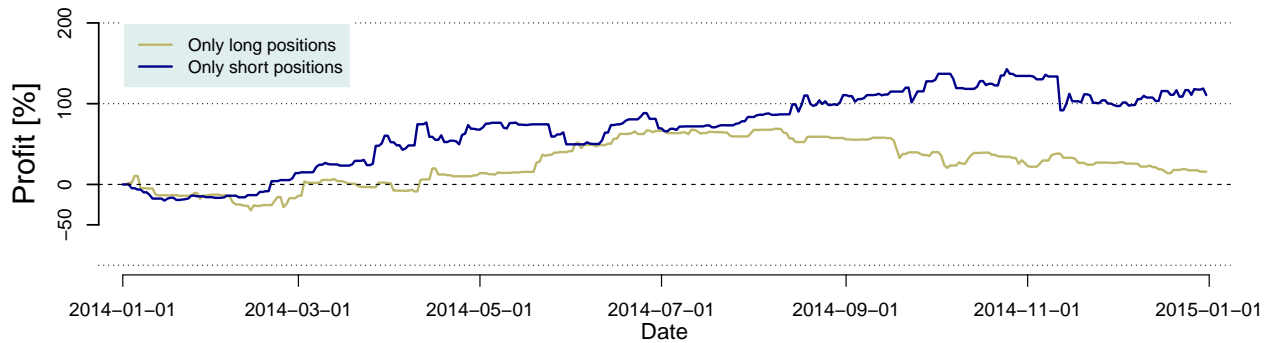


Figure 15: Time series of Combined cumulative returns when using only long and only short positions.

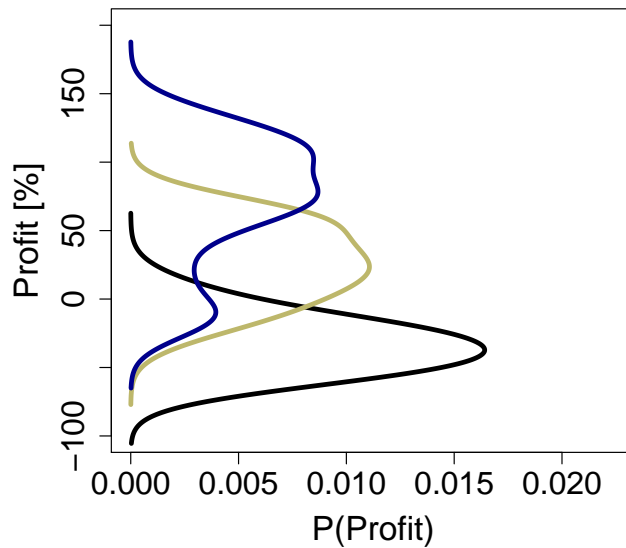


Figure 16: Kernel Density Plot of cumulative returns of data-driven strategies.