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Intraday trading patterns in Bitcoin: does the war in Ukraine matter?

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Abstract

Motivation: So far, nothing has been known about the impact of the war in Ukraine on the dynamics of cryptocurrency markets, in particular on the intraday trading patterns in Bitcoin, nowadays the largest market capitalization and trading volume cryptocurrency.
Aim: Use the data from the period January–April 2022 exhibiting over 1.5 million trades at Bitstamp, one out of four largest in trading volume Bitcoin markets, to identify and compare the day of the week and the hour of the day effects in the rate of return, bid-ask spread and trading volume at times preceding and following the war outbreak.
Results: The analysis based on the regression including dummy variables showed that the bid-ask spread and trading volume exhibited both the day of the week and the hour of the day effects. The same applied to the rate of return — but only incidentally. The effects differed in the magnitude across the peace and war periods being mostly smaller in the latter one due to increased risk faced by market participants who, as reflected in the number of trades and trading volume, lowered their activity. Since Bitcoin at Bitstamp is traded 24 hours a day and 7 days a week and incoming information is continuously impounded into its prices, the intraday trading patterns are different from those at the mature and emerging stock markets. The wider spreads and larger trading volumes were found present close to open of the major stock markets (NYSE, NASDAQ, London, Frankfurt, Tokyo).

Keywords: Bitcoin; Bitstamp; intraday trading patterns
JEL: C22; C58; G14; G15

1. Introduction

The interest in cryptocurrencies within the academia has grown enormously in the recent years as the capitalisation of many exceeded several billion of the US dollars, they became popular means of payment, speculative and tech-savy investments (Baur et al., 2018; Choi & Shin, 2021; de la Horra et al., 2019; Lee et al., 2020; White et al., 2020). At the time of writing more than 2,600 multidisciplinary articles, books and book chapters on the cryptocurrencies were included in the Web of Science Core Collection, out of which 1,240 belonged to economics, finance, business and management, with 903 entirely or partly being dedicated to Bitcoin, nowadays the largest market capitalisation and trading volume cryptocurrency.[1] Those most frequently cited are systemized by key topics and surveyed in Bariviera & Merediz-Solà (2020). They report on informational efficiency (Al-Yahyaee et al., 2020; Bariviera & Merediz-Solà, 2020; Nadarajah & Chu, 2017; Shynkevich, 2021; Urquhart, 2016; Vidal-Tomás et al., 2019), price discovery (Aalborg et al., 2019; Brauneis & Mestel, 2018; Urquhart, 2018), volatility (Ardia et al., 2019; Dimpfl & Elshiaty, 2021; Gkillas & Katsiampa, 2018; Katsiampa, 2017; 2019), assets correlation and portfolio formation (Aslanidis et al., 2019; Corbet et al., 2018; Dyhrberg, 2016a; Guesmi et al., 2019; Klein et al., 2018; Liu, 2019; Zieba et al., 2019), safe heaven characteristics (Bouri et al., 2017; Dyhrberg, 2016b; Klein et al., 2018; Smales, 2019), and other topics.[2] Surprisingly, contrary to publications on stocks and currencies, only tiny few deal with intraday trading patterns in Bitcoin which, if present, may help predict its price thereby providing new insights supportive for the rejection of informational efficiency (Kyriazis, 2019; Tiwari et al., 2018; Wang et al., 2022).[3]

This paper attempts to fill this gap contributing threefold into the field. First, based on the regression including dummy variables estimated on the transaction data from the period January–April 2022 originated from Bitstamp, one out of four largest in trading volume Bitcoin markets, it shows that the bid-ask spread and trading volume exhibited the day of the week, the hour of the day and their joint effects. The same applies to the rate of return — but only incidentally. Second, the effects differ in the magnitude across the peace and war periods in the Ukraine being mostly smaller in the latter one due to increased risk faced by market participants who, as reflected in the number of trades and trading volume, lowered their activity. Third, the wider spreads and larger trading volumes are found present close to open of the major stock markets (NYSE, NASDAQ, London, Frankfurt, Tokyo). The first two findings are the novel, the last one — strengthens that reported in Dyhrberg et al. (2018).

[1] As of September 23, 2022 the capitalisation of 5 largest in this regard cryptos, i.e. Bitcoin, Ether, Tether, USD Coin, and Binance Coin, reached 367.26, 161.94, 67.95, 49.77, and 44.23 bln US dollars, respectively; see Statista (2022).

[2] They include bubble formation, and initial coin offering.

[3] The next Section reviews the literature on the issue.

The rest of the paper is organized as follows. Section 2 reviews the literature. Section 3 highlights the research method. The following two sections show and discuss the data used in the analysis and the obtained empirical results. The last section briefly concludes.

2. Literature review

The occurrence of intraday trading patterns in rates of return, bid-ask spreads and trading volumes is a widely documented phenomenon on many contemporary financial markets. They include, inter alia, wider spreads, increased volumes and elevated returns at the market open and close. The spreads resemble the reversed J or are close to that while the volumes remain U-shaped. Their emergence is related to the different behaviour of traders at the market open and close (Brock & Kleidon, 1992), and to strategic behaviour of those agents who are better informed (Admati & Pfleiderer, 1988). First observed on NASDAQ, NYSE and CBOE by Chan et al. (1995a; 1995b), Foster & Viswanathan (1993), Jain & Joh (1988), Lee et al. (1993), McInish & Wood (1991; 1992), Smirlock & Stars (1986), and Wood et al. (1985), they were later found present on many mature and emerging stock markets, for instance in the UK (Chelley-Steeley & Park, 2011; Ibikunle, 2015; Kleidon & Werner, 1995; Levin & Wright, 1999), Canada (McInish & Wood, 1990), Australia (Kalev & Pam, 2009; Viljoen et al., 2014), France (Louhichi, 2011; Tilak et al., 2013), Italy (Gerace & Lepone, 2010), Spain (Garcia-Machado & Rybczyński, 2017), Greece (Panas, 2005), Japan (Ohta, 2006), South Korea (Ryu, 2011), Taiwan (Chiang et al., 2006; Huang et al., 2012), Brazil (da Costa et al., 2015), Turkey (Bildik, 2001; Köksal, 2012), and Poland (Miłobędzki & Nowak, 2018). Interestingly enough, the studies on the UK markets by Cai et al. (2004) and Ellul et al. (2002) revealed that the volumes were increased around the opening of the US markets.

The evidence for currencies is relatively scarce. The trading volumes of many are found M-shaped (Danielsson & Payne, 2001), with peaks at the London and New York open (McGroarty et al., 2009). Their bid-ask spreads have a prolonged U-shape and are narrowest during London and New York business hours (McGroarty et al., 2009). Breedon & Ranaldo (2013) and Ranaldo (2009) showed that they tend to depreciate during local working hours. Khademalomoom & Narayan (2019) demonstrated, however, that the latter was true only for the post-opening hours of the local markets. They also observed that the currency returns were significantly affected by the major markets open and close, and they remained so over the overlapping trading times between those markets. Lastly, Khademalomoom & Narayan (2020) revealed the intraday-of-the-week effects: the existence of patterns across the trading hours of the week as well as the tendency for currencies to depreciate mostly on Mondays and Tuesdays, and to appreciate on rest of the days.

The evidence on intraday trading patterns for cryptocurrencies is tinny. Dyhrberg et al. (2018) using high frequency data from Gdax, Gemini

and Kraken demonstrated that the trading activity in Bitcoin was the lowest early in the morning US time as the European markets opened. Next, it first increased to peak as the US markets opened, then declined through their close and dropped as the Asian markets closed. Eross et al. (2019) used tick data from Bitstamp aggregated to 5-minutely frequency to show that Bitcoin returns increased over time, while its volume increased throughout the day and fell from around 4 p.m., that is as European markets nearly close, until midnight.

3. Research method

The intraday trading patterns in Bitcoin are identified using the linear regression model:

$$y_t = \alpha + \beta w_t + \sum_{i=2}^{7} \gamma_i d_{it} + \sum_{j=1}^{23} \delta_j h_{jt} + \sum_{i=2}^{7} \theta_i w_t d_{it} + \sum_{j=1}^{23} \lambda_j w_t h_{jt} + \\ + \sum_{i=2}^{7} \sum_{j=1}^{23} \pi_{ij} d_{it} h_{jt} + \sum_{i=2}^{7} \sum_{j=1}^{23} \upsilon_{ij} w_t d_{it} h_{jt} + \epsilon_t, \quad (1)$$

where:

y_t — trading volume (BTC), bid-ask spread (USD), and rate of return (%) at trade t, respectively;

w_t — dummy equal 1 if the trade is executed in the war period and 0 otherwise;

d_{jt} — dummy equal 1 if the trade is executed on day j of the week and 0 otherwise (j=2, ..., 7); Tuesday through Sunday);

h_{kt} — dummy equal 1 if the trade is executed within time bar k of the day and 0 otherwise (k=0, ..., 23);

α, β, γ_i, δ_j, θ_i, λ_j, π_{ij}, υ_{ij} — structural parameters;

ϵ_t — random error.

Equation (1) enables to investigate the nature of the patterns of interest, i.e. whether a single, joint and mixed effects in y_t do exist. In what follows the appropriate zero restrictions on its structural parameters are set to test for the following research hypotheses:

- Hypothesis A: β=0, no war effect;
- Hypothesis B: γ_i=0 for all i, no day of the week effect;
- Hypothesis C: δ_j=0 for all j, no hour of the day effect;
- Hypothesis D: θ_i=0 for all i, no joint effect of A and B;
- Hypothesis E: λ_j=0 for all j, no joint effect of A and C;
- Hypothesis F: π_{ij}=0 for all i and j, no joint effect of B and C;
- Hypothesis G: υ_{ij}=0 for all i and j, no joint effect of A, B and C;
- Hypothesis H: β=γ_i=δ_j=θ_i=λ_j=π_{ij}=υ_{ij}=0 for all i and j, no single and joint effects of A, B and C.

Equation (1) is estimated using the ordinary least squares (OLS) method. Since it is very likely that in the case of transaction data errors ϵ_t are both heteroskedastic and autocorrelated of unknown form, as well as not normally distributed, the estimate of the variance-covariance matrix of structural param-

eters is obtained throughout a bootstrap. The significance of the restrictions is decided upon the Wald-type test statistics. The relevant hypotheses are tested for in an appropriate order, beginning from hypothesis H, the most restrictive. Then, in the case it is rejected, testing for joint hypotheses D–G and single hypotheses A–C follows. All computations are performed using Stata SE 16.

4. Data and results

Bitstamp is a fiat-cryptocurrency exchange established in 2011. It is based in Luxembourg and operates 7 days a week and 24 hours a day. It enables trade in 75 assets, including Bitcoin, Ether, Tether and USD Coin, against the US dollar, euro and the pound sterling. As of September 2022 it is the fourth Bitcoin exchange in terms of traded volumes and the third one in rank of the order book size in the last 6 months.[4] Bitcoin is traded there against the US dollar and euro. The main characteristics of the trade in the period January–June 2022 are gathered in Table 1. The figures show that the traded volumes against the US dollar and euro as well as the volatility continuously decreased until April while the spreads remained approximately at the same level. That suggests a drop in the market activity accompanied by diminished risk and a constant market liquidity. The latter two findings are rather a surprise in the light of the war.

The inspection of transactions in the US dollars, which dominated the trade in Bitcoin, changes that conjecture. The data exhibiting those transactions are recorded with the accuracy of one millisecond. They comprise observations from 1 January through 30 April 2022 on trade price, best bid, best ask and trading volume. Transactions from the period 9 February–11 March are removed from the data set to split it into two separate ones. The first set includes the trades effected before the outbreak of the war in Ukraine on 24 February, while the second set includes those effected after its outbreak. Such a proceeding allows to capture, and potentially to control for, the reaction of markets and market agents towards the warfare. The summary of remaining 1,508,460 data points is stacked in Table 2. The main conclusion stemming from the Table 2 is in favour of the drop in the market activity, and surprisingly — in favour of the increased market liquidity during the war. The mean tick transaction volume for the peace (0.12 BTC) is slightly larger than that for the war (0.1 BTC). The median one is twice as large (0.02 BTC), however. At the same time the mean bid-ask spread exhibiting liquidity is down from 19.45 US dollars to 16.86 US dollars.

More interestingly, when the transactions are accordingly assigned to the time bars of one hour length within the day-of-the week bins, separately for the peace and war periods, and the time-bar characteristics of the variables of interest are computed and plotted against time, the intraday and intraweek patterns of the latter appear visible. Those for the mean number of transactions,

[4] The current information on the parameters of Bitcoin markets can be found at Data.bitcoinity (2022).

mean trading volume, mean bid-ask spread and mean tick rate of return are shown in Charts 1–4. Their visual inspection leads to several conclusions.

First, the observed intraweek and intraday trading patterns for the peace and war periods are similar in the shape. The height of the bars suggests that the magnitude of characteristics they exhibit not only change over the hours of the day and differ across the days of the week, but they also differ across the peace and the war. For instance, the mean number of transactions and the mean treaded volumes within almost each time bar every day of the week are greater at the peace than those at the war. So is the mean bid-ask spread. Thus, it is to say the market activity at the peace was more intense than that at the war. Market liquidity behaved the opposite, however.

Second, the intraday patterns in the number of trades, trading volume, bid-ask spreads and rates of return from Monday to Friday to a great extent are affected by the major stock markets open and close. They reach local extrema at around Tokyo, London, Frankfurt, NYSE and NASDAQ open and close, i.e. at 0:00, 6:00, 8:00–9:00, 14:30, 16:30–17:30, and 21:00 hrs. GMT, respectively. The number of trades and the trading volume is the greatest in between the US markets open and the European markets close. Thus, it is concluded that the trade activity was the most intense in that period.

Third, the shape of the intraday patterns in the number of transactions and trading volumes for Saturday and Sunday are very similar to those from Monday to Friday. Nevertheless, the height of particular bars indicate that the trade activity at the weekends was less intense than that during the rest of the week.

The surprise of the wider bid-ask spreads at the peace compared to those at the war suggesting that the market was more liquid in the latter period may be explained examining the data on the bid-ask sums recorded in the electronic order book.[5] The x% such sum is an indicator of the market depth. It shows the quantity of the US dollars on the order book waiting to buy Bitcoin and the amount of Bitcoin waiting to be sold at the same time within x% range from the price. The daily series of 10% bid-ask sums and the price of Bitcoin in the period 1 January–30 April are shown in Chart 5. Their course suggests that over many days preceding the outbreak of the war demand for Bitcoin exceed its supply while after the outbreak — the reverse took place. Thus, on average, the cost of trade in Bitcoin decreased amid an increased risk caused by the war.

The above, yet preliminary conclusions, are confirmed on the ground of estimation of Equation (1) for the variables of interest using the OLS method with the standard errors obtained throughout the bootstrap with 500 replications. Since the number of estimated structural parameters in each case is large, only partial estimation results and the results of testing for hypotheses A–H are enclosed in Tables 3 and 4 to save the space.[6] The figures show that the war effect as well as most of the hour of the day and the day of the week effects in the trade

[5] The data are available at Data.bitcoinity (2022).

[6] The estimation results in full are available to concerned readers upon the request.

volume, spread and rate of return are significant at 5% significance level. The estimates of the Wald-type test statistics, which under the null of the validity of relevant restrictions are distributed as χ^2 with the appropriate number of degrees of freedom, indicate the rejection of hypotheses A–H for the trading volume and the bid-ask spread, and the rejection of hypotheses A, B and H for the rate of return. Thus, the trading volume and the bid-ask-spread exhibited the hour-of-the day, the day-of-the week, the war effects and their mix, while the rate of return — only those of the the-day-of-the week and the war.

The effects differed in the magnitude around the major markets open and close on particular days of the week at the peace and the war periods, as it is exhibited in Charts 6–7. For instance, the mean tick trading volume around the European markets open was grater at the peace than it was at the war except from Wednesdays (Chart 6, left middle panel). The same applies for the mean bid-ask spread (Chart 7, left middle panel).

5. Conclusion

This paper aimed showing the existence of the intraday trading patterns in Bitcoin, nowadays the largest capitalisation and trading volume cryptocurrency. Basing on the regression including dummy variables exhibiting the hour-of-the day, the day-of-the week, and the war in Ukraine effects, as well as their mix, estimated on the transaction data from Bitstamp in the period January–April 2022, it threefold contributed into the filed. First, it demonstrated that all those effects were present in the trading volume and the bid-ask spread. The rate of return exhibited only the day-of-the-week and the war effects. Second, the hour-of-the day and the day-of-the week effects differed in the magnitude across the peace and war periods being mostly smaller in the latter one. That was due to increased risk resulting in that market agents lowered their activity after the outbreak of the war. And lastly — the wider spreads and larger trading volumes were found present close to open of the major stock markets in both periods.

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Appendix

Table 1.
Summary of trades in Bitcoin at Bitstamp, January–June 2022

Variable	Currency	Month					
		January	February	March	April	May	June
trading vol	USD	71,876.09	57,968.47	57,991.93	43,758.28	47,598.59	108,871.42
trading vol	EUR	31,506.80	27,007.93	25,234.55	17,725.93	28,571.38	32,717.73
spread	USD	0.0481	0.0500	0.0465	0.0444	0.0549	0.0619
spread	EUR	0.0690	0.0659	0.0613	0.0557	0.0675	0.0695
volatility	USD	105.13	104.32	91.22	75.84	70.61	77.36
volatility	EUR	91.15	89.77	80.77	67.99	81.19	72.11
trades pm	EUR	13.44	11.71	12.38	10.43	9.73	14.27
trades pm	EUR	10.94	8.83	9.67	9.73	12.27	12.42

Notes:

Volatility — price volatility calculated as standard deviation from all market trades. Spread, volatility and trades pm (per minute) are monthly averages from daily data.

Source: Own preparation based on Data.bitcoinity (2022).

Table 2.
Summary of trades in Bitcoin against the US dollar at Bitstamp, 1 January–30 April 2022

Variable	Currency	Min	Max	Mean	Me	St. dev.	Skew.	Kurt.
peace		*N*=735,581						
price	USD	32,950.72	47,989.00	40,577.21	41,559.00	3,471.65	−0.01	2.09
trading vol	BTC	0.00	57.23	0.12	0.02	0.35	20.50	1,511.50
best bid	USD	32,950.72	47,984.82	40,564.05	41,547.69	3,473.38	−0.01	2.09
best ask	USD	32,975.76	47,993.51	40,583.51	41,566.00	3,471.95	−0.01	2.09
spread	USD	0.00	320.11	19.45	18.04	13.75	4.45	51.78
war		*N*=772,879						
price	USD	37,567.19	48,232.25	41,968.26	41,187.03	2761.08	0.65	2.25
trading vol	BTC	0.00	53.23	0.10	0.01	0.36	29.73	2,049.53
best bid	USD	37,561.90	48,226.46	41,957.11	41,175.94	2,760.74	0.65	2.25
best ask	USD	37,586.69	48,236.33	41,973.97	41,191.72	2,761.18	0.65	2.25
spread	USD	0.00	316.57	16.86	16.62	11.10	5.45	94.77

Source: Own preparation.

Table 3.
Partial estimation results for Equation (1)

Variable	Equation								
	Trading volume			Spread			Rate of return		
	Obs. coeff.	Bootstr. std. err.	*p.v*	Obs. coeff.	Bootstr. std. err.	*p.v*	Obs. coeff.	Bootstr. std. err.	*p.v*
const	0.1286	0.0050	0.00	20.5763	0.1898	0.00	−0.0018	0.0008	0.00
w_t	0.0248	0.0076	0.00	1.1059	0.3600	0.00	−0.0018	0.0006	0.04
d_{2t}	−0.0303	0.0064	0.00	−2.3572	0.2368	0.00	0.0010	0.0008	0.22
d_{3t}	−0.0475	0.0063	0.00	−3.9744	0.2306	0.00	0.0017	0.0008	0.04
d_{4t}	−0.0403	0.0061	0.00	0.2348	0.2348	0.00	0.0022	0.0008	0.01
d_{5t}	−0.0066	0.0072	0.36	−1.5398	0.2498	0.00	0.0018	0.0008	0.02
d_{6t}	0.0128	0.0083	0.12	−0.9327	0.2429	0.00	0.0022	0.0007	0.00
d_{7t}	−0.0389	0.0073	0.00	−1.9580	0.2768	0.00	0.0019	0.0008	0.02
h_{1t}	−0.0419	0.0063	0.00	−3.3978	0.2480	0.00	0.0021	0.0008	0.01
h_{2t}	−0.0118	0.0066	0.07	−4.8081	0.2254	0.00	0.0018	0.0007	0.01
h_{3t}	−0.0230	−0.0080	0.00	−1.6410	0.3304	0.00	0.0021	0.0008	0.01
h_{4t}	−0.0067	0.0070	0.33	−1.4470	0.3209	0.00	0.0017	0.0007	0.02
h_{5t}	−0.0126	0.0090	0.16	−2.0222	0.3095	0.00	0.0021	0.0007	0.00
h_{6t}	−o.0311	0.0070	0.00	−3.5141	0.2577	0.00	0.0017	0.0007	0.02
h_{7t}	−0.0359	0.0068	0.00	−3.7583	0.2360	0.00	0.0017	0.0007	0.02
h_{8t}	−0.0046	0.0066	0.49	−2.3734	0.2748	0.00	0.0018	0.0007	0.02
h_{9t}	−0.0103	0.0071	0.15	−3.1669	−0.2512	0.00	0.0015	0.0007	0.04
h_{10t}	0.0297	0.0072	0.00	2.2888	0.2741	0.00	0.0013	0.0008	0.11
h_{11t}	0.0666	0.0112	0.00	9.2266	0.5672	0.00	0.0020	0.0022	0.35
h_{12t}	0.0029	0.0074	0.69	0.4233	0.2663	0.11	0.0010	0.0007	0.20
h_{13t}	−0.0168	0.0061	0.01	−0.0615	0.2526	0.81	0.0020	0.0008	0.01
h_{14t}	0.0530	0.0071	0.00	6.1377	0.2863	0.00	0.0021	0.0007	0.00
h_{15t}	0.0097	0.0063	0.13	1.0372	0.2400	0.00	0.0022	0.0007	0.00
h_{16t}	0.0166	0.0065	0.01	3.0142	0.2489	0.00	0.0022	0.0007	0.00
h_{17t}	0.0082	0.0067	0.22	3.2337	0.2681	0.00	0.0021	0.0007	0.00
h_{18t}	−0.0105	0.0065	0.10	2.1759	0.2357	0.00	0.0023	0.0008	0.00
h_{19t}	−0.0366	0.0059	0.00	−1.0813	0.2228	0.00	0.0017	0.0007	0.02
h_{20t}	−0.0174	0.0059	0.00	0.2191	0.2273	0.33	0.0021	0.0007	0.00
h_{21t}	−0.0199	0.0070	0.00	−2.8631	0.2333	0.00	0.0015	0.0007	0.02
h_{22t}	−0.0209	0.0064	0.00	−2.7008	0.2398	0.00	0.0019	0.0007	0.01
h_{23t}	−0.0390	0.0073	0.00	−4.4444	0.2342	0.00	0.0023	0.0008	0.00

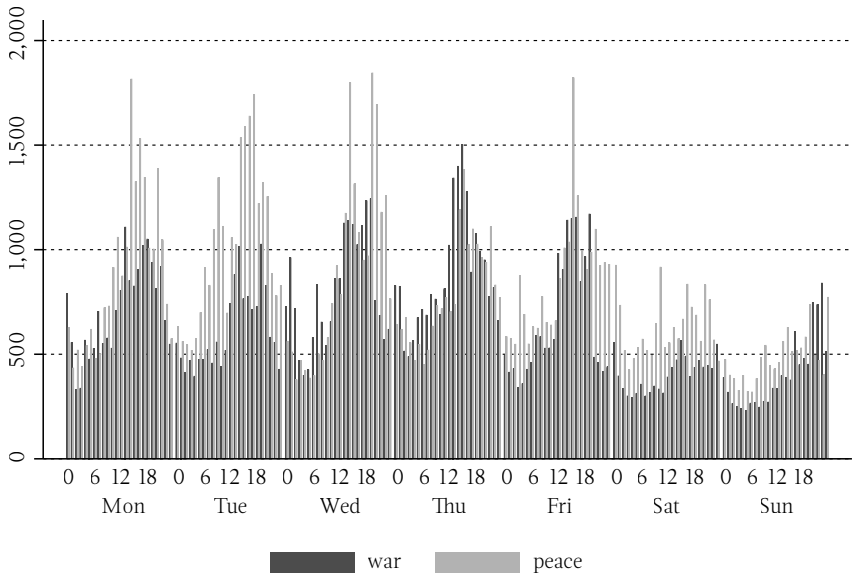
Source: Own preparation.

Table 4.
Results of testing for hypotheses A–H

Hypothesis	Effect	Restriction	Statistic distribution	5% c.v.	Trading volume	Spread	Rate of return
			Single				
A	War	$\beta=0$	$\chi^2(1)$	3.84	10.65	9.43	4.38
B	DoW	$\gamma_i=0$	$\chi^2(6)$	12.59	144.83	442.73	12.67
C	HoD	$\delta_j=0$	$\chi^2(23)$	35.17	676.10	7,029.47	22.38
			Joint				
D	A#B	$\theta_i=0$	$\chi^2(6)$	12.59	196.23	727.44	4.60
E	A#C	$\lambda_j=0$	$\chi^2(23)$	35.17	521.95	6,522.30	16.53
F	B#C	$\pi_{ij}=0$	$\chi^2(138)$	166.41	4,763.43	33,924.04	129.58
G	A#B#C	$\upsilon_{ij}=0$	$\chi^2(138)$	166.41	4,283.48	37,851.96	120.49
			Overall				
H	A##B##C	$\beta=\gamma_i=\delta_j=\theta_i=$ $=\lambda_j=\pi_{ij}=\upsilon_{ij}=0$	$\chi^2(335)$	378.68	55,601.01	2.3×10^5	641.55

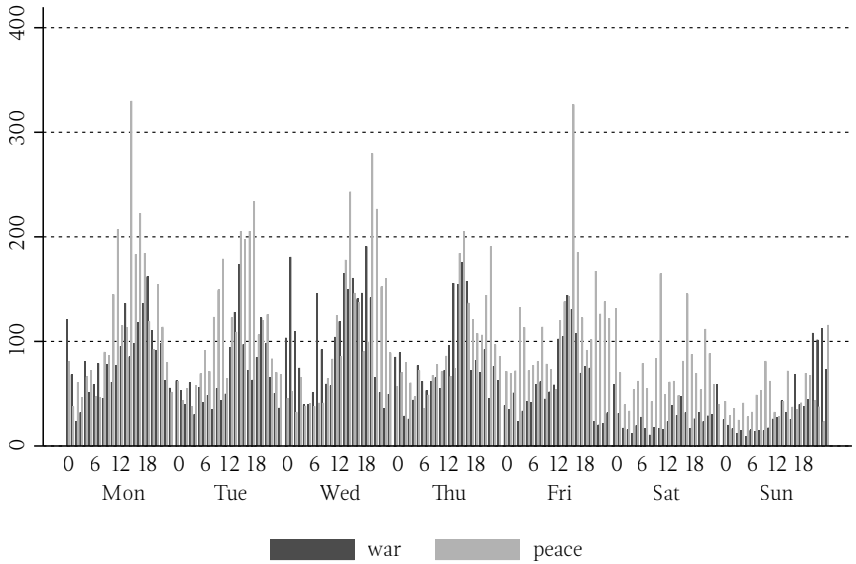
Notes:
Effects: DoW — day of the week, HoD — hour of the day, # — joint, ## — overall.
Source: Own preparation.

Chart 1.
Mean number of transactions by the hour of the day within the days of the week



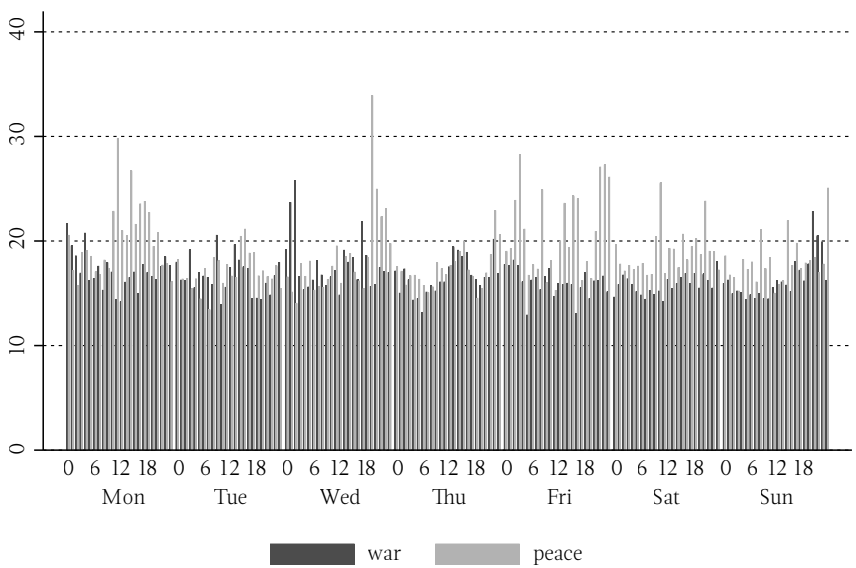
Source: Own preparation.

Chart 2.
Mean trading volume (BTC) by the hour of the day within the days of the week



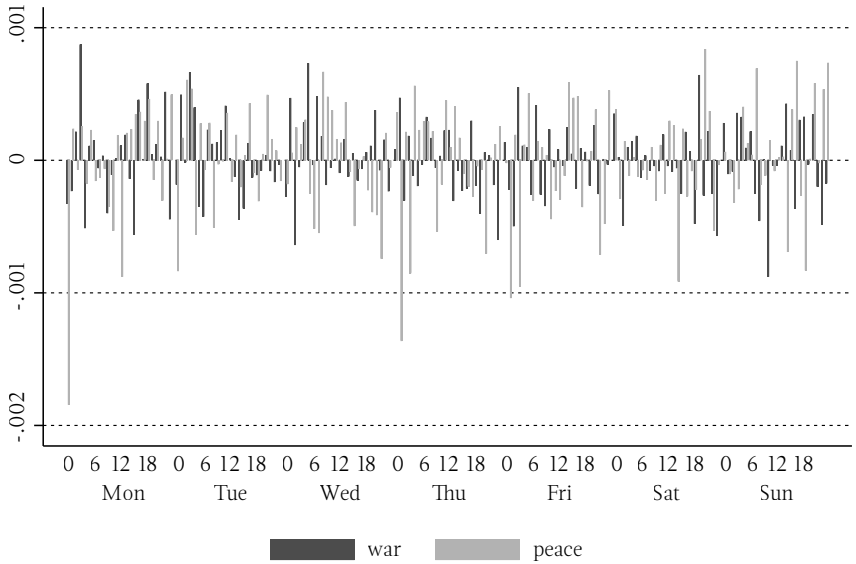
Source: Own preparation.

Chart 3.
Mean bid-ask spread (USD) by the hour of the day within the days of the week



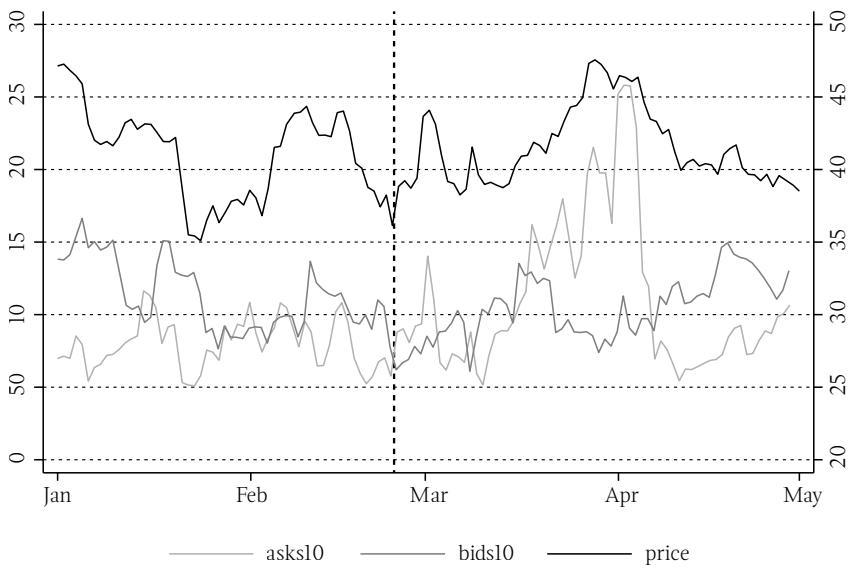
Source: Own preparation.

Chart 4.
Mean tick rate of return (%) by the hour of the day within the days of the week



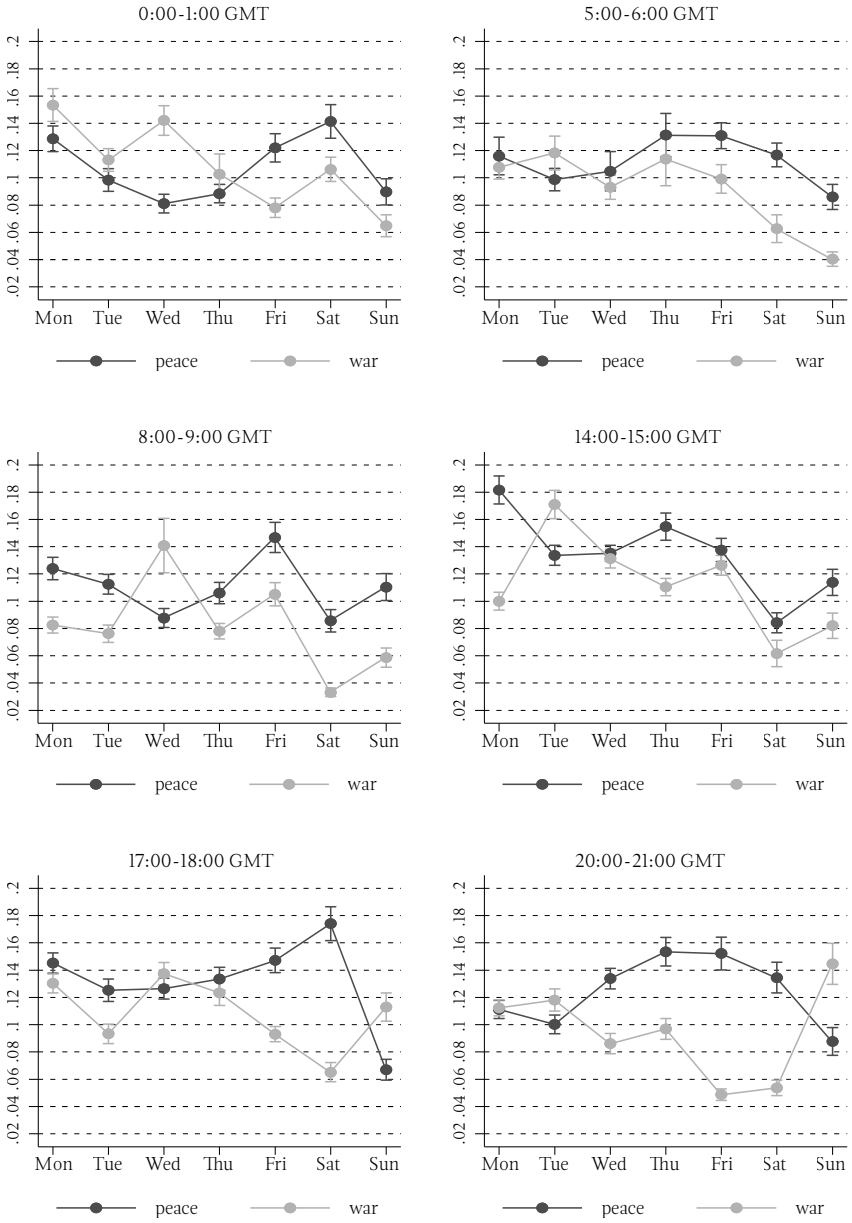
Source: Own preparation.

Chart 5.
10% bid-ask sums (USD Mil, left axis) and Bitoin price (USD Ths, right axis)



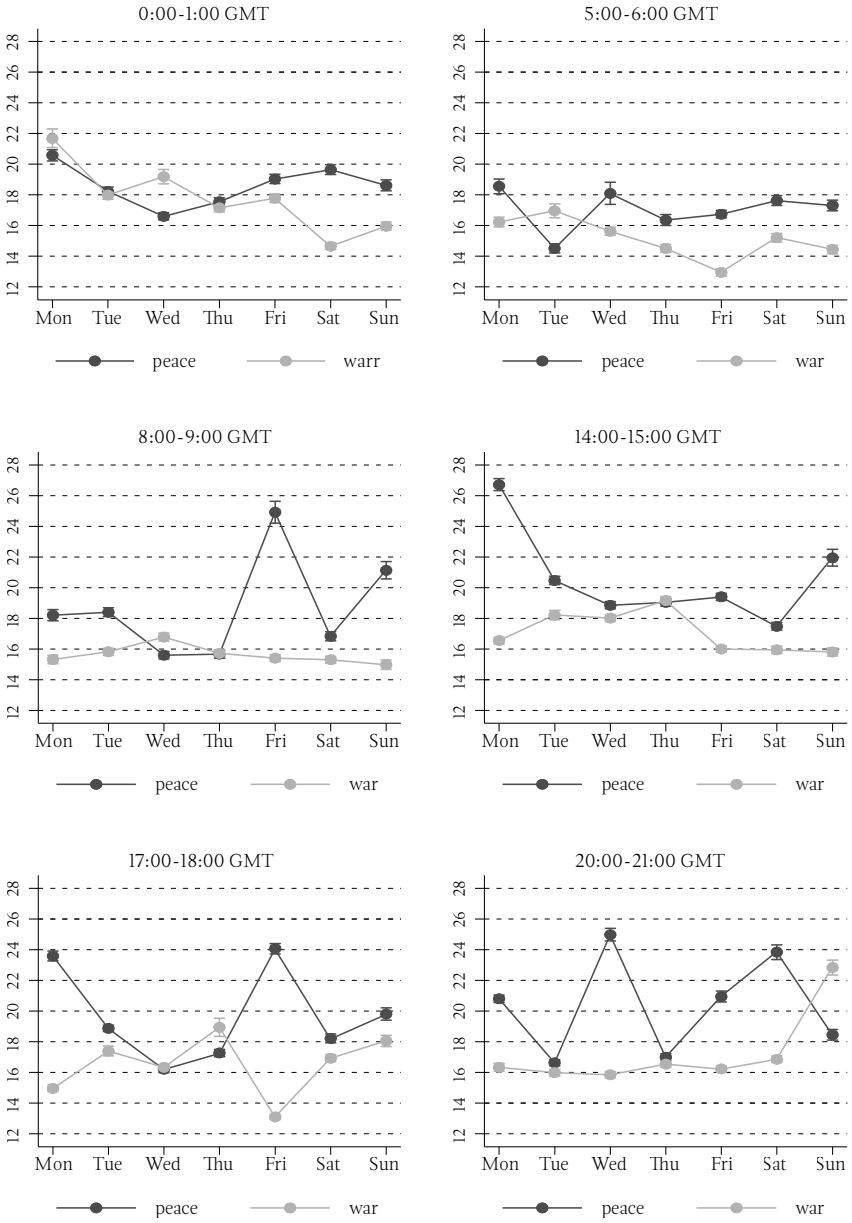
Source: Own preparation based on Data.bitcoinity (2022).

Chart 6.
Mean tick trading volume (BTC) around the major markets open and close across the peace and war



Source: Own preparation.

Chart 7.
Mean bid-ask spread (USD) around the major markets open and close across the peace and war



Source: Own preparation.