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Momentum Effects In The Cryptocurrency Market After One-Day Abnormal Returns

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MOMENTUM EFFECTS IN THE CRYPTOCURRENCY MARKET

AFTER ONE-DAY ABNORMAL RETURNS

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Abstract

This paper examines whether there exists a momentum effect after one-day abnormal returns in the cryptocurrency market. For this purpose a number of hypotheses of interest are tested for the BitCoin, Ethereum and LiteCoin exchange rates vis-à-vis the US dollar over the period 01.01.2017-01.09.2019, specifically whether or not: H1) the intraday behaviour of hourly returns is different on overreaction days compared to normal days; H2) there is a momentum effect on overreaction days, and H3) after one-day abnormal returns. The methods used for the analysis include a number of statistical methods as well as a trading simulation approach. The results suggest that hourly returns during the day of positive/negative overreactions are significantly higher/lower than those during the average positive/negative day. Overreactions can usually be detected before the day ends by estimating specific timing parameters. Prices tend to move in the direction of the overreaction till the end of the day when it occurs, which implies the existence of a momentum effect on that day giving rise to exploitable profit opportunities. This effect (together with profit opportunities) is also observed on the following day. In two cases (BTCUSD positive overreactions and ETHUSD negative overreactions) a contrarian effect is detected instead.

Keywords: *cryptocurrencies, anomalies, momentum effect, overreactions, abnormal returns, patterns*

JEL classification: G12, G17, C63

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1. Introduction

It is well known that the Efficient Market Hypothesis (EMH) is inconsistent with the existence of abnormal returns, i.e. of fat tails in the price distribution. However, numerous empirical studies have reported evidence of so-called market overreactions. De Bondt and Thaler (1985) developed the overreaction hypothesis to describe price patterns caused by abnormal price changes. The subsequent literature has also analysed the reasons for abnormal price changes (Griffin and Tversky, 1992; Aiyagari and Gertler, 1999; Madura and Richie, 2004; Mynhardt and Plastun, 2013); price patterns (Cutler et al., 1991; Ferri and Min, 1996); trading strategies based on overreactions (Jegadeesh, 1993; Caporale and Plastun, 2019); the influence of price overreactions on market participants (Savor, 2012), etc. According to the overreaction hypothesis there should be price reversals after abnormal price changes; various studies have analysed the US stock market (De Bondt and Thaler, 1985; Jegadeesh, 1993; Ferri and Min, 1996), other stock markets (Lobe and Rieks, 2011; Mynhardt and Plastun, 2013), the FOREX (Caporale et al., 2018), option (Poteshman, 2001) and commodity markets (Cutler et al., 1991), and most of them have provided evidence in favour of price reversals after overreactions, with a few detecting instead momentum effects (Cox and Peterson, 1994).

The cryptocurrency market represents a particularly interesting case being rather new, relatively unexplored and at the same time extremely vulnerable to overreactions, given its high volatility relative to the FOREX, stock and commodity markets etc. (Cheung et al., 2015; Aalborg et al., 2019). Recent studies have analysed its efficiency (Bartos, 2015; Urquhart, 2016), long-memory properties and persistence (Bariviera et al., 2017;), the existence of price bubbles (Corbet et al, 2018), its competitiveness (Halaburda and Gandal, 2014), the issue of predictability (Bouri et al, 2018; Caporale et al., 2019) and the presence of anomalies (Kurihara and Fukushima, 2017; Caporale and Plastun, 2018). However, there are very few studies focusing on overreactions in the cryptocurrency market. Chevapatrakul and Mascia (2019) using the quantile autoregressive model show that days with extremely negative returns are likely to be followed by periods characterised by negative returns and weekly positive returns as Bitcoin prices continue to rise. Caporale and Plastun (2019) find evidence of price patterns after overreactions, i.e. the next-day price changes in both directions are bigger than after “normal” days; they show that a strategy based on the momentum effect (rather than counter-movements) after overreactions is profitable.

The present paper extends the analysis of Caporale and Plastun (2019) by examining whether there exists a momentum effect after one-day abnormal returns in the cryptocurrency market. For this purpose a number of hypotheses of interest are tested for the BitCoin, Ethereum and LiteCoin exchange rates vis-à-vis the US dollar over the period 01.01.2017-01.09.2019, specifically whether or not: H1) the intraday behaviour of hourly returns is different on overreaction days compared to normal days; H2) there is a momentum effect on overreaction days, and H3) after one-day abnormal returns. The methods used for the analysis include statistical tests and the cumulative abnormal returns and trading simulation approaches. The results are relevant to both academics interested in the EMH and practitioners (traders, investors, financial analysts, etc.) aiming to design profitable trading strategies using information about the existence or not of a momentum effect, the timing of the overreactions and the duration of the anomaly.

The remainder of the paper is organised as follows. Section 2 describes the methodology. Section 3 discusses the empirical results. Section 4 offers some concluding remarks.

2. Methodology

Our sample includes daily and hourly data for the following cryptocurrencies: BitCoin, Ethereum and LiteCoin. These are the most popular cryptocurrencies with the highest market capitalisation and longest time horizon (Table 1). We analyse their exchange rates vis-à-vis the US dollar: BTCUSD, ETHUSD and LTCUSD. The sample period is 01.01.2015-01.09.2019, and the data sources are CoinMarketCap (https://coinmarketcap.com/coins/), Gemini (https://gemini.com/) and Bitstamp (https://www.bitstamp.net). These are leading exchanges and trading platforms in the cryptocurrency market. For example, CoinMarketCap calculates prices as the volume-weighted average of all prices reported for each market. As a result BitCoin prices are the average of those from 400 markets.

Table 1: Capitalisation of the cryptocurrency market (08.10.2019)

#	Name	Market Cap	Price	Circulating Supply	Data start from
1	Bitcoin	$148 657 197 170	$8 267.84	17 980 175 BTC	28 Apr 2013
2	Ethereum	$19 674 550 330	$182.07	108 059 235 ETH	07 Aug 2015
3	Ripple	$12 017 970 035	$0.278408	43 166 787 298 XRP	04 Aug 2013
4	Bitcoin Cash	$4 236 366 686	$234.76	18 045 263 BCH	23 Jul 2017

#	Name	Market Cap	Price	Circulating Supply	Data start from
5	Litecoin	$3 659 603 443	$57.70	63 420 942 LTC	28 Apr 2013

Cryptocurrency Market Capitalisation. Data source: https://coinmarketcap.com/coins/

We define overreactions on the basis of the number of standard deviations to be added to the average return.

In order to avoid the distortions caused by price gaps, returns (R_i) are computed as follows:

$$\mathrm{R_i} = (\frac{\mathrm{Close_i}}{\mathrm{Open_i}}\text{-}1) \times 100\% , \quad (1)$$

where R_i – returns on the *i-th* day in %;

$\mathrm{Open_i}$ – open price on the *i-th* day;

$\mathrm{Close_i}$ – close price on the *i-th* day.

The returns calculated using (1) are divided into two data sets corresponding respectively to positive and negative overreactions with the aim of testing for possible differences in price behaviour between those two cases.

A positive overreaction is defined as follows:

$$R_i > (\overline{R}_n + k \times \delta_n) \quad (2)$$

and a negative overreaction as:

$$R_i < (\overline{R}_n - k \times \delta_n) \quad (3)$$

where k is the number of standard deviations used to identify the overreaction (k=2 for BTCUSD and k=1.5 for ETHUSD and LTCUSD, k being chosen on the basis of the sample size to generate in each case a sufficient number of overreactions); $\overline{R}_n$ is the average size of daily returns for period n.

$$\overline{R}_n = \sum_{i=1}^{n} R_i / n \quad (4)$$

and δ_n is the standard deviation of daily returns for period n

$$\delta_n = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(R_i - \overline{R})^2} \quad (5)$$

Then the following hypotheses are tested:

Hypothesis 1 (H1): The intraday behaviour of hourly returns is different on overreaction days compared to normal days.

Hypothesis 2 (H2): There is a momentum effect on overreaction days.

Hypothesis 3 (H3): There is a momentum effect after one-day abnormal returns.

To test these hypotheses we use the following methods:

– Visual inspection and average analysis;
– Student's t-tests;
– A cumulative abnormal returns approach;
– A trading simulation approach.

The cumulative abnormal returns approach is based on MacKinlay (1997) and is standard for event studies. Abnormal returns are defined as follows:

$$AR_t = R_t - E(R_t) \quad (6)$$

where R_t is the return at time t and $E(R_t)$ is corresponding average return computed over the whole sample period as follows:

$$E(R_t) = (\frac{1}{T}) \sum_{i=1}^{T} R_i \quad (7)$$

where T is the sample size.

The cumulative abnormal return denoted as CAR_i is simply the sum of the abnormal returns:

$$CAR_i = \sum_{i=1}^{24} \ AR_i \quad (8)$$

Parametric t-tests are also carried out for Hypothesis 1. The Null Hypothesis (H0) is that the data (hourly returns on the overreaction day and in the full sample) belong to the same population, a rejection of the null suggesting the presence of a statistical anomaly in the price behavior on the overreaction day. The test is carried out at the 95% confidence level, and the degrees of freedom are N – 1 (N being equal to N1+ N2).

The trading simulation approach replicates the actions of traders by using appropriate algorithms for trading strategies based on the observed price patterns; its aim is to establish whether the detected anomalies can be exploited to generate abnormal profits. It should be mentioned that our analysis does not incorporate transaction costs such as spreads, broker or bank fees, swaps etc., and therefore is only a proxy for actual trading. However, in the case of Internet trading such costs are typically small and ignoring them does not affect the results.

The percentage results for an individual deal are computed as follows:

$$\%\, result = \left(\frac{P_{close}}{P_{open}} - 1\right) \times 100\% \tag{9}$$

where P_{open} – opening price for the trade

P_{close} – closing price for the trade

The sum of the results from each trade is the total financial result of trading. A strategy producing positive total profits implies that there exists an exploitable market anomaly.

Another important indicator of the degree of success of the trading strategy is the percentage of successful trades:

$$\%\ \text{successful trades} = \frac{100\% \times number\ of\ successful\ trades}{overall\ number\ of\ trades} \tag{10}$$

To establish whether or not the results obtained are statistically different from the random trading ones t-tests are carried out. These compare the means from two samples to see whether or not they come from the same population. The first sample consists of the trading results from the trading strategy, and the second one of random trading results. The null hypothesis is that the mean is the same in both samples, and the alternative that it is not. The computed values of the t-test are compared with the critical ones at the 5% significance level. Failure to reject the null implies that there are no advantages from exploiting the trading strategy being considered since the trading results do not differ from the random ones, whilst a rejection suggests that the adopted strategy can generate abnormal profits since the trading results are not random and therefore it is possible to "beat the market". As an example, the t-test results for LTCUSD in the case of Strategy 1 are shown in Table 3.

Table 2: t-test for evaluating the success of the trading strategy: LTCUSD, positive overreactions, Strategy 1

Parameter	Value
Number of the trades	38
Total profit	311.39%
Average profit per trade	8.19%
Standard deviation	7.01%
t-test	7.20
t critical value (0.95%)	1.78
Null hypothesis	rejected

3. Empirical Results

We divide the results into two sets including respectively those for the day of overreactions and those for the day after in order to explore price behaviour when abnormal price movements are observed and after them. The results for BTCUSD are presented in Appendices A and B (for the day of overreactions and the day after in turn). Figures A.1 and A.2 show that returns on overreaction days differ from those on normal days; the t-test statistics confirm that these differences are statistically significant. This holds for both positive and negative overreactions (Table A.2 and Table A.3).

The cumulative abnormal returns analysis (Table A.4 and Figure A.2) provides information on the average timing of the anomaly appearance: in general positive overreactions are detected after 6pm and negative ones after 4pm, namely in both cases some time before the end of the trading day.

Concerning price behaviour on the day after overreactions, average hourly BTCUSD returns after a positive overreaction are much lower than on normal days during the first hours of the following day (Figure B.1), and these differences are statistically significant (Table B.1), which implies the existence of a contrarian effect. As for negative overreactions, on the following day prices tend to move in the direction of the overreaction (Figure B.2 and Table B.2), which represents evidence of a momentum effect.

Specific timings for trading can be determined. The contrarian strategy for BTCUSD after a positive overreaction is as follows: sell on the start of the day and close position after 4pm. The momentum strategy for the case of negative overreactions is instead to sell at the start of the day after the negative overreaction and close this position after 11am (Table B.3 and Figure B.3). A similar analysis is carried out for LTCUSD (Appendices C and D) and ETHUSD (Appendices E and F). These results are summarised in Table 3 (for positive overreactions) and Table 4 (for

negative overreactions). As can be seen, they are generally very similar to those for BTCUSD.

Table 3: Overall results for the case of positive overreactions

Parameter/Instrument	BTCUSD	LTCUSD	ETHUSD
Day of the overreaction			
Are there significant differences in returns (overreaction day vs usual day)?	Yes	Yes	Yes
Are there any patterns in cumulative abnormal returns dynamics?	Yes. CAR increase till the end of the day	Yes. CAR increase till the end of the day	Yes. CAR increase till the end of the day
Timing of overreaction	18:00	13:00	12:00
Day after the overreaction			
Is there momentum effect on the day after the overreaction?	No	Yes	Yes
Timing parameters of momentum movements	Since the start of the day till 16:00*	Since the start of the day till 13:00	Since the start of the day till 21:00

* contrarian effect detected

Table 4: Overall results for the case of negative overreactions

Parameter/ Instrument	BTCUSD	LTCUSD	ETHUSD
Day of the overreaction			
Are there significant differences in returns (overreaction day vs usual day)?	Yes	Yes	Yes
Any patterns in cumulative abnormal returns dynamics?	Yes. CAR decrease till the end of the day	Yes. CAR decrease till the end of the day	Yes. CAR decrease till the end of the day
Timing of overreaction	16:00	14:00	13:00
Day after the overreaction			
Is there momentum effect on the day after the overreaction?	Yes	Yes	No
Timing parameters of contrarian movements	Since the start of the day till 11:00	Since the start of the day till 10:00	Since the start of the day till the end of the day*

* contrarian effect detected

Our findings can be summarised as follows:

- hourly returns during the day of positive/negative overreactions are significantly higher/lower than those during the average positive/negative day;

- overreaction can be detected before the day ends and specific timing parameters for the overreactions can be estimated;

- prices tend to move in the direction of overreactions till the end of the day, i.e. H2 cannot be rejected: there is a momentum effect on the day of the overreaction;

- the behaviour of the market after one-day abnormal returns in most cases also confirms the existence of a momentum effect. Usually it is short-term, and specific timing parameters can be estimated for the asset of interest;

- in two cases (BTCUSD positive overreactions and ETHUSD negative overreactions) a contrarian effect is detected.

On the basis of these results the following profitable strategies can be developed:

Strategy 1: when it becomes clear that the current day is an overreaction day (see the timing of overreaction parameter in Tables 3 and 4) a position in the direction of overreaction should be opened. This position should then be closed at the end of the day.

Strategy 2: at the beginning of the day after the overreaction a position in the direction of the overreaction should be opened. This position should then be closed on the basis of the timing parameters for the momentum effect displayed in Tables 3 and 4. If this effect is not present, a contrarian trading strategy should be used: at the beginning of the day after the overreaction a position in the opposite direction to the overreaction should be opened.

The trading simulation results for the two strategies are presented in Tables 5 (for positive overreactions) and 6 (for negative overreactions).

Table 5: Trading simulation results for the case of positive overreactions

Instrument	Number of trades. units	Number of successful trades. units	Number of successful trades. %	Profit. %	Profit % per year	Profit % per trade	t-test calculated value	t-test status
Strategy 1								
BTCUSD	49	42	86%	143.11%	28.62%	2.92%	6.62	rejected
LTCUSD	38	37	97%	311.39%	103.80%	8.19%	7.20	rejected
ETHUSD	58	45	78%	507.63%	50.76%	8.75%	11.06	rejected
Strategy 2								
BTCUSD*	49	29	59.2%	75.3%	15.06%	1.54%	1.75	not rejected
LTCUSD	38	14	37%	61.80%	20.60%	1.63%	0.76	not rejected
ETHUSD	58	25	43%	130.20%	43.40%	2.24%	1.87	rejected

* A contrarian trading strategy is used

Table 6: Trading simulation results for the case of negative overreactions

Instrument	Number of trades. units	Number of successful trades. units	Number of successful trades. %	Profit. %	Profit % per year	Profit % per trade	t-test calculated value	t-test status
Strategy 1								
BTCUSD	46	42	91%	202.41%	40.48%	4.40%	8.21	rejected
LTCUSD	39	33	85%	170.75%	56.92%	4.38%	4.31	rejected

ETHUSD	57	43	75%	334.54%	111.51%	5.87%	7.84	rejected
Strategy 2								
BTCUSD	46	25	54.3%	52.0%	10.4%	1.13%	1.55	not rejected
LTCUSD	39	20	51.3%	75.8%	25.3%	1.94%	1.93	rejected
ETHUSD*	57	38	66.7%	225.6%	75.2%	3.96%	3.46	rejected

* A contrarian trading strategy is used

As can be seen, the detected anomalies can be exploited in most cases to generate abnormal profits from trading and to "beat the market".

4. Conclusions

This paper explores the momentum effect in the cryptocurrency market after one-day abnormal returns. Daily and intraday data on the BTCUSD, ETHUSD and LTCUSD exchange rates over the period 01.01.2017-01.09.2019 are analysed using a number of statistical methods as well as a trading simulation approach. The results suggest that hourly returns during the day of positive/negative overreactions are significantly higher/lower than those during the average positive/negative day.

Further, overreactions can usually be detected before the day ends by estimating specific timing parameters. Prices tend to move in the direction of the overreaction till the end of the day when it occurs, which implies the existence of a momentum effect during that day giving rise to exploitable profit opportunities. This effect (together with profit opportunities) is also observed on the following day. In two cases (BTCUSD positive overreactions and ETHUSD negative overreactions) a contrarian effect is detected instead. These findings are of interest to both investors aiming to maximize their profits and academics interested in the empirical relevance of the EMH.

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Appendix A

BTCUSD: day of overreaction

Table A.1: Descriptive statistics for BTCUSD data: daily, hourly, days with positive and negative returns

Parameter	Daily data	Positive days	Negative days	Hourly data	Positive days (hourly data)	Negative days (hourly data)
Mean	0.0034	0.1178	-0.1086	0.0002	0.0047	-0.0045
Standard error	0.0011	0.0053	0.0033	0.0000	0.0005	0.0006
Median	0.0025	0.1051	-0.1029	0.0000	0.0029	-0.0019
Mode	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Std. Dev.	0.0409	0.0372	0.0225	0.0091	0.0162	0.0203
Variance	0.0017	0.0014	0.0005	0.0001	0.0003	0.0004
Kurtosis	4.5097	8.1529	-0.1042	27.3573	8.9389	13.6233
Skewness	0.2498	2.6496	-0.8845	-0.1641	1.1748	-0.4895
Minimum	-0.1617	0.0853	-0.1617	-0.1854	-0.0768	-0.1854
Maximum	0.2763	0.2763	-0.0789	0.1664	0.1209	0.1664
Sum	4.9027	5.7742	-4.9956	5.1913	5.5753	-5.0193
Observations	1427	49	46	34235	1176	1104

Figure A.1: Average hourly returns on overreaction and normal days: the case of positive overreactions, BTCUSD

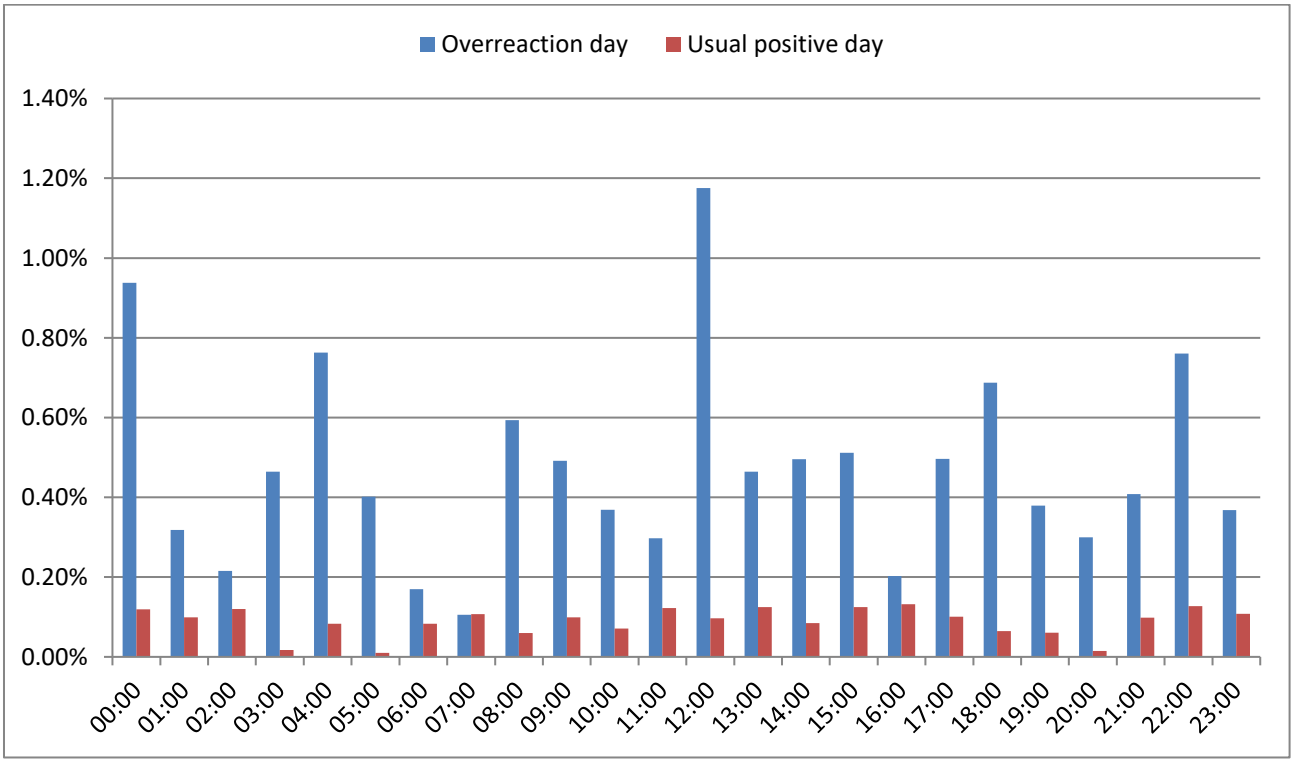


Figure A.2: Average hourly returns on overreaction and normal days: the case of negative overreactions, BTCUSD

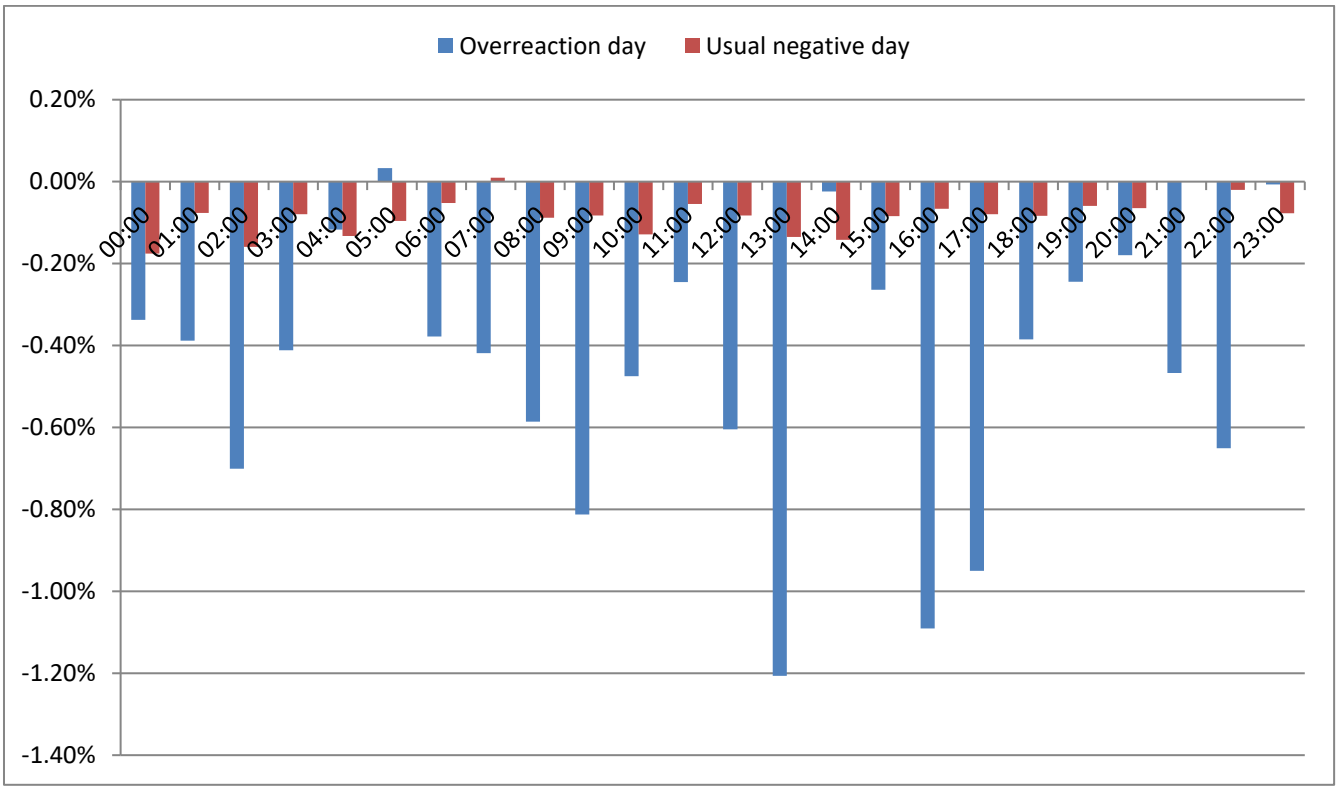


Table A.2: t-test of hourly returns on overreaction and normal days: the case of positive overreactions, BTCUSD

Hour	Average return on positive overreaction day (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day with positive returns (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	0.94%	1.16%	48	0.12%	0.81%	756	4.80
1:00	0.32%	1.62%	48	0.10%	0.76%	756	0.93
2:00	0.22%	1.17%	48	0.12%	0.72%	756	0.56
3:00	**0.46%**	**1.38%**	**48**	**0.02%**	**0.65%**	**756**	**2.24**
4:00	**0.76%**	**2.19%**	**48**	**0.08%**	**0.69%**	**756**	**2.15**
5:00	**0.40%**	**1.41%**	**48**	**0.01%**	**0.62%**	**756**	**1.92**
6:00	0.17%	1.61%	48	0.08%	0.65%	756	0.37
7:00	0.11%	1.19%	48	0.11%	0.70%	756	-0.01
8:00	**0.59%**	**1.66%**	**48**	**0.06%**	**0.72%**	**756**	**2.22**
9:00	0.49%	1.78%	48	0.10%	0.72%	756	1.52
10:00	0.37%	1.14%	48	0.07%	0.69%	756	1.80
11:00	0.30%	2.36%	48	0.12%	0.70%	756	0.51
12:00	**1.18%**	**2.17%**	**48**	**0.10%**	**0.70%**	**756**	**3.44**
13:00	0.46%	1.64%	48	0.12%	0.83%	756	1.42
14:00	0.50%	2.09%	48	0.08%	0.73%	756	1.36
15:00	**0.51%**	**1.19%**	**48**	**0.12%**	**0.83%**	**756**	**2.22**
16:00	0.20%	1.93%	48	0.13%	0.74%	756	0.25
17:00	0.50%	1.70%	48	0.10%	0.67%	756	1.61
18:00	**0.69%**	**1.20%**	**48**	**0.06%**	**0.58%**	**756**	**3.56**

19:00	0.38%	1.55%	48	0.06%	0.69%	756	1.42
20:00	0.30%	1.80%	48	0.01%	0.70%	756	1.09
21:00	0.41%	1.25%	48	0.10%	0.79%	756	1.69
22:00	**0.76%**	**1.59%**	**48**	**0.13%**	**0.73%**	**756**	**2.75**
23:00	0.37%	1.14%	48	0.11%	0.73%	756	1.56

Table A.3:t-test of hourly returns on overreaction and normal days: the case of negative overreactions, BTCUSD

Hour	Average return on positive overreaction day (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day with positive returns (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	-0.34%	1.83%	45	-0.18%	0.93%	570	-0.59
1:00	-0.39%	1.37%	45	-0.08%	0.82%	570	-1.50
2:00	**-0.70%**	**1.52%**	**45**	**-0.16%**	**0.87%**	**570**	**-2.37**
3:00	-0.41%	1.49%	45	-0.08%	0.74%	570	-1.48
4:00	-0.12%	1.43%	45	-0.13%	0.89%	570	0.07
5:00	0.03%	1.12%	45	-0.10%	0.87%	570	0.75
6:00	-0.38%	1.33%	45	-0.05%	0.75%	570	-1.62
7:00	**-0.42%**	**1.01%**	**45**	**0.01%**	**0.90%**	**570**	**-2.75**
8:00	**-0.59%**	**1.42%**	**45**	**-0.09%**	**0.80%**	**570**	**-2.32**
9:00	**-0.81%**	**1.80%**	**45**	**-0.08%**	**0.76%**	**570**	**-2.70**
10:00	-0.47%	1.68%	45	-0.13%	0.88%	570	-1.37
11:00	-0.25%	1.82%	45	-0.05%	0.73%	570	-0.70
12:00	-0.60%	2.16%	45	-0.08%	0.84%	570	-1.61
13:00	**-1.21%**	**2.20%**	**45**	**-0.13%**	**1.10%**	**570**	**-3.24**
14:00	-0.02%	2.46%	45	-0.14%	0.93%	570	0.32
15:00	-0.26%	2.04%	45	-0.08%	0.85%	570	-0.59
16:00	**-1.09%**	**2.26%**	**45**	**-0.07%**	**1.11%**	**570**	**-3.01**
17:00	**-0.95%**	**2.26%**	**45**	**-0.08%**	**0.87%**	**570**	**-2.57**
18:00	-0.38%	1.70%	45	-0.08%	0.73%	570	-1.18
19:00	-0.24%	1.45%	45	-0.06%	0.94%	570	-0.85
20:00	-0.18%	2.62%	45	-0.06%	0.88%	570	-0.29
21:00	-0.47%	2.05%	45	0.00%	1.07%	570	-1.51
22:00	-0.65%	3.79%	45	-0.02%	0.84%	570	-1.12
23:00	-0.01%	3.25%	45	-0.08%	0.93%	570	0.14

Figure A.2: Dynamics of cumulative abnormal returns: case of BTCUSD

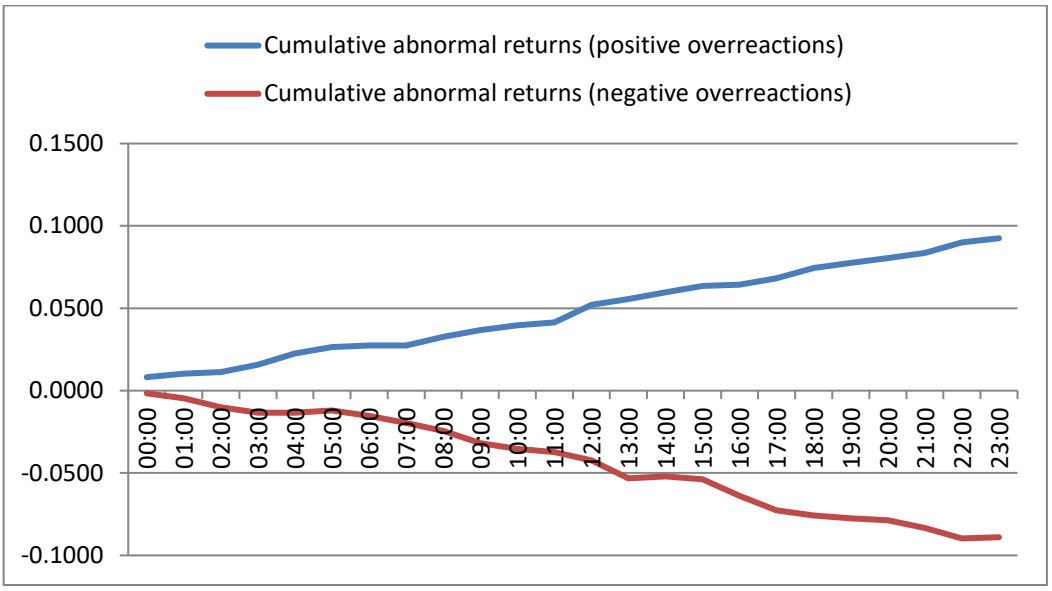


Table A.4: Cumulative abnormal returns: the case of positive and negative overreactions, BTCUSD

Hour	Positive overreactions			Negative overreactions		
	Abnormal returns	CAR	Overreaction cross	Abnormal returns	CAR	Overreaction cross
0:00	0.82%	0.82%	7.58%	-0.16%	-0.16%	-7.49%
1:00	0.22%	1.04%	7.26%	-0.31%	-0.47%	-7.10%
2:00	0.10%	1.13%	7.04%	-0.54%	-1.01%	-6.40%
3:00	0.45%	1.58%	6.58%	-0.33%	-1.35%	-5.99%
4:00	0.68%	2.26%	5.82%	0.02%	-1.33%	-5.87%
5:00	0.39%	2.65%	5.41%	0.13%	-1.20%	-5.91%
6:00	0.09%	2.74%	5.24%	-0.33%	-1.53%	-5.53%
7:00	0.00%	2.74%	5.14%	-0.43%	-1.96%	-5.11%
8:00	0.53%	3.27%	4.54%	-0.50%	-2.45%	-4.52%
9:00	0.39%	3.67%	4.05%	-0.73%	-3.18%	-3.71%
10:00	0.30%	3.96%	3.68%	-0.35%	-3.53%	-3.24%
11:00	0.17%	4.14%	3.39%	-0.19%	-3.72%	-2.99%
12:00	1.08%	5.22%	2.21%	-0.52%	-4.24%	-2.39%
13:00	0.34%	5.56%	1.75%	-1.07%	-5.31%	-1.18%
14:00	0.41%	5.97%	1.25%	0.12%	-5.20%	-1.16%
15:00	0.39%	6.35%	0.74%	-0.18%	-5.38%	-0.89%
16:00	0.07%	6.43%	0.54%	-1.02%	-6.40%	**0.20%**
17:00	0.40%	6.82%	0.04%	-0.87%	-7.27%	1.15%
18:00	0.62%	7.44%	**-0.65%**	-0.30%	-7.57%	1.53%
19:00	0.32%	7.76%	-1.03%	-0.19%	-7.76%	1.78%
20:00	0.28%	8.05%	-1.33%	-0.12%	-7.87%	1.96%
21:00	0.31%	8.36%	-1.73%	-0.47%	-8.34%	2.43%
22:00	0.63%	8.99%	-2.49%	-0.63%	-8.97%	3.08%
23:00	0.26%	9.25%	-2.86%	0.07%	-8.90%	3.08%

Appendix B

BTCUSD: day after the overreaction

Figure B.1: Average hourly returns on the day after the overreaction and normal days: the case of positive overreactions, BTCUSD

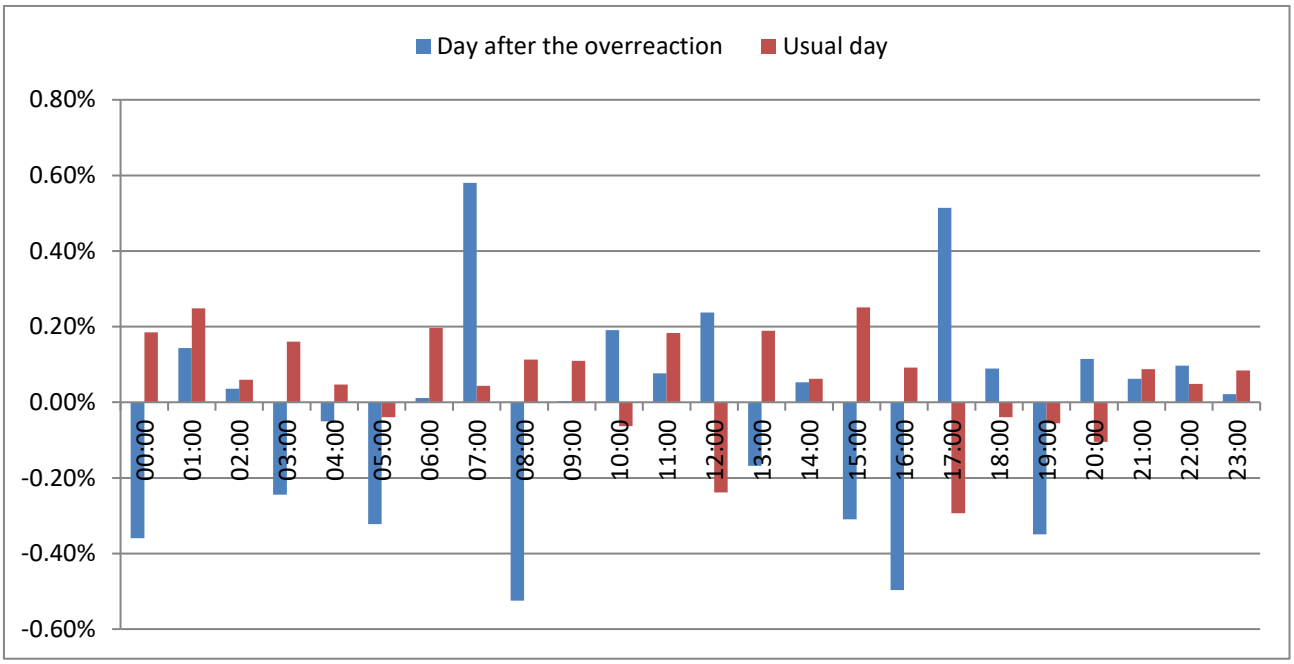


Table B.1: t-test of hourly returns on the day after the overreaction and normal days: the case of positive overreactions, BTCUSD

Hour	Average return on day after positive overreaction (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	**-0.36%**	**1.46%**	**49**	**0.18%**	**0.47%**	**1427**	**-2.60**
1:00	0.14%	1.44%	49	0.25%	0.85%	1427	-0.51
2:00	0.04%	1.46%	49	0.06%	0.57%	1427	-0.11
3:00	**-0.24%**	**1.16%**	**49**	**0.16%**	**0.44%**	**1427**	**-2.43**
4:00	-0.05%	1.89%	49	0.05%	0.85%	1427	-0.36
5:00	-0.32%	1.52%	49	-0.04%	0.66%	1427	-1.29
6:00	0.01%	1.37%	49	0.20%	0.53%	1427	-0.95
7:00	**0.58%**	**1.28%**	**49**	**0.04%**	**0.78%**	**1427**	**2.91**
8:00	**-0.52%**	**1.36%**	**49**	**0.11%**	**0.42%**	**1427**	**-3.28**
9:00	0.00%	1.36%	49	0.11%	0.80%	1427	-0.55
10:00	0.19%	1.27%	49	-0.06%	0.66%	1427	1.39
11:00	0.08%	1.53%	49	0.18%	0.51%	1427	-0.49
12:00	0.24%	2.33%	49	-0.24%	1.02%	1427	1.43
13:00	**-0.17%**	**1.36%**	**49**	**0.19%**	**0.91%**	**1427**	**-1.82**
14:00	0.05%	1.75%	49	0.06%	0.44%	1427	-0.04
15:00	**-0.31%**	**1.31%**	**49**	**0.25%**	**0.70%**	**1427**	**-2.99**
16:00	**-0.50%**	**1.70%**	**49**	**0.09%**	**0.63%**	**1427**	**-2.42**
17:00	**0.51%**	**1.28%**	**49**	**-0.29%**	**0.90%**	**1427**	**4.36**
18:00	0.09%	1.32%	49	-0.04%	0.48%	1427	0.68

19:00	-0.35%	1.31%	49	-0.06%	0.64%	1427	-1.56
20:00	0.11%	1.21%	49	-0.10%	1.07%	1427	1.25
21:00	0.06%	1.98%	49	0.09%	1.01%	1427	-0.09
22:00	0.10%	1.74%	49	0.05%	0.66%	1427	0.19
23:00	0.02%	1.57%	49	0.08%	0.69%	1427	-0.28

Figure B.2: Average hourly returns on the day after the overreaction and normal days: the case of negative overreactions, BTCUSD

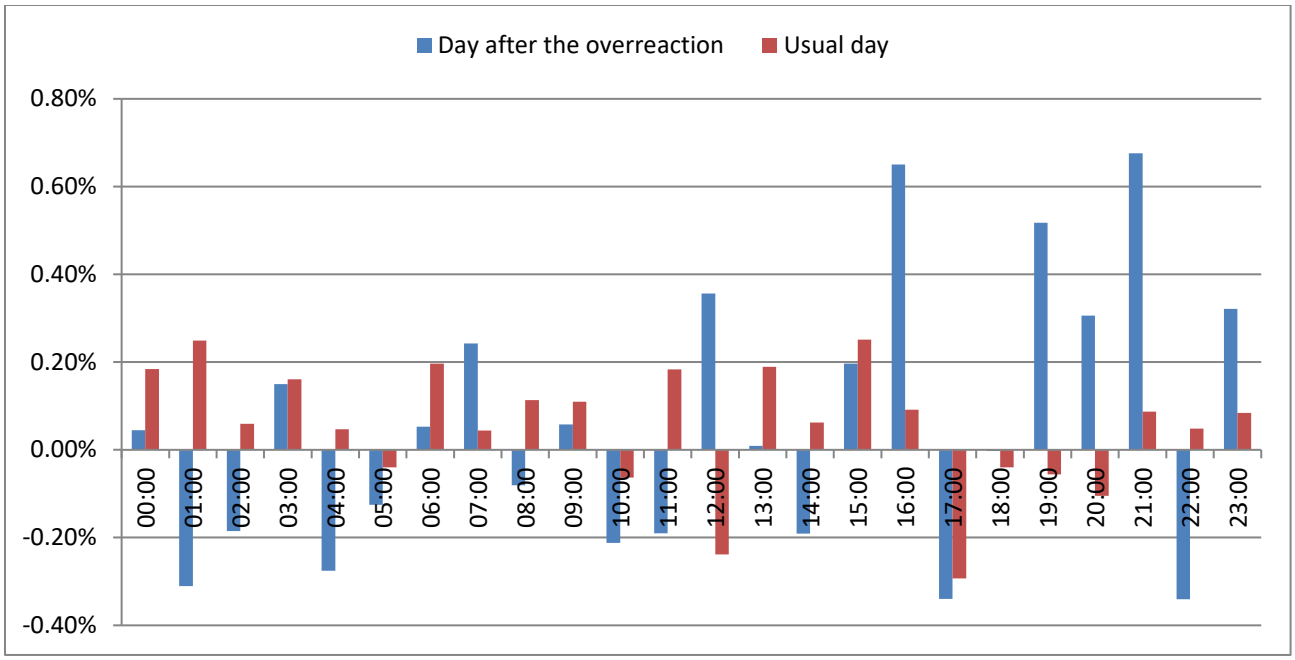


Table B.2: t-test of hourly returns on the day after the overreaction and normal days: the case of negative overreactions, BTCUSD

Hour	Average return on day after negative overreaction (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	0.04%	1.76%	46	0.18%	0.47%	1427	-0.54
1:00	**-0.31%**	**1.83%**	**46**	**0.25%**	**0.85%**	**1427**	**-2.07**
2:00	-0.19%	1.91%	46	0.06%	0.57%	1427	-0.87
3:00	0.15%	1.47%	46	0.16%	0.44%	1427	-0.05
4:00	**-0.28%**	**1.22%**	**46**	**0.05%**	**0.85%**	**1427**	**-1.78**
5:00	-0.12%	1.89%	46	-0.04%	0.66%	1427	-0.31
6:00	0.05%	1.50%	46	0.20%	0.53%	1427	-0.65
7:00	0.24%	1.31%	46	0.04%	0.78%	1427	1.02
8:00	-0.08%	1.87%	46	0.11%	0.42%	1427	-0.70
9:00	0.06%	2.27%	46	0.11%	0.80%	1427	-0.15
10:00	-0.21%	1.67%	46	-0.06%	0.66%	1427	-0.60
11:00	-0.19%	1.59%	46	0.18%	0.51%	1427	-1.59
12:00	0.36%	2.20%	46	-0.24%	1.02%	1427	1.83

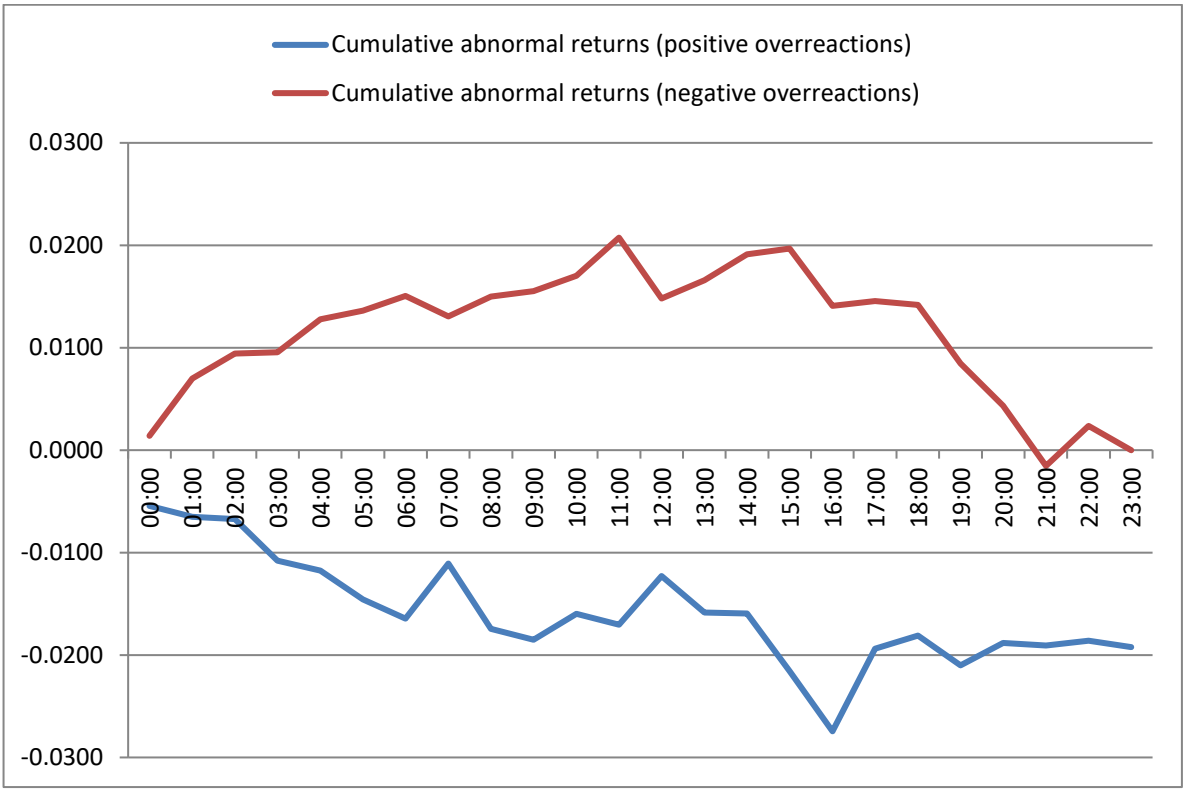
13:00	0.01%	2.66%	46	0.19%	0.91%	1427	-0.46
14:00	-0.19%	2.48%	46	0.06%	0.44%	1427	-0.69
15:00	0.20%	1.69%	46	0.25%	0.70%	1427	-0.22
16:00	0.65%	2.24%	46	0.09%	0.63%	1427	1.69
17:00	-0.34%	1.59%	46	-0.29%	0.90%	1427	-0.20
18:00	0.00%	1.38%	46	-0.04%	0.48%	1427	0.18
19:00	0.52%	1.81%	46	-0.06%	0.64%	1427	2.14
20:00	0.31%	2.02%	46	-0.10%	1.07%	1427	1.38
21:00	0.68%	1.22%	46	0.09%	1.01%	1427	3.23
22:00	**-0.34%**	**1.51%**	**46**	**0.05%**	**0.66%**	**1427**	**-1.75**
23:00	0.32%	1.01%	46	0.08%	0.69%	1427	1.58

Table B.3: Cumulative abnormal returns: the case of positive and negative overreactions, BTCUSD

	Positive overreactions		Negative overreactions	
Hour	Abnormal returns	Cumulative abnormal returns	Abnormal returns	Cumulative abnormal returns
0:00	-0.54%	-0.54%	-0.14%	0.14%
1:00	-0.11%	-0.65%	-0.56%	0.70%
2:00	-0.02%	-0.67%	-0.24%	0.94%
3:00	-0.41%	-1.08%	-0.01%	0.95%
4:00	-0.10%	-1.18%	-0.32%	1.28%
5:00	-0.28%	-1.46%	-0.09%	1.36%
6:00	-0.19%	-1.64%	-0.14%	1.51%
7:00	0.54%	-1.11%	0.20%	1.31%
8:00	-0.64%	-1.74%	-0.19%	1.50%
9:00	-0.11%	-1.85%	-0.05%	1.55%
10:00	0.25%	-1.60%	-0.15%	1.70%
11:00	-0.11%	-1.70%	**-0.37%**	**2.07%**
12:00	0.48%	-1.23%	0.60%	1.48%
13:00	-0.36%	-1.59%	-0.18%	1.66%
14:00	-0.01%	-1.60%	-0.25%	1.91%
15:00	-0.56%	-2.16%	-0.05%	1.97%
16:00*	**-0.59%**	**-2.74%**	0.56%	1.41%
17:00	0.81%	-1.94%	-0.05%	1.46%
18:00	0.13%	-1.81%	0.04%	1.42%
19:00	-0.29%	-2.10%	0.57%	0.85%
20:00	0.22%	-1.88%	0.41%	0.43%
21:00	-0.02%	-1.91%	0.59%	-0.15%
22:00	0.05%	-1.86%	-0.39%	0.24%
23:00	-0.06%	-1.92%	0.24%	0.00%

* contrarian effect detected

Figure B.3: Dynamics of cumulative abnormal returns, BTCUSD



Appendix C

LTCUSD: day of overreaction

Table C.1: Descriptive statistics for LTCUSD data: daily, hourly, days with positive and negative returns

Parameter	Daily data	Positive days	Negative days	Hourly data	Positive days (hourly data)	Negative days (hourly data)
Mean	0.0047	0.2057	-0.1201	0.0001	0.0072	-0.0050
Standard error	0.0021	0.0192	0.0043	0.0001	0.0009	0.0008
Median	-0.0024	0.1504	-0.1184	-0.0001	0.0027	-0.0035
Mode	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Std. Dev.	0.0698	0.1368	0.0304	0.0136	0.0265	0.0252
Variance	0.0049	0.0187	0.0009	0.0002	0.0007	0.0006
Kurtosis	27.9109	9.1535	9.5862	23.1228	10.2157	9.8648
Skewness	3.2292	2.7385	-2.3506	1.2878	1.8318	0.3360
Minimum	-0.2650	0.1095	-0.2650	-0.1773	-0.0876	-0.1773
Maximum	0.8349	0.8349	-0.0872	0.2061	0.1950	0.2002
Sum	5.1325	10.4890	-5.8864	2.2125	6.5569	-4.6369
Observations	1095	51	49	19047	912	936

Figure C.1: Average hourly returns on overreaction and normal days: the case of positive overreactions, LTCUSD

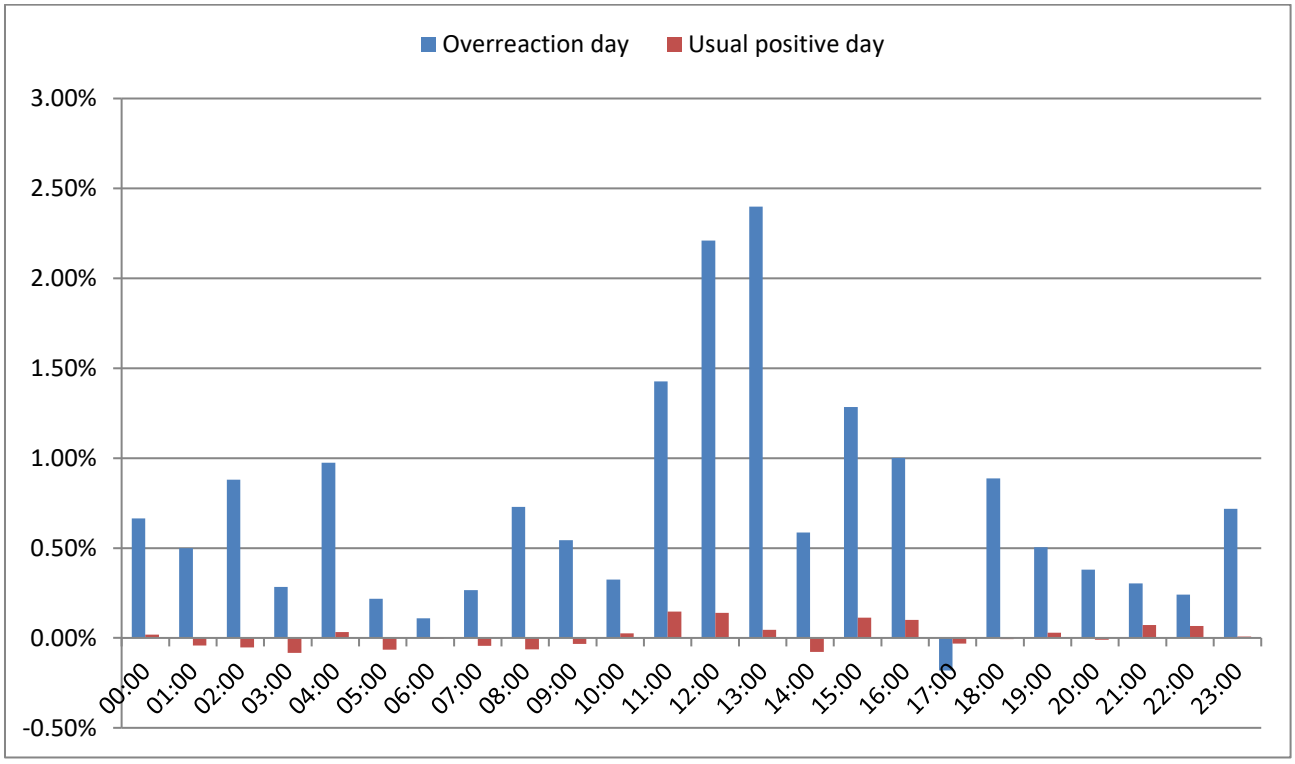


Figure C.2: Average hourly returns on overreaction and normal days: the case of negative overreactions, LTCUSD

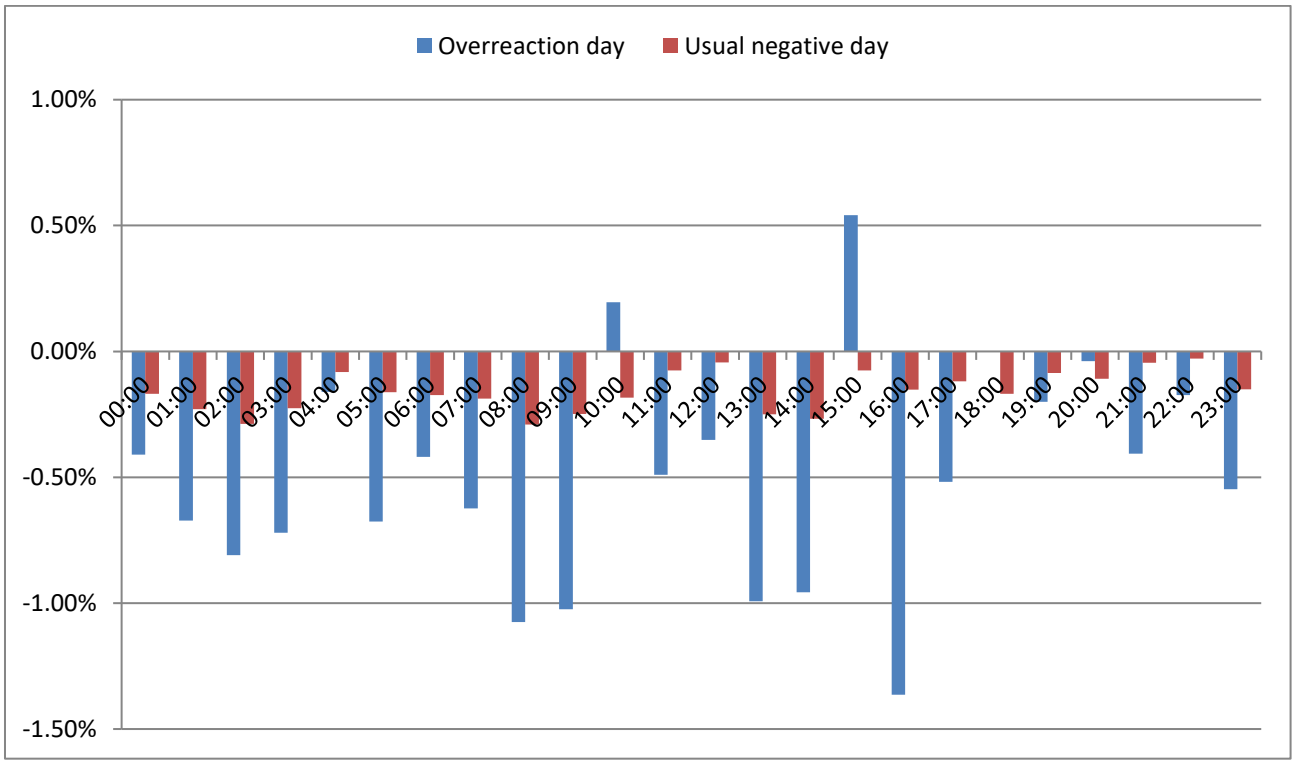


Table C.2: t-test of hourly returns on overreaction and normal days: the case of positive overreactions, LTCUSD

Hour	Average return on positive overreaction day (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day with positive returns (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	**0.67%**	**1.34%**	**37**	**0.02%**	**1.31%**	**794**	**2.88**
1:00	0.50%	2.63%	37	-0.04%	1.26%	794	1.24
2:00	**0.88%**	**2.05%**	**37**	**-0.05%**	**1.32%**	**793**	**2.75**
3:00	0.28%	1.82%	37	-0.08%	1.09%	793	1.22
4:00	0.97%	3.71%	37	0.03%	1.38%	793	1.54
5:00	0.22%	1.87%	37	-0.07%	1.21%	793	0.91
6:00	0.11%	2.03%	37	0.00%	1.21%	793	0.34
7:00	0.27%	1.61%	37	-0.04%	1.04%	793	1.16
8:00	**0.73%**	**2.19%**	**37**	**-0.06%**	**1.18%**	**793**	**2.19**
9:00	0.54%	2.17%	37	-0.03%	1.33%	793	1.60
10:00	0.33%	2.67%	37	0.03%	1.30%	793	0.68
11:00	**1.43%**	**2.71%**	**37**	**0.15%**	**1.30%**	**794**	**2.86**
12:00	**2.21%**	**3.85%**	**37**	**0.14%**	**1.54%**	**794**	**3.26**
13:00	**2.40%**	**4.46%**	**37**	**0.04%**	**1.84%**	**794**	**3.20**
14:00	0.59%	2.59%	37	-0.08%	1.55%	794	1.55
15:00	**1.28%**	**2.56%**	**37**	**0.11%**	**1.59%**	**794**	**2.76**
16:00	1.00%	3.63%	37	0.10%	1.84%	794	1.50
17:00	-0.18%	2.24%	37	-0.03%	1.26%	794	-0.40

18:00	**0.89%**	**2.45%**	**37**	**-0.01%**	**1.09%**	**794**	**2.21**
19:00	0.50%	1.94%	37	0.03%	1.25%	794	1.47
20:00	0.38%	2.49%	37	-0.01%	1.37%	794	0.95
21:00	0.30%	1.88%	37	0.07%	1.28%	794	0.74
22:00	0.24%	3.18%	37	0.07%	1.48%	794	0.33
23:00	**0.72%**	**2.08%**	**37**	**0.01%**	**1.24%**	**794**	**2.06**

Table C.3:t-test of hourly returns on overreaction and normal days: the case of negative overreactions, LTCUSD

Hour	Average return on negative overreaction day (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day with negative returns (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	-0.41%	2.10%	38	-0.17%	1.36%	409	-0.69
1:00	-0.67%	1.67%	38	-0.23%	1.22%	409	-1.59
2:00	-0.81%	2.03%	38	-0.29%	1.33%	409	-1.55
3:00	**-0.72%**	**1.60%**	**38**	**-0.23%**	**1.11%**	**409**	**-1.86**
4:00	-0.16%	1.62%	38	-0.08%	1.12%	409	-0.29
5:00	-0.68%	2.14%	38	-0.16%	1.21%	409	-1.46
6:00	-0.42%	2.79%	38	-0.17%	1.31%	409	-0.54
7:00	-0.62%	1.51%	38	-0.19%	1.02%	409	-1.75
8:00	**-1.08%**	**1.94%**	**38**	**-0.29%**	**1.12%**	**409**	**-2.46**
9:00	-1.02%	2.68%	38	-0.25%	1.35%	409	-1.76
10:00	0.20%	1.90%	38	-0.18%	1.22%	409	1.21
11:00	-0.49%	2.44%	38	-0.08%	1.13%	409	-1.03
12:00	-0.35%	2.13%	38	-0.04%	1.31%	409	-0.87
13:00	-0.99%	3.55%	38	-0.25%	1.69%	409	-1.27
14:00	-0.96%	3.45%	38	-0.27%	1.64%	409	-1.22
15:00	0.54%	4.02%	38	-0.08%	1.64%	409	0.94
16:00	**-1.36%**	**2.39%**	**38**	**-0.15%**	**1.87%**	**409**	**-3.04**
17:00	-0.52%	2.84%	38	-0.12%	1.35%	409	-0.86
18:00	0.00%	2.06%	38	-0.17%	1.07%	409	0.50
19:00	-0.20%	2.20%	38	-0.09%	1.38%	409	-0.32
20:00	-0.04%	3.73%	38	-0.11%	1.54%	409	0.11
21:00	-0.41%	2.51%	38	-0.05%	1.35%	409	-0.87
22:00	-0.17%	2.20%	38	-0.03%	1.36%	409	-0.40
23:00	-0.55%	2.63%	38	-0.15%	1.27%	409	-0.92

Figure C.3: Dynamics of cumulative abnormal returns, LTCUSD

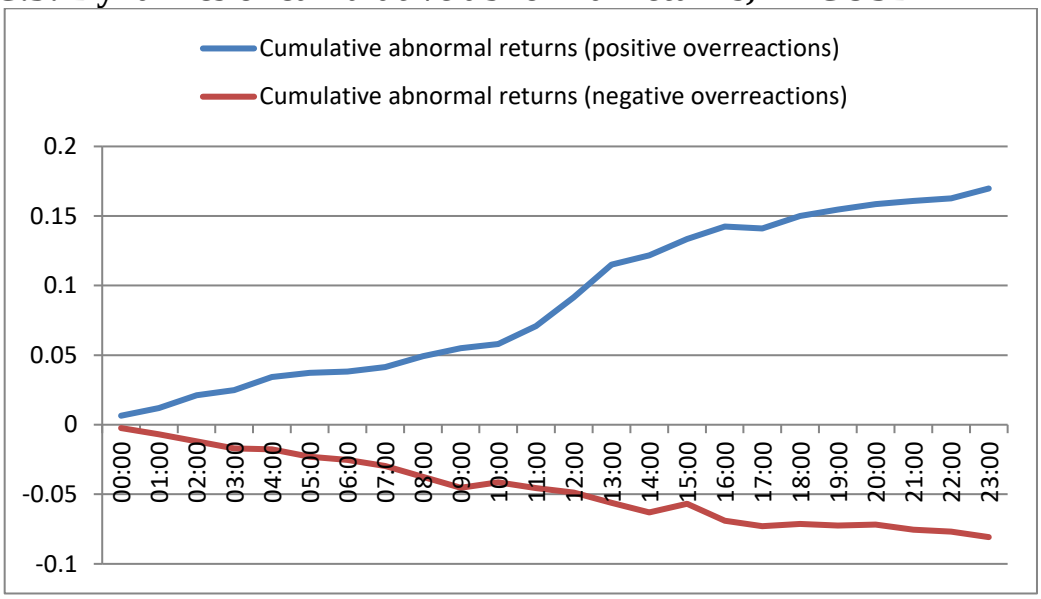


Table C.4: Cumulative abnormal returns: the case of positive and negative overreactions, LTCUSD

Hour	Positive overreactions			Negative overreactions		
	Abnormal returns	Cumulative abnormal returns	Overreaction cross	Abnormal returns	Cumulative abnormal returns	Overreaction cross
0:00	0.65%	0.65%	10.27%	-0.24%	-0.24%	-8.19%
1:00	0.54%	1.19%	9.77%	-0.44%	-0.68%	-7.52%
2:00	0.93%	2.12%	8.89%	-0.52%	-1.20%	-6.71%
3:00	0.37%	2.49%	8.61%	-0.49%	-1.70%	-5.99%
4:00	0.94%	3.43%	7.63%	-0.08%	-1.78%	-5.83%
5:00	0.28%	3.72%	7.42%	-0.51%	-2.29%	-5.16%
6:00	0.11%	3.83%	7.31%	-0.25%	-2.53%	-4.74%
7:00	0.31%	4.14%	7.04%	-0.44%	-2.97%	-4.12%
8:00	0.79%	4.93%	6.31%	-0.78%	-3.75%	-3.04%
9:00	0.58%	5.51%	5.77%	-0.78%	-4.53%	-2.02%
10:00	0.30%	5.81%	5.44%	0.38%	-4.15%	-2.21%
11:00	1.28%	7.09%	4.01%	-0.41%	-4.56%	-1.72%
12:00	2.07%	9.16%	1.81%	-0.31%	-4.87%	-1.37%
13:00	**2.35%**	**11.51%**	**-0.59%**	-0.74%	-5.61%	-0.38%
14:00	0.67%	12.18%	-1.18%	**-0.69%**	**-6.30%**	**0.58%**
15:00	1.17%	13.35%	-2.46%	0.62%	-5.69%	0.04%
16:00	0.90%	14.25%	-3.47%	-1.21%	-6.90%	1.40%
17:00	-0.15%	14.10%	-3.29%	-0.40%	-7.30%	1.92%
18:00	0.89%	14.99%	-4.17%	0.17%	-7.13%	1.92%
19:00	0.47%	15.47%	-4.68%	-0.11%	-7.24%	2.12%
20:00	0.39%	15.86%	-5.06%	0.07%	-7.17%	2.16%
21:00	0.23%	16.09%	-5.36%	-0.36%	-7.54%	2.56%
22:00	0.17%	16.27%	-5.60%	-0.14%	-7.68%	2.74%
23:00	0.71%	16.98%	-6.32%	-0.40%	-8.08%	3.29%

Appendix D

LTCUSD: day after the overreaction

Figure D.1: Average hourly returns on the day after the overreaction and normal days: the case of positive overreactions, LTCUSD

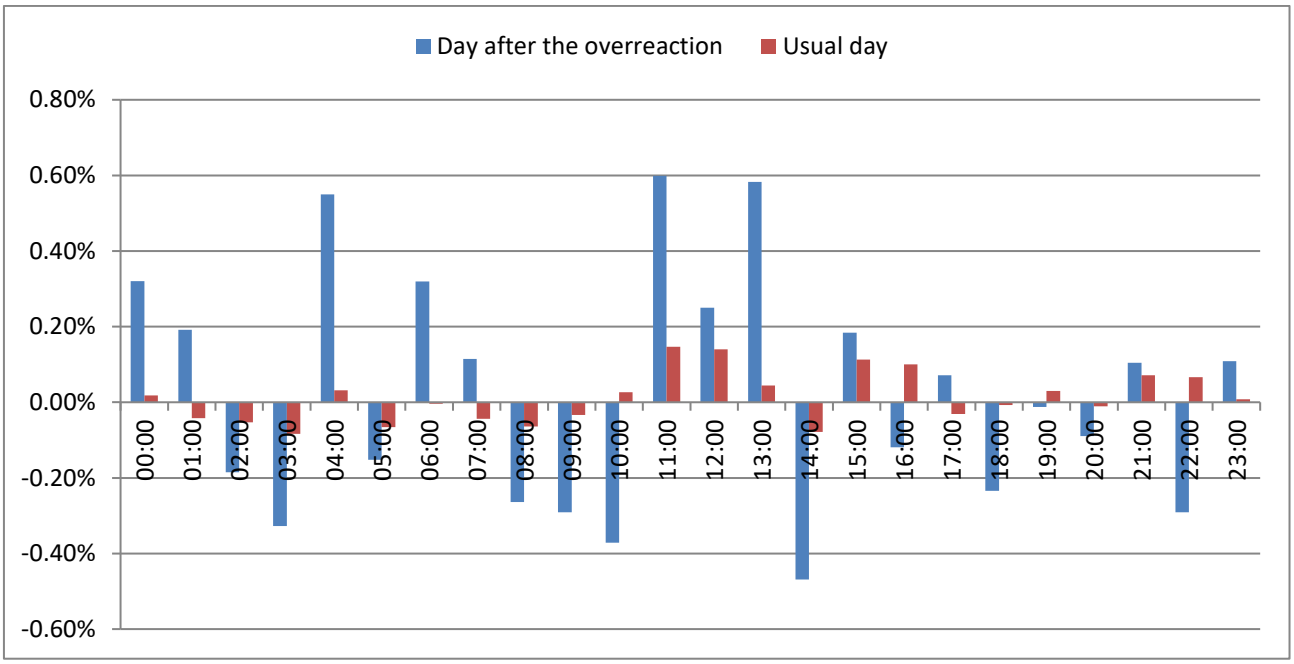


Table D.1: t-test of hourly returns on the day after the overreaction and normal days: the case of positive overreactions, LTCUSD

Hour	Average return on day after positive overreaction (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	0.32%	2.13%	38	0.02%	1.31%	794	0.87
1:00	0.19%	2.29%	38	-0.04%	1.26%	794	0.62
2:00	-0.18%	2.32%	38	-0.05%	1.32%	793	-0.35
3:00	-0.33%	1.75%	38	-0.08%	1.09%	793	-0.85
4:00	0.55%	3.48%	38	0.03%	1.38%	793	0.91
5:00	-0.15%	2.22%	38	-0.07%	1.21%	793	-0.24
6:00	0.32%	2.12%	38	0.00%	1.21%	793	0.93
7:00	0.11%	1.61%	38	-0.04%	1.04%	793	0.60
8:00	-0.26%	1.58%	38	-0.06%	1.18%	793	-0.77
9:00	-0.29%	2.11%	38	-0.03%	1.33%	793	-0.75
10:00	-0.37%	2.35%	38	0.03%	1.30%	793	-1.04
11:00	0.60%	2.43%	38	0.15%	1.30%	794	1.14
12:00	0.25%	2.38%	38	0.14%	1.54%	794	0.28
13:00	0.58%	3.47%	38	0.04%	1.84%	794	0.95
14:00	-0.47%	2.37%	38	-0.08%	1.55%	794	-1.00
15:00	0.18%	1.92%	38	0.11%	1.59%	794	0.22
16:00	-0.12%	2.56%	38	0.10%	1.84%	794	-0.52
17:00	0.07%	2.11%	38	-0.03%	1.26%	794	0.30
18:00	-0.23%	1.47%	38	-0.01%	1.09%	794	-0.94

19:00	-0.01%	1.17%	38	0.03%	1.25%	794	-0.22
20:00	-0.09%	1.38%	38	-0.01%	1.37%	794	-0.34
21:00	0.10%	1.92%	38	0.07%	1.28%	794	0.11
22:00	-0.29%	2.65%	38	0.07%	1.48%	794	-0.82
23:00	0.11%	1.68%	38	0.01%	1.24%	794	0.36

Figure D.2: Average hourly returns on the day after the overreaction and normal days: the case of negative overreactions, LTCUSD

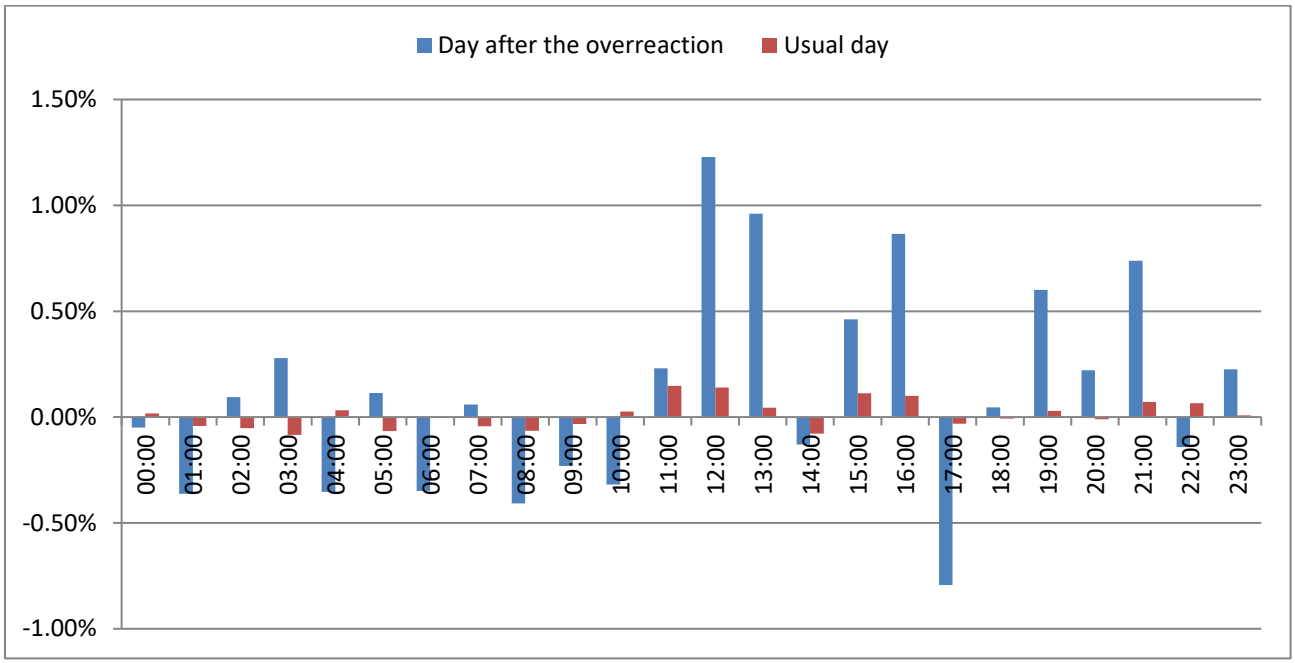


Table D.2: t-test of hourly returns on the day after the overreaction and normal days: the case of negative overreactions, LTCUSD

Hour	Average return on day after negative overreaction (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	-0.05%	1.90%	39	0.02%	1.31%	794	-0.22
1:00	-0.36%	2.08%	39	-0.04%	1.26%	794	-0.95
2:00	0.09%	1.81%	39	-0.05%	1.32%	793	0.50
3:00	0.28%	1.70%	39	-0.08%	1.09%	793	1.31
4:00	-0.35%	1.78%	39	0.03%	1.38%	793	-1.33
5:00	0.11%	2.62%	39	-0.07%	1.21%	793	0.42
6:00	-0.35%	1.97%	39	0.00%	1.21%	793	-1.09
7:00	0.06%	1.32%	39	-0.04%	1.04%	793	0.48
8:00	-0.41%	2.03%	39	-0.06%	1.18%	793	-1.05
9:00	-0.23%	2.42%	39	-0.03%	1.33%	793	-0.51
10:00	-0.32%	2.00%	39	0.03%	1.30%	793	-1.07
11:00	0.23%	2.00%	39	0.15%	1.30%	794	0.26
12:00	1.23%	4.06%	39	0.14%	1.54%	794	1.67
13:00	0.96%	4.31%	39	0.04%	1.84%	794	1.32

14:00	-0.13%	3.36%	39	-0.08%	1.55%	794	-0.09
15:00	0.46%	2.85%	39	0.11%	1.59%	794	0.76
16:00	0.87%	3.98%	39	0.10%	1.84%	794	1.20
17:00	-0.79%	1.61%	39	-0.03%	1.26%	794	-2.91
18:00	0.05%	1.63%	39	-0.01%	1.09%	794	0.20
19:00	0.60%	1.97%	39	0.03%	1.25%	794	1.80
20:00	0.22%	1.78%	39	-0.01%	1.37%	794	0.80
21:00	0.74%	1.90%	39	0.07%	1.28%	794	2.17
22:00	-0.14%	1.90%	39	0.07%	1.48%	794	-0.67
23:00	0.23%	1.13%	39	0.01%	1.24%	794	1.16

Figure D.3: Dynamics of cumulative abnormal returns on the day after the overreaction, LTCUSD

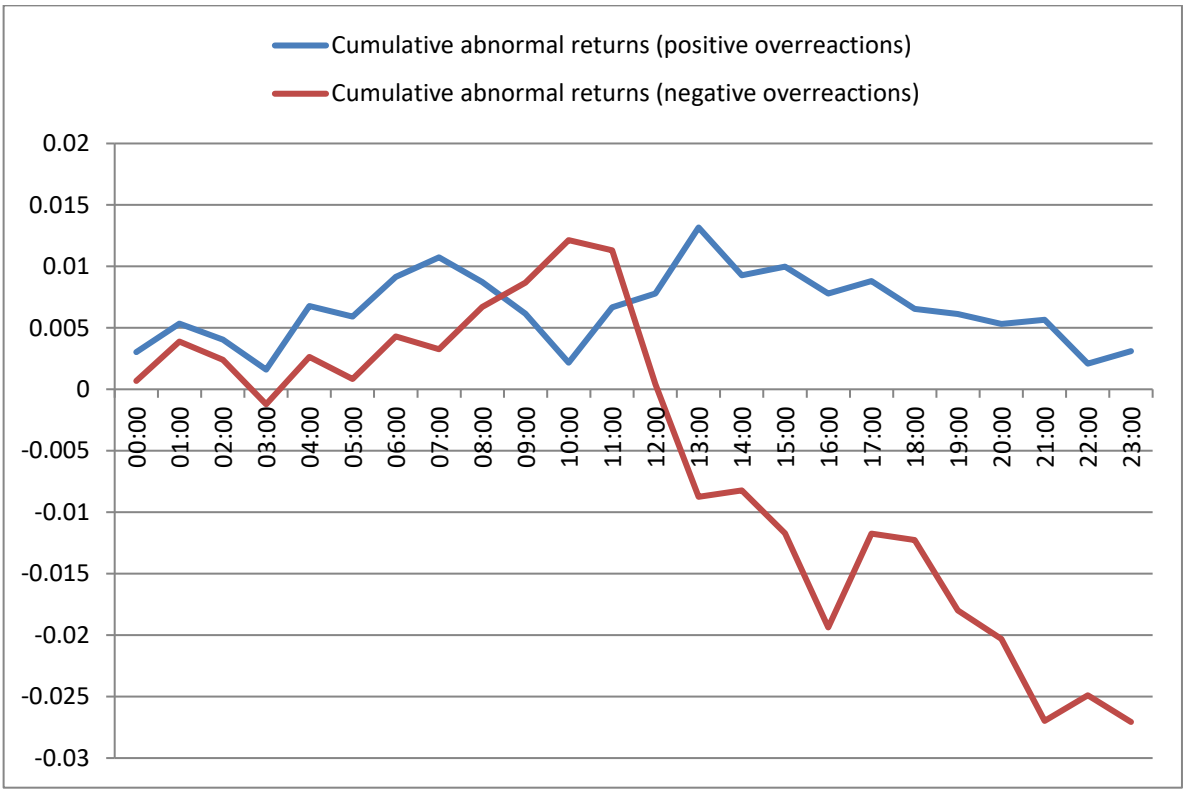


Table D.3: Cumulative abnormal returns on the day after the overreaction: the case of positive and negative overreactions, LTCUSD

	Positive overreactions		Negative overreactions	
Hour	Abnormal returns	Cumulative abnormal returns	Abnormal returns	Cumulative abnormal returns
0:00	0.30%	0.30%	-0.07%	0.07%
1:00	0.23%	0.54%	-0.32%	0.39%
2:00	-0.13%	0.40%	0.15%	0.24%
3:00	-0.24%	0.16%	0.36%	-0.12%
4:00	0.52%	0.68%	-0.38%	0.26%
5:00	-0.09%	0.59%	0.18%	0.08%
6:00	0.32%	0.91%	-0.35%	0.43%
7:00	0.16%	1.07%	0.10%	0.33%
8:00	-0.20%	0.87%	-0.34%	0.67%
9:00	-0.26%	0.61%	-0.20%	0.87%

10:00	-0.40%	0.22%	**-0.35%**	**1.21%**
11:00	0.45%	0.67%	0.08%	1.13%
12:00	0.11%	0.78%	1.09%	0.04%
13:00	**0.54%**	**1.32%**	0.92%	-0.87%
14:00	-0.39%	0.93%	-0.05%	-0.82%
15:00	0.07%	1.00%	0.35%	-1.17%
16:00	-0.22%	0.78%	0.77%	-1.94%
17:00	0.10%	0.88%	-0.76%	-1.17%
18:00	-0.23%	0.65%	0.05%	-1.23%
19:00	-0.04%	0.61%	0.57%	-1.80%
20:00	-0.08%	0.53%	0.23%	-2.03%
21:00	0.03%	0.57%	0.67%	-2.70%
22:00	-0.36%	0.21%	-0.21%	-2.49%
23:00	0.10%	0.31%	0.22%	-2.71%

Appendix E

ETHUSD: day of overreaction

Table E.1: Descriptive statistics for ETHUSD data: daily, hourly, days with positive and negative returns

Parameter	Daily data	Positive days	Negative days	Hourly data	Positive days (hourly data)	Negative days (hourly data)
Mean	0.0039	0.1626	-0.1355	0.0002	0.0066	-0.0054
Standard error	0.0018	0.0060	0.0056	0.0001	0.0007	0.0010
Median	0.0000	0.1484	-0.1225	0.0000	0.0040	-0.0032
Mode	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Std. Dev.	0.0613	0.0454	0.0426	0.0139	0.0233	0.0308
Variance	0.0038	0.0021	0.0018	0.0002	0.0005	0.0010
Kurtosis	3.3418	2.2361	1.9070	21.4268	3.9199	11.7349
Skewness	0.3911	1.5380	-1.4479	0.4050	0.4461	0.3255
Minimum	-0.2703	0.1143	-0.2703	-0.2347	-0.1138	-0.2347
Maximum	0.3029	0.3029	-0.0896	0.2371	0.1263	0.2371
Sum	4.7596	9.4321	-7.7234	5.6704	7.7909	-5.0130
Observations	1213	58	57	29100	1176	936

Figure E.1: Average hourly returns on overreaction and normal days: the case of positive overreactions, ETHUSD

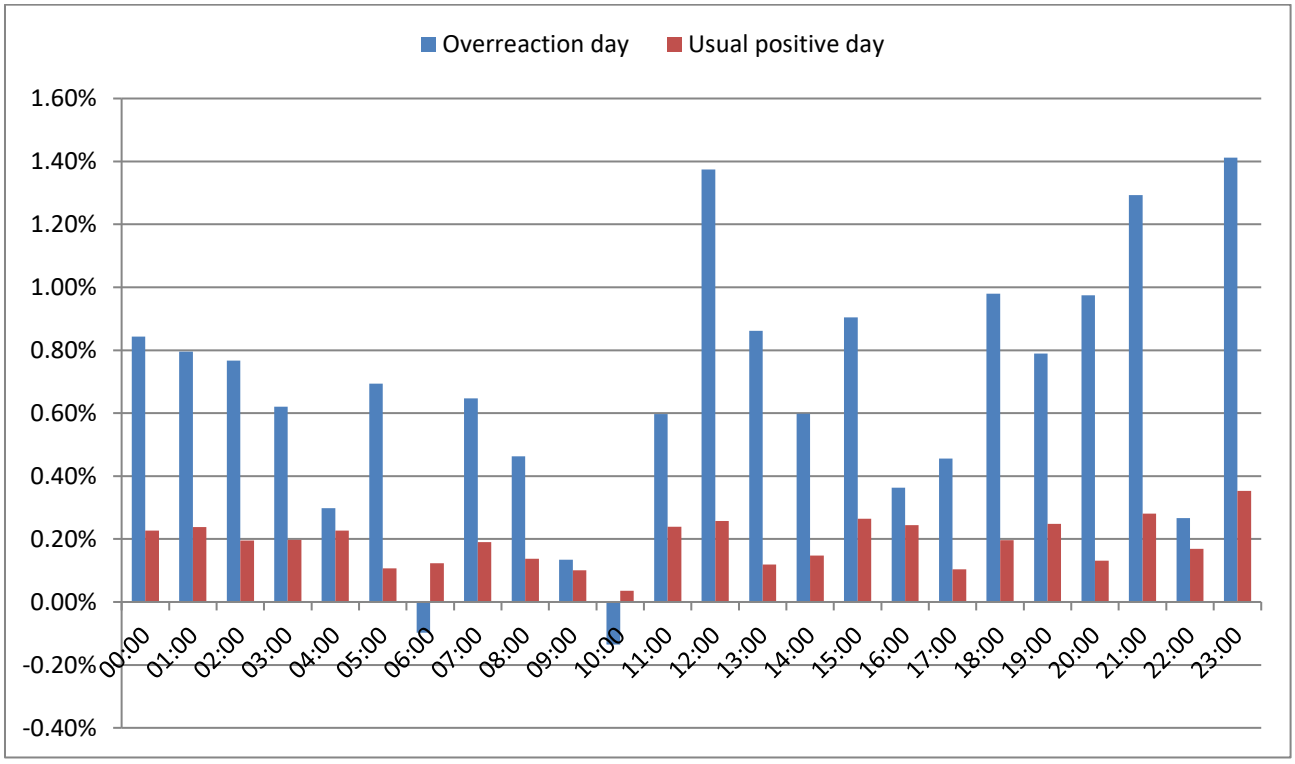


Figure E.2: Average hourly returns on overreaction and normal days: the case of negative overreactions, ETHUSD

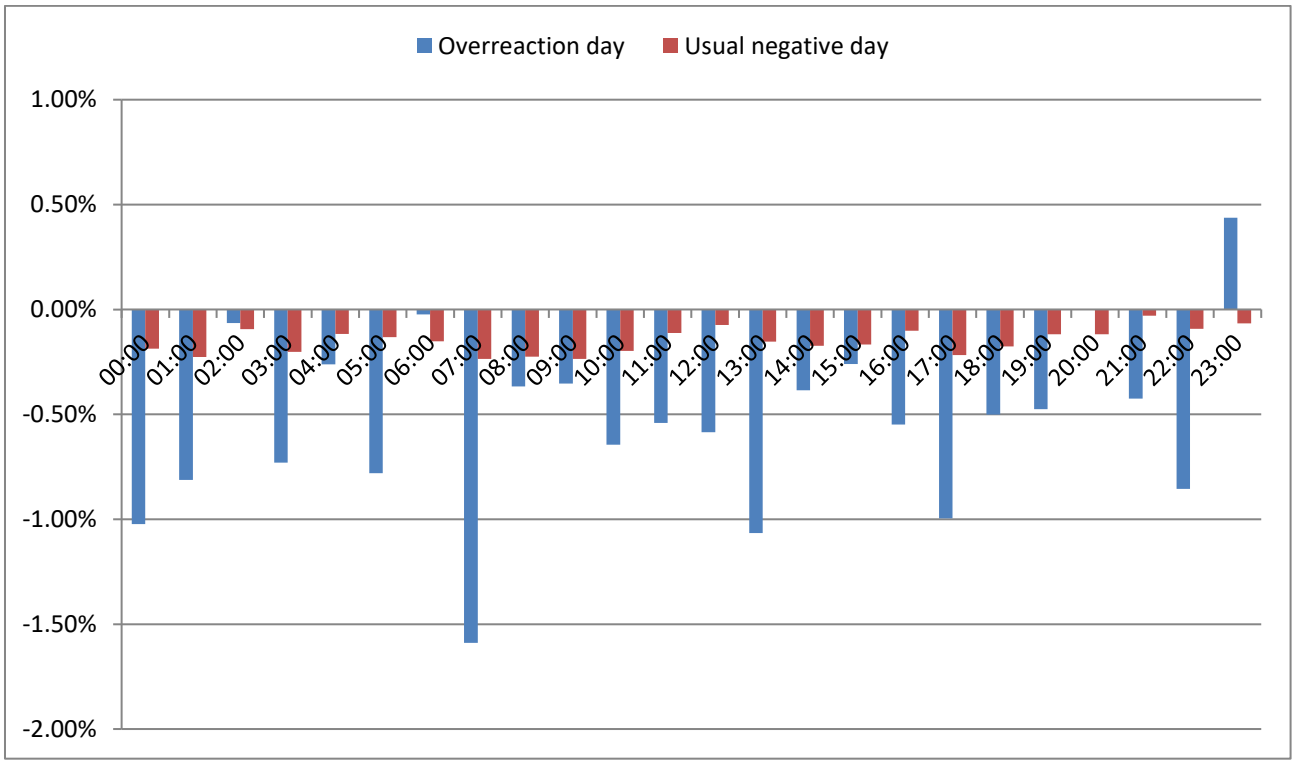


Table E.2: t-test of hourly returns on overreaction and normal days: the case of positive overreactions, ETHUSD

Hour	Average return on positive overreaction day (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day with positive returns (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	0.84%	2.19%	48	0.23%	1.52%	604	1.91
1:00	0.80%	2.44%	48	0.24%	1.39%	604	1.56
2:00	0.77%	2.04%	48	0.20%	1.22%	604	1.92
3:00	0.62%	2.19%	48	0.20%	1.28%	604	1.32
4:00	0.30%	2.35%	48	0.23%	1.31%	604	0.21
5:00	0.69%	2.28%	48	0.11%	1.23%	604	1.76
6:00	-0.10%	1.89%	48	0.12%	1.07%	604	-0.80
7:00	0.65%	1.87%	48	0.19%	1.07%	604	1.67
8:00	0.46%	1.41%	48	0.14%	1.17%	604	1.56
9:00	0.13%	2.40%	48	0.10%	1.21%	604	0.10
10:00	-0.13%	2.46%	48	0.04%	1.18%	604	-0.48
11:00	0.60%	2.07%	48	0.24%	1.25%	604	1.18
12:00	1.37%	2.75%	48	0.26%	1.45%	604	2.78
13:00	0.86%	2.76%	48	0.12%	1.44%	604	1.84
14:00	0.60%	3.02%	48	0.15%	1.58%	604	1.02
15:00	0.90%	2.08%	48	0.26%	1.55%	604	2.09
16:00	0.36%	2.04%	48	0.24%	1.47%	604	0.40
17:00	0.46%	2.38%	48	0.10%	1.39%	604	1.01
18:00	0.98%	1.97%	48	0.20%	1.21%	604	2.71

19:00	0.79%	2.10%	48	0.25%	1.27%	604	1.76
20:00	0.97%	2.43%	48	0.13%	1.33%	604	2.37
21:00	1.29%	2.34%	48	0.28%	1.30%	604	2.95
22:00	0.27%	2.98%	48	0.17%	1.26%	604	0.22
23:00	1.41%	2.60%	48	0.35%	1.35%	604	2.79

Table E.3:t-testof hourly returns on overreaction and normal days: the case of negative overreactions, ETHUSD

Hour	Average return on negative overreaction day (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day with negative returns (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	**-1.02%**	**2.49%**	**38**	**-0.19%**	**1.35%**	**602**	**-2.05**
1:00	-0.81%	2.87%	38	-0.23%	1.30%	602	-1.25
2:00	-0.07%	2.94%	38	-0.09%	1.40%	602	0.06
3:00	-0.73%	2.25%	38	-0.20%	1.16%	602	-1.43
4:00	-0.26%	2.16%	38	-0.12%	1.12%	602	-0.41
5:00	**-0.78%**	**2.22%**	**38**	**-0.13%**	**1.09%**	**602**	**-1.79**
6:00	-0.02%	2.27%	38	-0.15%	1.13%	602	0.34
7:00	**-1.59%**	**4.05%**	**38**	**-0.23%**	**1.48%**	**602**	**-2.05**
8:00	-0.37%	4.92%	38	-0.22%	1.64%	602	-0.18
9:00	-0.35%	2.77%	38	-0.24%	1.49%	602	-0.26
10:00	-0.65%	1.99%	38	-0.20%	1.17%	602	-1.38
11:00	-0.54%	2.96%	38	-0.11%	1.37%	602	-0.89
12:00	-0.59%	2.01%	38	-0.07%	1.27%	602	-1.55
13:00	-1.07%	3.94%	38	-0.15%	1.68%	603	-1.42
14:00	-0.38%	2.59%	38	-0.17%	1.66%	603	-0.50
15:00	-0.26%	4.26%	38	-0.17%	1.74%	603	-0.14
16:00	-0.55%	2.56%	38	-0.10%	1.72%	603	-1.06
17:00	**-1.00%**	**2.65%**	**38**	**-0.22%**	**1.39%**	**603**	**-1.79**
18:00	-0.50%	3.27%	38	-0.18%	1.38%	603	-0.61
19:00	-0.48%	2.88%	38	-0.12%	1.42%	603	-0.76
20:00	0.00%	3.84%	38	-0.12%	1.58%	603	0.19
21:00	-0.42%	2.47%	38	-0.03%	1.28%	603	-0.98
22:00	-0.85%	3.76%	38	-0.09%	1.51%	603	-1.24
23:00	0.44%	3.73%	38	-0.07%	1.54%	603	0.83

Figure E.3: Dynamics of cumulative abnormal returns, ETHUSD

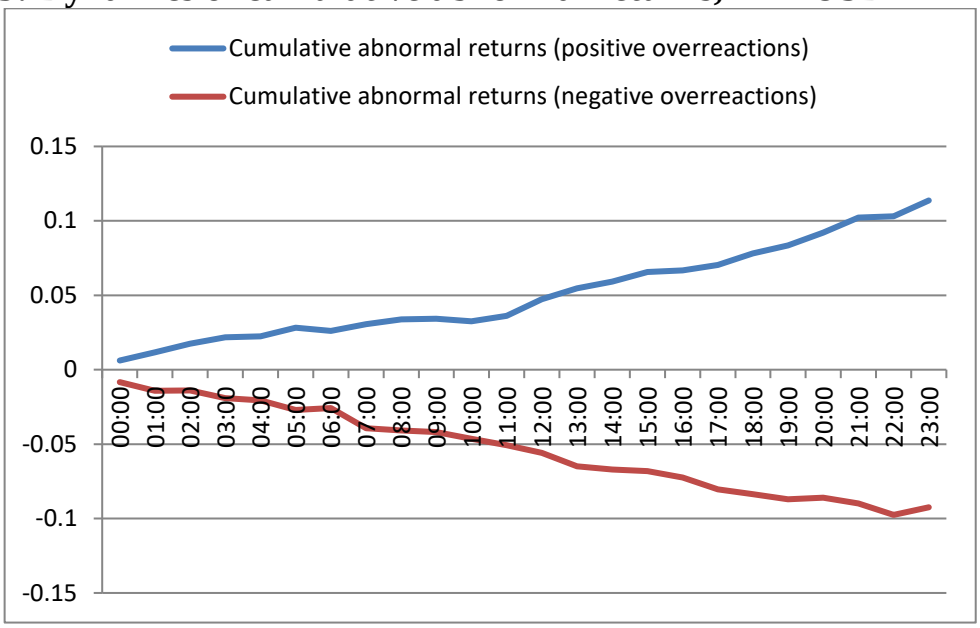


Table E.4: Cumulative abnormal returns: the case of positive and negative overreactions, ETHUSD

Hour	Positive overreactions			Negative overreactions		
	Abnormal returns	CAR	Overreaction cross	Abnormal returns	CAR	Overreaction cross
0:00	0.62%	0.62%	5.68%	-0.84%	-0.84%	-7.77%
1:00	0.56%	1.17%	4.88%	-0.59%	-1.42%	-6.96%
2:00	0.57%	1.75%	4.11%	0.03%	-1.39%	-6.90%
3:00	0.42%	2.17%	3.49%	-0.53%	-1.92%	-6.17%
4:00	0.07%	2.24%	3.19%	-0.14%	-2.07%	-5.90%
5:00	0.59%	2.83%	2.50%	-0.65%	-2.71%	-5.12%
6:00	-0.22%	2.61%	2.60%	0.13%	-2.59%	-5.10%
7:00	0.46%	3.06%	1.95%	-1.35%	-3.94%	-3.51%
8:00	0.33%	3.39%	1.49%	-0.14%	-4.08%	-3.14%
9:00	0.03%	3.42%	1.35%	-0.12%	-4.20%	-2.79%
10:00	-0.17%	3.25%	1.49%	-0.45%	-4.65%	-2.15%
11:00	0.36%	3.61%	0.89%	-0.43%	-5.08%	-1.60%
12:00	**1.12%**	**4.73%**	**-0.48%**	-0.51%	-5.59%	-1.02%
13:00	0.74%	5.47%	-1.34%	**-0.91%**	**-6.50%**	**0.05%**
14:00	0.45%	5.92%	-1.94%	-0.21%	-6.71%	0.43%
15:00	0.64%	6.56%	-2.85%	-0.09%	-6.81%	0.69%
16:00	0.12%	6.68%	-3.21%	-0.45%	-7.25%	1.24%
17:00	0.35%	7.03%	-3.67%	-0.78%	-8.03%	2.24%
18:00	0.78%	7.81%	-4.65%	-0.33%	-8.36%	2.74%
19:00	0.54%	8.36%	-5.44%	-0.36%	-8.72%	3.21%
20:00	0.84%	9.20%	-6.41%	0.12%	-8.60%	3.22%
21:00	1.01%	10.21%	-7.70%	-0.40%	-8.99%	3.64%
22:00	0.10%	10.31%	-7.97%	-0.76%	-9.76%	4.49%
23:00	1.06%	11.37%	-9.38%	0.50%	-9.25%	4.06%

Appendix F

ETHUSD: day after the overreaction

Figure F.1: Average hourly returns on the day after the overreaction and normal days: the case of positive overreactions, ETHUSD

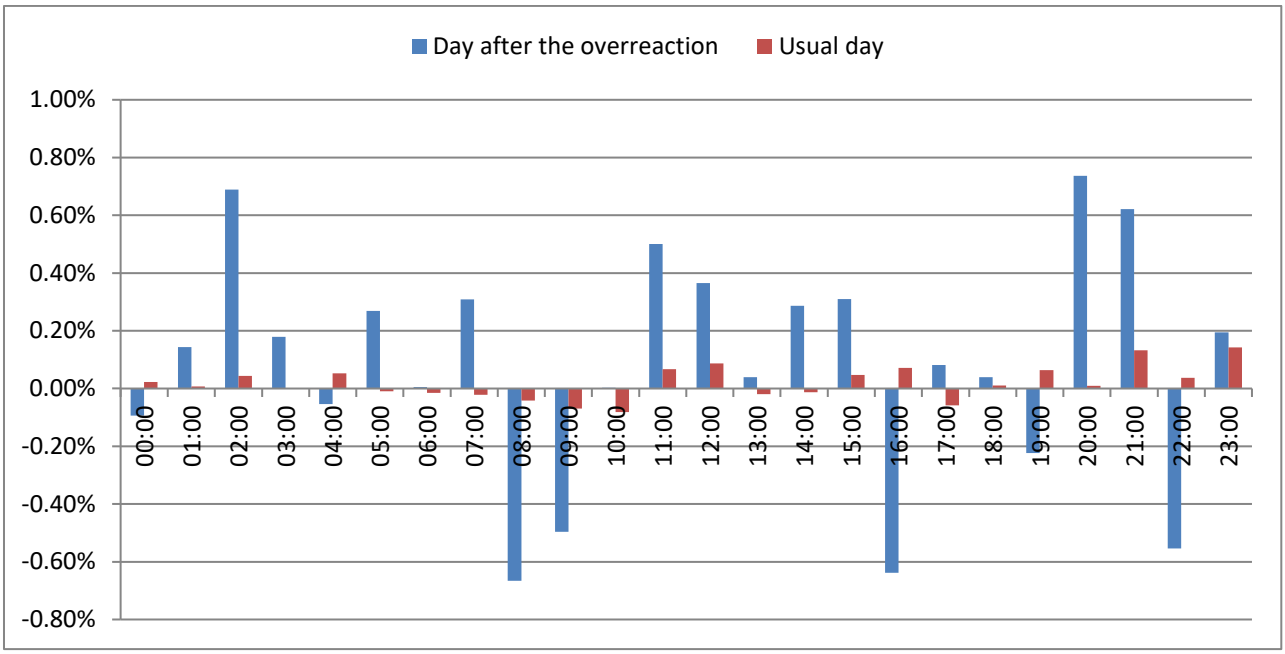


Table F.1: t-test of hourly returns on the day after the overreaction and normal days: the case of positive overreactions, ETHUSD

Hour	Average return on day after positive overreaction (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	-0.09%	2.76%	58	0.02%	1.47%	1213	-0.32
1:00	0.14%	1.94%	58	0.01%	1.36%	1212	0.52
2:00	**0.69%**	**2.54%**	**58**	**0.04%**	**1.33%**	**1212**	**1.92**
3:00	0.18%	1.93%	58	0.00%	1.24%	1212	0.69
4:00	-0.05%	1.93%	58	0.05%	1.23%	1212	-0.41
5:00	0.27%	1.85%	58	-0.01%	1.16%	1212	1.14
6:00	0.01%	1.63%	58	-0.02%	1.11%	1212	0.09
7:00	0.31%	1.77%	58	-0.02%	1.31%	1212	1.40
8:00	-0.67%	2.98%	58	-0.04%	1.44%	1212	-1.59
9:00	-0.50%	1.93%	58	-0.07%	1.36%	1212	-1.66
10:00	0.00%	1.91%	58	-0.08%	1.18%	1212	0.33
11:00	**0.50%**	**1.79%**	**58**	**0.07%**	**1.32%**	**1212**	**1.82**
12:00	0.37%	2.19%	58	0.09%	1.37%	1212	0.96
13:00	0.04%	1.96%	58	-0.02%	1.57%	1213	0.22
14:00	0.29%	2.88%	58	-0.01%	1.62%	1213	0.79
15:00	0.31%	2.86%	58	0.05%	1.66%	1213	0.69
16:00	-0.64%	2.76%	58	0.07%	1.61%	1213	-1.95
17:00	0.08%	2.27%	58	-0.06%	1.40%	1213	0.46
18:00	0.04%	2.21%	58	0.01%	1.31%	1213	0.10
19:00	-0.22%	2.64%	58	0.06%	1.36%	1213	-0.82

20:00	**0.74%**	**2.45%**	**58**	**0.01%**	**1.47%**	**1213**	**2.24**
21:00	0.62%	2.43%	58	0.13%	1.32%	1213	1.52
22:00	-0.55%	2.64%	58	0.04%	1.40%	1213	-1.69
23:00	0.19%	2.89%	58	0.14%	1.46%	1213	0.14

Figure F.2: Average hourly returns on the day after the overreaction and normal days: the case of negative overreactions, ETHUSD

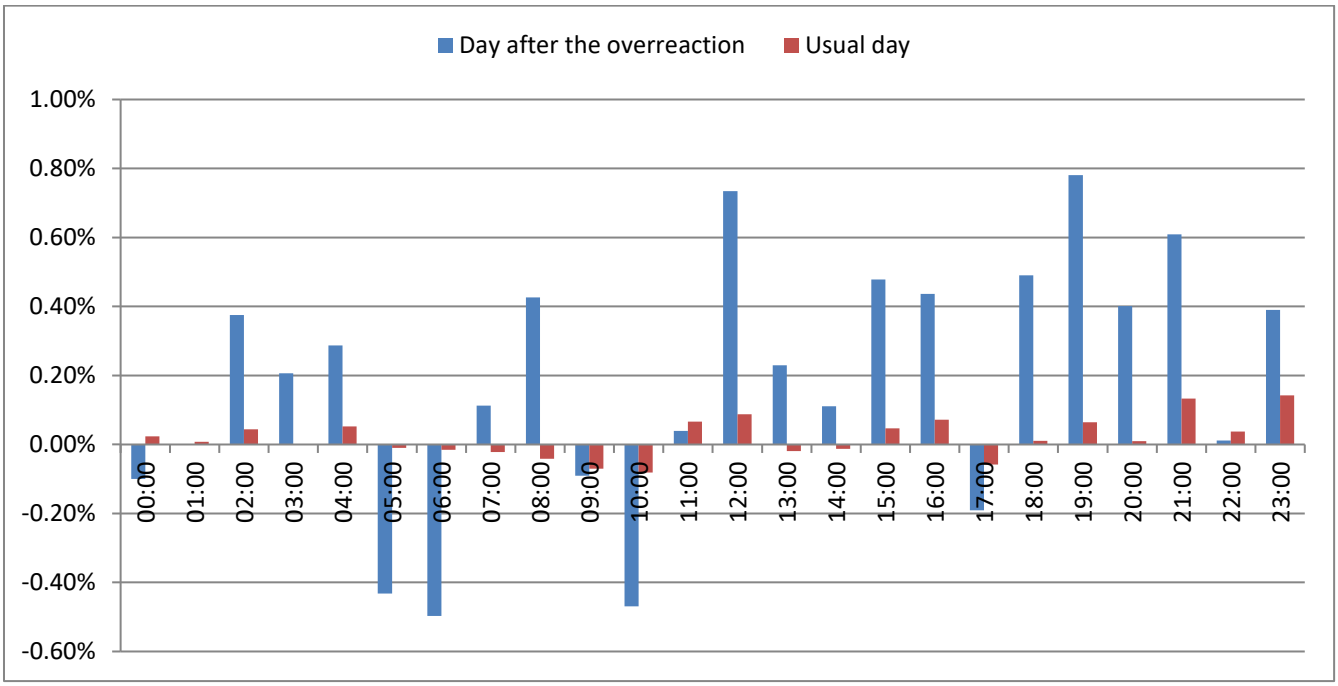


Table F.2: t-test of hourly returns on the day after the overreaction and normal days: the case of negative overreactions, ETHUSD

Hour	Average return on day after negative overreaction (OD)	Standard deviation (OD)	Number of observations (OD)	Average return on usual day (UD)	Standard deviation (UD)	Number of observation (UD)	t criterion
0:00	-0.10%	2.57%	57	0.02%	1.47%	1213	-0.36
1:00	0.00%	3.14%	57	0.01%	1.36%	1212	-0.02
2:00	0.38%	2.85%	57	0.04%	1.33%	1212	0.87
3:00	0.21%	2.22%	57	0.00%	1.24%	1212	0.69
4:00	0.29%	2.47%	57	0.05%	1.23%	1212	0.71
5:00	-0.43%	2.41%	57	-0.01%	1.16%	1212	-1.31
6:00	-0.50%	2.12%	57	-0.02%	1.11%	1212	-1.70
7:00	0.11%	3.53%	57	-0.02%	1.31%	1212	0.29
8:00	0.43%	3.68%	57	-0.04%	1.44%	1212	0.96
9:00	-0.09%	2.51%	57	-0.07%	1.36%	1212	-0.06
10:00	-0.47%	1.80%	57	-0.08%	1.18%	1212	-1.61
11:00	0.04%	1.88%	57	0.07%	1.32%	1212	-0.11
12:00	**0.73%**	**2.70%**	**57**	**0.09%**	**1.37%**	**1212**	**1.80**

13:00	0.23%	3.13%	57	-0.02%	1.57%	1213	0.60
14:00	0.11%	3.43%	57	-0.01%	1.62%	1213	0.27
15:00	0.48%	2.91%	57	0.05%	1.66%	1213	1.11
16:00	0.44%	2.92%	57	0.07%	1.61%	1213	0.94
17:00	-0.19%	2.17%	57	-0.06%	1.40%	1213	-0.46
18:00	**0.49%**	**1.88%**	**57**	**0.01%**	**1.31%**	**1213**	**1.91**
19:00	0.78%	3.12%	57	0.06%	1.36%	1213	1.72
20:00	0.40%	2.92%	57	0.01%	1.47%	1213	1.01
21:00	**0.61%**	**1.59%**	**57**	**0.13%**	**1.32%**	**1213**	**2.22**
22:00	0.01%	2.05%	57	0.04%	1.40%	1213	-0.09
23:00	0.39%	1.55%	57	0.14%	1.46%	1213	1.19

Figure F.3: Dynamics of cumulative abnormal returns, ETHUSD

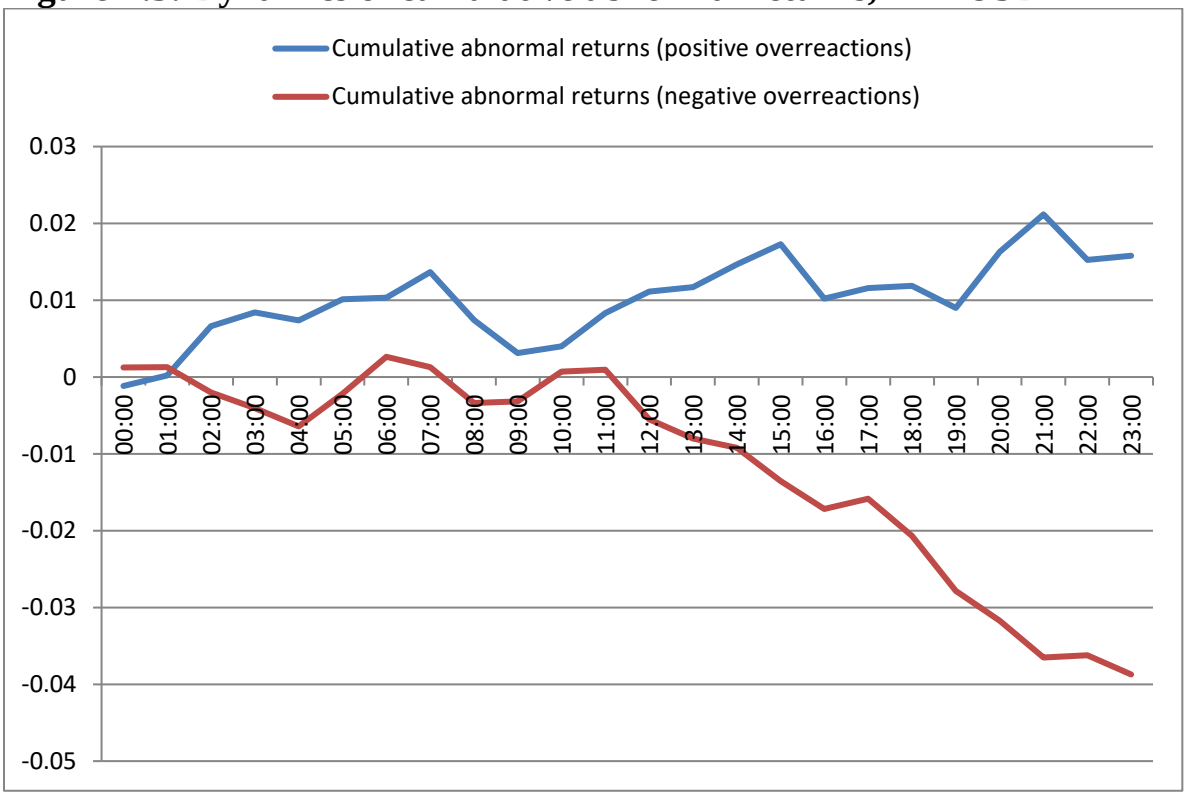


Table F.3: Cumulative abnormal returns: the case of positive and negative overreactions, ETHUSD

Hour	Positive overreactions		Negative overreactions	
	Abnormal returns	Cumulative abnormal returns	Abnormal returns	Cumulative abnormal returns
0:00	-0.12%	-0.12%	-0.12%	0.12%
1:00	0.14%	0.02%	-0.01%	0.13%
2:00	0.64%	0.66%	0.33%	-0.20%
3:00	0.18%	0.84%	0.21%	-0.41%
4:00	-0.11%	0.73%	0.23%	-0.64%
5:00	0.28%	1.01%	-0.42%	-0.22%
6:00	0.02%	1.03%	-0.48%	0.26%
7:00	0.33%	1.36%	0.13%	0.13%
8:00	-0.62%	0.74%	0.47%	-0.34%

9:00	-0.43%	0.31%	-0.02%	-0.32%
10:00	0.08%	0.40%	-0.39%	0.07%
11:00	0.43%	0.83%	-0.03%	0.10%
12:00	0.28%	1.11%	0.65%	-0.55%
13:00	0.06%	1.17%	0.25%	-0.80%
14:00	0.30%	1.47%	0.12%	-0.92%
15:00	0.26%	1.73%	0.43%	-1.35%
16:00	-0.71%	1.02%	0.36%	-1.72%
17:00	0.14%	1.16%	-0.13%	-1.59%
18:00	0.03%	1.19%	0.48%	-2.07%
19:00	-0.29%	0.90%	0.72%	-2.78%
20:00	0.73%	1.63%	0.39%	-3.17%
21:00	**0.49%**	**2.12%**	0.48%	-3.65%
22:00	-0.59%	1.53%	-0.03%	-3.62%
23:00*	0.05%	1.58%	**0.25%**	**-3.87%**

* contrarian effect detected