

# Price Manipulation in the Bitcoin Ecosystem Online Supplementary Material

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## 1 Appendix A: Bitcoin Trading Market Share by Exchange

2 [Figure 1 about here.]

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### 3 Appendix B: Dataset Validation and Details of Markus and Willy Activity

#### 4 (i) Dataset Validation:

5 With the exception of a few key steps, validating the Mt. Gox data closely followed previous work  
6 done by Feder et al. (2016) in which duplicates were removed by inspecting combinations of key fields.  
7 The duplicate rows contained matching values for user ID, time stamp, transaction type (buy/sell), and  
8 transaction amount. Two methods were examined to remove duplicate entries. Both methods treated  
9 tuples as unique (user ID, timestamp, transaction type, amount in BTC, amount in JPY, i.e., Japanese  
10 Yen) with the more aggressive of the two methods excluding amount in JPY from the tuple.<sup>1</sup> Both methods  
11 produced results that were more consistent with other publicly available trading data than the original  
12 dataset. Feder et al. (2016) chose to proceed with the less aggressive of the two strategies, which resulted  
13 in a clean dataset of approximately 14 million records. The more aggressive method was employed, but our  
14 results are robust to both methods.

15 During the data exploration phase, additional duplicate records were found that did not fit the unique  
16 tuple model outlined above. In these instances they appeared to be copies of either one side (buy/sell) of the  
17 transaction or of the entire transaction with minor alterations to the data in the "User\_ID," "Money," and  
18 "Money\_JPY" columns. The common factor used to start the removal process was the new user ID. One side  
19 of the transaction could be found by matching on this user ID, and then using the Money and Money\_JPY  
20 columns to find the matching opposite side of the transaction. In total 5,991 additional rows were removed  
21 using this method, all involving a single user ID. Later, these duplicate entries were identified as originating  
22 from the trader denoted "Markus." Additional sanity checks of the data were performed utilizing publicly  
23 available historical Mt. Gox trading data from [bitcoincharts.org](http://bitcoincharts.org). The conclusion is that the data are  
24 high-quality.

#### 25 (ii) Details of Markus and Willy Activity:

26 Initial data exploration uncovered a group of users with attributes that differed from the rest of the users  
27 in the dataset. In particular, for these users every transaction had "???" as an entry for the user country and  
28 user state fields. This appeared suspicious as these fields normally contain FIPS location codes, a NULL  
29 value, or "!!". One account containing the abnormal location values stood out when compared to the others  
30 because this account bought and sold bitcoins, where as the others only bought. The blogs referred to this  
31 first account as Markus.<sup>2</sup>

32 Upon closer inspection, Markus's trades raised many red flags. He never paid transaction fees and  
33 reportedly paid seemingly random prices for bitcoins. Most curious of all, many duplicate transactions were  
34 found in which the amount paid was changed from an implausibly random price to one that was consistent  
35 with other trades that day.

36 Markus seemingly paid random rates for the bitcoins he acquired. For example, in two transactions  
37 that took place the same hour on 2013-04-03, he paid 0.000374 USD per bitcoin on one transaction and  
38 925 489.67 USD per bitcoin on another.

39 Table 1 shows the wide range of rates that Markus paid. The table reports the number of purchases that  
40 Markus made for different ranges of rates. During the time when Markus traded, published exchange rates  
41 ranged from \$20 to \$229. Hence, any transactions with rates outside this range raise suspicion. In fact, only  
42 a quarter of Markus's trades fell within this range. 13% of the time, Markus paid less than one dollar, while  
43 in 821 transactions (3% of the total), he supposedly paid a rate of exceeding \$100,000 per bitcoin.

44 [Table 1 about here.]

45 Upon closer inspection, the random exchange rates appear to come from transactions posted before  
46 Markus' transactions. Table 2 illustrates the pattern. Transaction 1362466144485228 was posted with user  
47 238168 buying  $\approx 0.398$  bitcoin for 15.13 USD. Every Markus transaction that followed (indicated in bold)  
48 "borrowed" the Money, and Money\_JPY values from the previous transaction. This pattern of behavior

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<sup>1</sup>Mt Gox was based in Tokyo.

<sup>2</sup>Despite the fact that Markus sold bitcoin on a few occasions, most of his activity involved acquiring bitcoins.

49 was confirmed throughout – whenever Markus bought, the amount paid came from a previous unrelated  
50 transaction, while the number of bitcoins acquired appears randomly.

51 [Table 2 about here.]

52 Occasionally Markus would also sell bitcoin, and the BTC-fiat currency exchange rate for these trans-  
53 actions appears to be correct. For example, on 2013-06-02 Markus sold 31.5 bitcoins for 3 757.95 USD, or  
54 119.3 USD per bitcoin, which is similar to the average rate paid by users that day. In total, Markus sold  
55 35867.18 bitcoin worth approximately 4 018 681.65 USD in 2927 transactions on 6 different days.

56 As stated in Section 3.2, closer attention was paid to what records to remove while de-duplicating the  
57 data. This was due to the fact that several transactions contained duplicate buy and sell rows; see Table 3  
58 for an example of these transactions. Apparently user 201601 sold one bitcoin twice at the same exact time,  
59 first to user 698630 for 15.13 USD and second to user 634 for 38.11 USD.

60 [Table 3 about here.]

61 Upon closer inspection, it is clear that the rows containing 15.13163 in the money columns are the original  
62 rows for this transaction. In every instance where duplicates were discovered they involved user 698630 and  
63 user 634; 634 appeared to “correct” the 698630. There are multiple oddities involving user 634. First, the  
64 numeric user ID is extremely low, which strongly suggests that it could be an internal Mt. Gox account.  
65 Second, prior to issuing the corrected transactions, user 634 bought and sold a total of 824,297.7 bitcoin  
66 between 2011-04-07 and 2012-08-01. This account was inactive for 197 days before it was used again in the  
67 duplicate transactions involving Markus.

68 Table 4 summarizes the discrepancies between Markus’s identities. 2 966 buy transactions made by  
69 698630 were later duplicated as originating from user 634 at market prices. In total, as user 698630, Markus  
70 reportedly paid 1 080 617 USD for 67 452 bitcoin. When acting as user 634 instead, Markus “paid” 2 000 729  
71 USD for the same transactions. This only includes the corrected transactions involving user 634, not trading  
72 activity that occurred before Markus was active. It is worth noting that only the amounts paid for bitcoins  
73 were altered, never the bitcoin amount. Additionally, for the 196 transactions where user 698630 sold bitcoin  
74 and there was a duplicate row with user 634, no monetary amounts were altered. Only the user ID had  
75 changed.

76 Finally, it is worth noting that the majority of transactions by user 698630 were never changed, despite  
77 the presence of often wild exchange rates. User 698630 only operated between February and September  
78 2013, and during that time he purchased 268 446.09 BTC, reportedly at prices totaling \$76.4 million. This  
79 total USD amount should be viewed with caution, given that it is based on seemingly random exchange  
80 rates.

81 [Table 4 about here.]

82 In the case of Willy, in addition to the circumstantial evidence of sequential use and proximity to Markus,  
83 the most solid evidence that foul play was involved can be traced to the internal user ID. Previous research  
84 into the account IDs used for this activity showed that they were abnormally high for the time period in  
85 which they operated (Anonymous, 2014b). Normal accounts for this time period had IDs that capped around  
86 650000 where the users at the center of this research had IDs in the range of 658152-832432. Furthermore,  
87 several reports can be found online of the Mt. Gox trading API going offline for various periods of time  
88 in which no trading activity was being processed with one exception; Willy trading activity continued  
89 unabashed (Anonymous, 2014a). On 2014-01-07 the trading API was offline for 90 minutes. During this  
90 time period the only activity being processed followed the exact buying pattern of Willy when he was active:  
91 10-19 bitcoins purchased every 6-20 minutes.

92 **Appendix C: Descriptive Statistics and Other Tables**

93 [Table 5 about here.]

94 [Table 6 about here.]

95 [Table 7 about here.]

96 [Table 8 about here.]

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98 [Table 10 about here.]

99 [Table 11 about here.]

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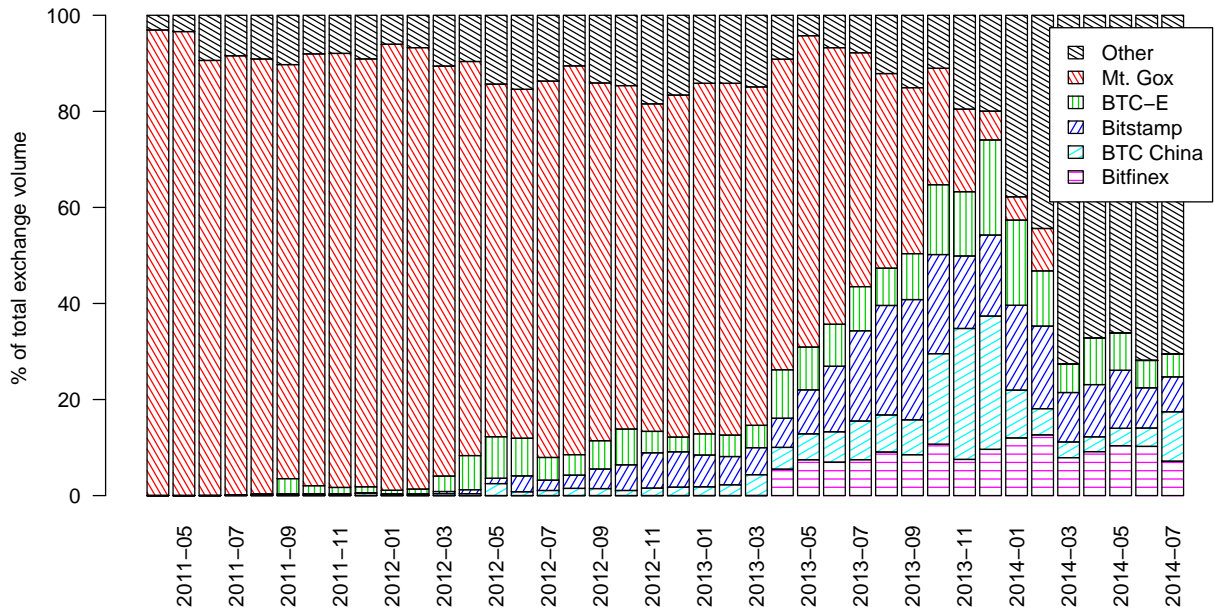


Figure 1: Distribution of market share among Bitcoin currency exchanges by reported trade volume, April 2011 to July 2014. (Source: [bitcoincharts.com](http://bitcoincharts.com))

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Table 1: Distribution of USD/BTC rates paid by Markus

|   | $\leq \$0.10$ | $> \$0.10,$<br>$\leq \$1$ | $> \$1,$<br>$\leq \$20$ | $> \$20,$<br>$\leq \$229$ | $> \$229,$<br>$\leq \$1K$ | $> \$1K,$<br>$\leq \$10K$ | $> \$10K,$<br>$\leq \$100K$ | $> \$100K$ |
|---|---------------|---------------------------|-------------------------|---------------------------|---------------------------|---------------------------|-----------------------------|------------|
| # | 1 050         | 2 586                     | 6 320                   | 7 009                     | 3 658                     | 4 604                     | 2 311                       | 821        |
| % | 3.7%          | 9.2%                      | 22.3%                   | 24.7%                     | 12.9%                     | 16.2%                     | 8.1%                        | 2.9%       |

Table 2: Fraudulent transactions initiated by Markus (user ID in bold)

| Trade.Id         | Date             | User.Id       | Type | Bitcoins   | Money    | Money_JPY |
|------------------|------------------|---------------|------|------------|----------|-----------|
| 1362466099116388 | 2013-03-05 6:48  | 238168        | buy  | 0.58932091 | 22.39419 | 2094.796  |
| 1362466099116388 | 2013-03-05 6:48  | 109955        | sell | 0.58932091 | 22.39419 | 2094.796  |
| 1362466144485228 | 2013-03-05 06:49 | 238168        | buy  | 0.3982007  | 15.13163 | 1415.442  |
| 1362466144485228 | 2013-03-05 06:49 | 132909        | sell | 0.3982007  | 15.13163 | 1415.442  |
| 1362466154623847 | 2013-03-05 06:49 | <b>698630</b> | buy  | 1.70382    | 15.13163 | 1415.442  |
| 1362466154623847 | 2013-03-05 06:49 | 96376         | sell | 1.70382    | 15.13163 | 1415.442  |
| 1362466154714939 | 2013-03-05 06:49 | <b>698630</b> | buy  | 1          | 15.13163 | 1415.442  |
| 1362466154714939 | 2013-03-05 06:49 | 201601        | sell | 1          | 15.13163 | 1415.442  |

Table 3: Duplicate Markus Transactions

| Trade_Id         | Date             | User_Id       | Type | Bitcoins | Money           | Money_JPY |
|------------------|------------------|---------------|------|----------|-----------------|-----------|
| 1362466154714939 | 2013-03-05 06:49 | 201601        | sell | 1        | 15.13163        | 1415.442  |
| 1362466154714939 | 2013-03-05 06:49 | <b>698630</b> | buy  | <b>1</b> | <b>15.13163</b> | 1415.442  |
| 1362466154714939 | 2013-03-05 06:49 | 201601        | sell | 1        | 38.11000        | 3564.883  |
| 1362466154714939 | 2013-03-05 06:49 | <b>634</b>    | buy  | <b>1</b> | <b>38.11000</b> | 3564.883  |

Table 4: Summary of Markus transactions

|                  | User ID | # Transactions | Total BTC  | Total USD |
|------------------|---------|----------------|------------|-----------|
| Manipulated Buy  | 698630  | 2966           | 67 451.61  | \$1.1M    |
| Manipulated Buy  | 634     | 2966           | 67 451.61  | \$2.0M    |
| Unchanged Buy    | 698630  | 25407          | 268 446.09 | \$76.4M   |
| Manipulated Sell | 698630  | 196            | 5 049.86   | \$0.2M    |
| Manipulated Sell | 634     | 196            | 5 049.86   | \$0.2M    |
| Unchanged Sell   | 698630  | 2 927          | 35 867.18  | \$4.0M    |

Table 5: Summary statistics of independent and dependent variables

|  | Mean | SD    | Min     | Max    |
|--|------|-------|---------|--------|
| Markus                                       | 0.09 | 0.29  | 0       | 1      |
| Willy  | 0.14 | 0.34  | 0       | 1      |
| DDOS   | 0.08 | 0.27  | 0       | 1      |
| Day after DDOS                               | 0.08 | 0.27  | 0       | 1      |
| Other Attacks                                | 0.02 | 0.13  | 0       | 1      |
| Mt.Gox daily rate change (\$)                | 3.24 | 22.39 | -139.78 | 257.5  |
| Bitstamp daily rate change (\$)              | 3.06 | 19.53 | -132.99 | 190.91 |
| Bitfinex daily rate change (\$) <sup>3</sup> | 4.25 | 33.30 | -295.97 | 294    |
| BTC-e daily rate change (\$)                 | 2.86 | 19.28 | -134.30 | 198.14 |
| Mt.Gox daily % rate change                   | 1.4% | 6.6%  | -28%    | 49%    |
| Bitstamp daily % rate change                 | 1.5% | 6.9%  | -49%    | 40%    |
| Bitfinex daily % rate change <sup>4</sup>    | 1.4% | 8.4%  | -37%    | 59%    |
| BTC-e % daily rate change                    | 1.4% | 6.7%  | -50%    | 41%    |
| <i>N</i>                                     | 365  |       |         |        |

Table 6: Correlation between daily rate changes and the independent variables

|                | Mt.Gox<br>Rate Change | Bitstamp<br>Rate Change | Bitfinex<br>Rate Change | BTC-e<br>Rate Change |
|----------------|-----------------------|-------------------------|-------------------------|----------------------|
| Markus         | 0.001                 | 0.01                    | -0.02                   | 0.00009              |
| Willy          | 0.33                  | 0.35                    | 0.23                    | 0.34                 |
| DDoS           | -0.06                 | -0.06                   | -0.05                   | -0.06                |
| Day After DDoS | -0.07                 | -0.07                   | -0.05                   | -0.06                |
| Other Attacks  | 0.02                  | 0.02                    | 0.013                   | 0.02                 |
| <i>N</i>       | 365                   | 365                     | 244                     | 365                  |

Table 7: Correlation between daily percent rate changes and the independent variables

|                | Mt.Gox %<br>Rate Change | Bitstamp %<br>Rate Change | Bitfinex %<br>Rate Change | BTC-e %<br>Rate Change |
|----------------|-------------------------|---------------------------|---------------------------|------------------------|
| Markus         | 0.14                    | 0.16                      | 0.07                      | 0.13                   |
| Willy          | 0.21                    | 0.2                       | 0.22                      | 0.2                    |
| DDoS           | -0.1                    | -0.05                     | -0.05                     | -0.06                  |
| Day After DDoS | -0.09                   | -0.06                     | -0.08                     | -0.06                  |
| Other Attacks  | 0.07                    | 0.04                      | 0.02                      | 0.04                   |
| <i>N</i>       | 365                     | 365                       | 365                       | 365                    |

Table 8: Correlation between independent variables

|                | Markus | Willy | DDoS  | Day After DDoS | Other Attacks |
|----------------|--------|-------|-------|----------------|---------------|
| Markus         | 1      |       |       |                |               |
| Willy          | -0.1   | 1     |       |                |               |
| DDoS           | 0.05   | -0.06 | 1     |                |               |
| Day After DDoS | 0.05   | -0.06 | 0.33  | 1              |               |
| Other Attacks  | 0.03   | -0.05 | -0.04 | 0.04           | 1             |
| <i>N</i>       | 365    |       |       |                |               |



Table 9: Suspicious trading activity and price changes on Bitstamp

|        |                     | Days with no STA |    | Days with STA |    |
|--------|---------------------|------------------|----|---------------|----|
|        |                     | days             | %  | Days          | %  |
| Markus | Daily rate decrease | 88               | 45 | 6             | 18 |
|        | Daily rate increase | 105              | 55 | 27            | 82 |
| Willy  | Daily rate decrease | 6                | 40 | 9             | 18 |
|        | Daily rate increase | 9                | 60 | 41            | 82 |
| Total  | Daily rate decrease | 94               | 45 | 15            | 18 |
|        | Daily rate increase | 114              | 55 | 67            | 82 |

Table 10: Willy: Volume activity (period 4)

|   | mean   | median | N  |
|---|--------|--------|----|
| Volume bought by Willy (Mt. Gox)              | 4,962  | 3,881  | 50 |
| Total BTC volume on Mt. Gox (Willy active)    | 30,854 | 25,939 | 50 |
| Total BTC volume on Mt. Gox (Willy inactive ) | 17,472 | 10,444 | 41 |
| Total BTC volume on Bitstamp (Willy active)   | 26,084 | 23,684 | 50 |
| Total BTC volume on Bitstamp (Willy inactive) | 14,793 | 10,505 | 41 |
| Total BTC volume on Bitfinex (Willy active)   | 12,981 | 11,756 | 50 |
| Total BTC volume on Bitfinex (Willy inactive) | 6,467  | 3,829  | 41 |
| Total BTC volume on BTC-e (Willy active)      | 20,691 | 18,661 | 50 |
| Total BTC volume on BTC-e (Willy inactive)    | 7,529  | 3,737  | 41 |
| Total BTC volume (Willy active)               | 90,611 | 82,779 | 50 |
| Total BTC volume (Willy inactive)             | 46,263 | 29,476 | 41 |

Table 11: Markus: Volume activity (period 3)

|  | mean   | median | N  |
|--|--------|--------|----|
| Volume bought by Markus (Mt. Gox)              | 10,056 | 8,901  | 17 |
| Total BTC volume on Mt.Gox (Markus active)     | 39,619 | 42,022 | 17 |
| Total BTC volume on Mt.Gox (Markus inactive)   | 27,672 | 17,421 | 75 |
| Total BTC volume on Bitstamp (Markus active)   | 13,547 | 12,840 | 17 |
| Total BTC volume on Bitstamp (Markus inactive) | 10,299 | 8,850  | 75 |
| Total BTC volume on Bitfinex (Markus active)   | 5,976  | 5,622  | 17 |
| Total BTC volume on Bitfinex (Markus inactive) | 4,331  | 3,197  | 75 |
| Total BTC volume on BTC-e (Markus active)      | 4,840  | 4,699  | 17 |
| Total BTC volume on BTC-e (Markus inactive)    | 4,660  | 3,589  | 75 |
| Total BTC volume (Markus active)               | 63,984 | 67,691 | 17 |
| Total BTC volume (Markus inactive)             | 46,962 | 31,173 | 75 |