RESEARCH ARTICLE

Bitcoin Average Dormancy: A Measure of Turnover and Trading Activity

Reginald D. Smith[†*]

Abstract. Attempts to accurately measure the monetary velocity or related properties of Bitcoin have often attempted to either directly apply definitions from traditional macroeconomic theory or to use specialized metrics relative to the properties of the Blockchain such as *bitcoin-days destroyed*. In this paper, it is demonstrated that beyond being a useful metric, bitcoin-days destroyed has mathematical properties that allow one to calculate the average dormancy (time since last use in a transaction) of the bitcoins used in transactions over a given time period. In addition, transaction volume and average dormancy are shown to have unexpected significance in helping estimate the average size of the pool of traded bitcoins by virtue of the expression Little's Law, though only under limited conditions.

1. Introduction

Since the white paper by Satoshi Nakamoto in 2008 proposing the concept of Bitcoin and its later launch in January 2009,[1] Bitcoin has rapidly emerged to become one of the most unique financial innovations in recent times.[2, 3, 4, 5, 6] As Bitcoin grew and evolved, it became increasingly important to have metrics to characterize the growth and behavior of Bitcoin. This was enabled by the Blockchain whose public and decentralized nature made measurements relatively easy. The first metric was the measurement of total transaction volume in bitcoin (BTC) on-chain (transactions recorded in the Blockchain). While clear and easily calculated, this metric had drawbacks since not all transactions represent the same type of spending activity. For example, users moving bitcoin between several addresses they own versus market transactions reflecting the acceptance of bitcoin and usage in the wider economy.[5, 6]

In order to deal with this issue, the idea of *bitcoin-days destroyed* was first proposed on the forum Bitcointalk.org on April 20, 2011 by the user ByteCoin.[7] Bitcoin-days destroyed would be a weighted measure of transaction volume where transactions in BTC would be multiplied by the number of days since those bitcoin were last spent. The intention was for Bitcoin-days destroyed to give a more nuanced measure of the economic activity in Bitcoin by discounting higher frequency transactions. In days-destroyed, 1 BTC created 100 days prior produces an equivalent days-destroyed to 100 BTC spent one day after their creation. The heavier weighting for less frequently circulating coins helps remove some "noise" that is due to rapid, repeating short term transactions that may not be indicative of the true demand for Bitcoin usage. It has been viewed by some as both a better indicator of relative economic activity than raw transaction volume and also a proxy for monetary velocity.[8, 9, 10] While

[†] R.D. Smith (rsmith@supremevinegar.com) is an independent researcher and owner of Supreme Vinegar LLC in Pennsylvania.
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several studies have referenced bitcoin-days destroyed as a measure of economic activity or liquidity,[11, 12] no studies have yet analyzed bitcoin-days destroyed itself in detail.

The analysis of bitcoin-days destroyed in a fuller context is important since it is not just a good metric, it also gives insights into Bitcoin transaction behavior over multiple timescales. Therefore, placing bitcoin-days destroyed in a general framework can help us understand the past, present, and future evolution of Bitcoin.

2. Bitcoin-Days Destroyed and Average Dormancy

The bitcoin-days destroyed (d) by a transaction is defined as the product of the number of bitcoins in the transaction (b) and the number of days since those bitcoins were last spent (Δt):

$$d = b\Delta t. \tag{1}$$

(Note that if the transaction spends more than a single output, the bitcoin-weighted average time must be used—see below for more details). The total days-destroyed (D) by any set S of transactions—for example all transactions within a certain 24-hour period—is found by summing the days-destroyed by each transaction in the set:

$$D = \sum_{j=1}^{|S|} d_j == b_1\Delta t_1 + b_2\Delta t_2 + \cdots. \tag{2}$$

The total bitcoins transacted is clearly given by $B = \sum_{j=1}^{|S|} b_j$. Factoring out B from the previous equation yields:

$$D = B\sum_{j=1}^{|S|} \frac{b_j}{B}\Delta t_j = B\left(\frac{b_1}{B}\Delta t_1 + \frac{b_2}{B}\Delta t_2 + \cdots\right). \tag{3}$$

Since $\sum_{j=1}^{|S|} \frac{b_j}{B} = 1$, we can interpret the terms $\frac{b_j}{B}$ as "weighting factors" that weight the length of time each coin spent dormant in proportion to its size. Thus we can define $\langle t \rangle = \sum_{j=1}^{|S|} \frac{b_j}{B}\Delta t_j$ and interpret it as the "bitcoin-weighted" average time the coins lay dormant, that is, as *average dormancy*. With this definition, and by rearranging (3), average dormancy for a set of transactions can be calculated by dividing the total bitcoin-days destroyed by the total bitcoins transacted:

$$\langle t \rangle = \frac{D}{B}. \tag{4}$$

Average dormancy is interesting in several respects. First, and most obvious, it links two important measures of Bitcoin economic activity together in a straightforward manner. Second, it gives a rough idea of how long coins involved in current transactions are being left unused between transactions.

To understand average dormancy, an example may be helpful. Take a Bitcoin user, Jill, who receives 10 BTC on Day 0. On Day 5, she decides to make transactions sending 2 BTC each to Anya, Bob, Cai, Dave, and Elena. A total of 10 BTC created 5 days ago is spent creating 50 days destroyed. Next, each of the five recipients spends 2 BTC staggered by one

day per person. Thus we have 2 × (1+2+3+4+5) = 30 bitcoin-days destroyed. From the time of Jill's first receipt of her bitcoins, on average, how long were these bitcoins dormant between creation and destruction (spending)? The answer is now easy. Over the entire period, 80 bitcoin-days were destroyed. During the same time, 20 BTC in total transactions occurred. Thus $\langle t \rangle$ = 80 bitcoin-days destroyed / 20 BTC transaction volume = 4 days. This is in agreement with the fact the first time 10 BTC was spent, the bitcoins were dormant for 5 days while the second period over which 10 BTC was spent, the bitcoins were dormant an average of 3 days.

While the average dormancy is not a true monetary velocity measure since it does not take the money supply or price levels into account as in the exchange equation, it can give us a good idea about the movement and circulation of those bitcoins that are actively being used in economic activity. Valuably, this metric correlates with other indicators, particularly the exchange rate of Bitcoin with fiat (USD/BTC) and allows us to test hypotheses on the behavior of bitcoin users, especially hoarders, under various economic conditions. In addition, because $\langle t \rangle$ is the average turn-over time, its inverse multiplied by a period of time (say 90 days or 365 days) tells us the average number of times the actively used bitcoins can be expected to turn over during that time.

3. Average Dormancy Over Time

The data for days destroyed came from OXT while all other data analyzed in this paper came from Blockchain.info. [13,14] Blockchain.info's "Estimated Transaction Value" was used to measure transaction volume since it removes "change" re-sent to a sender's wallet in a transaction. Fig. 1 shows the average dormancy between January 2009 and November 27, 2017 with data aggregated in windows of 1, 30, and 90 days. The aggregation of trailing data introduces lag but smooths out daily fluctuations and clarifies long-term trends. Fig. 2 shows the inverse of average dormancy multiplied by 365, thereby estimating the annual turnover of actively traded bitcoins.
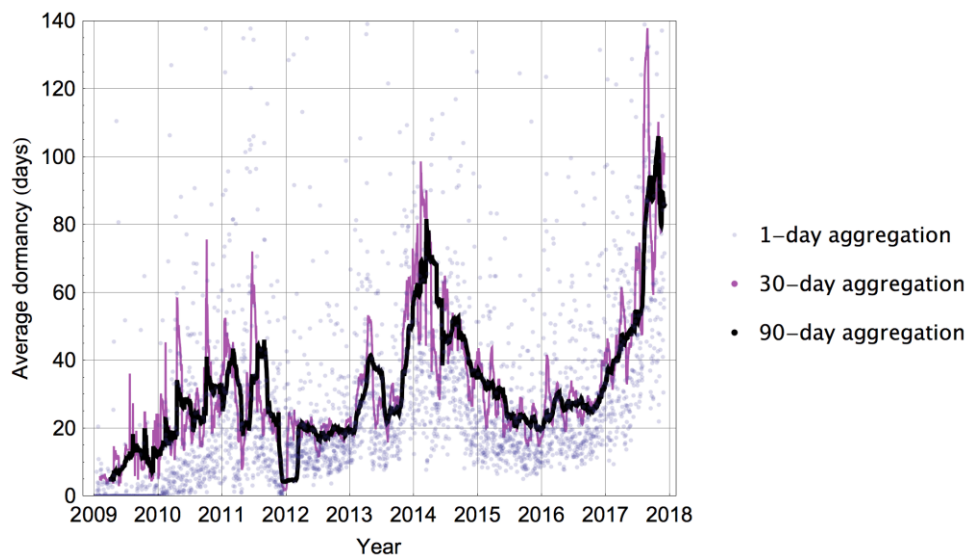

Fig. 1. Average dormancy over time using daily (blue dots), 30-day aggregated transactions (thin purple line), and 90 day aggregated transactions (thick black line).
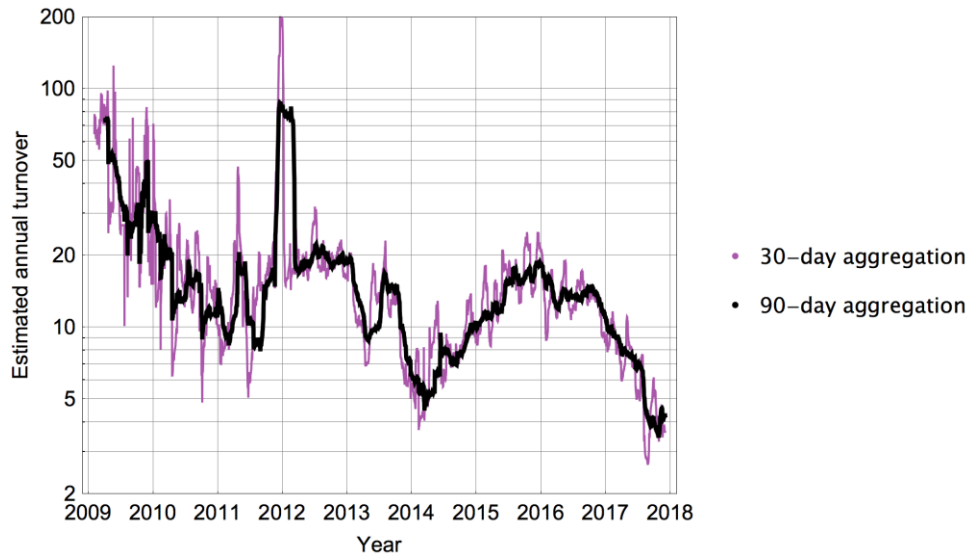
Fig. 2. Annual turnover of actively traded bitcoin for 30 day and 90 day aggregated transaction data.

Several trends are clear. First, the average dormancy, as well as the annual turnover, have both risen and fallen respectively over time since Bitcoin's inception. These trends were not monotonic and average dormancy especially seems to track Bitcoin exchange rate surges and falls. Since late 2012, average dormancy for bitcoins traded has rarely fallen below 20 days and only risen above 70 days during times of significant USD/BTC price volatility such as rapid appreciation of BTC relative to USD. At the time of writing (during a price surge), the 30-day-aggregated average dormancy is approximately 100 days, and peaked close to 140 days in August 2017. Annual turnover is approximately 3.5 and has rarely exceeded 20 since late 2012.

The all-time peak in turnover, in December 2011, is not attributable to one clear factor though it was the beginning of a price rally after a prior crash where transactions were at their second highest level while days destroyed plummeted. It also coincided with exposure in the mainstream media for Bitcoin during an episode of *The Good Wife*,[15] but the surge had started before the show aired. Subsequently, turnover experienced a nearly universally downward trend where annual turnover has now comfortably stayed between 10 to 20 times per year for nearly two years, until the recent Bitcoin appreciation to thousands of USD where it dropped to below 3 days briefly in August 2017.

Average dormancy's correlation to USD/BTC price trends is not a coincidence. In Fig. 3 we see how closely the USD/BTC exchange rate and average dormancy track each other. In fact, given the shorter lag for the 30-day aggregation, we see up to the current price surge average dormancy and USD/BTC have tracked closely. The full context is shown, however, in the two graphs in Fig. 4. The first shows average dormancy (30 day aggregated) vs. USD/BTC for all time while the second shows the same data but only when USD/BTC exceeds $1000 per BTC. This clearly demonstrates the pattern is most apparent and consistent at times of relatively high value relative to the USD. Above the threshold of $1000 per BTC there is a correlation of 0.68 between the two variables suggesting that at least 46% of the variance in average dormancy is possibly directly related to the variance in the USD/BTC exchange rate

at high values of exchange. This suggests that relatively valuable bitcoin heavily influences user spending behavior patterns.
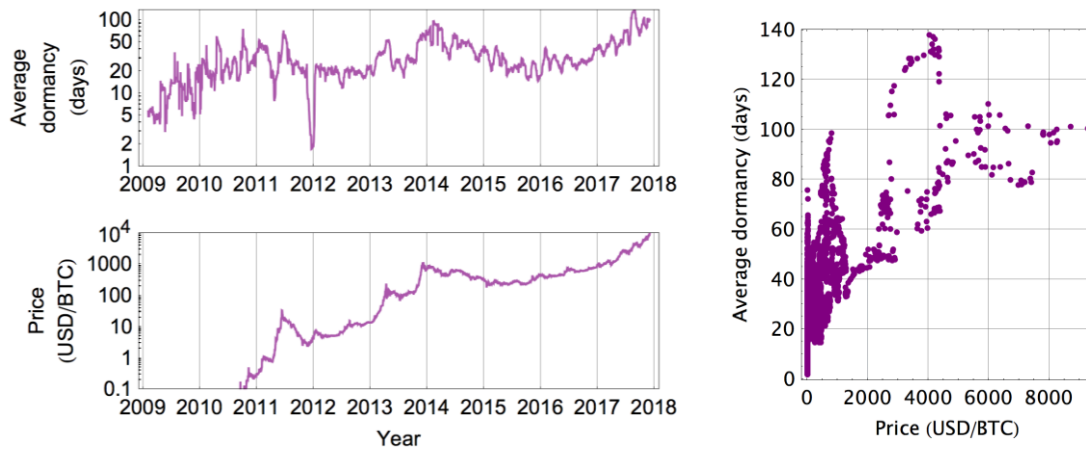

Fig. 3. 30-day average dormancy and Bitcoin exchange rate (green color) tracked over time (left), and versus each other (right).

The rise in average dormancy with price does not mean coins are being used less often at higher prices. In fact, its most likely explanation is that long unused coins are brought back into circulation at higher prices. Long inactive coins being spent raises the average dormancy due to the long time since the last spending of such coins. Therefore, the average dormancy can actually increase with increased spending activity in bitcoin. This highlights an important conceptual understanding of average dormancy: it only measures the dormancy of coins used in active transactions. It does not tell us how dormant the overall monetary base of all bitcoins are.

During lower price periods, a substantially smaller proportion of the money supply of bitcoin may be trading, but the average dormancy rate is lower since it only reflects the relatively short holding time of bitcoin users whose buying, selling, and trading activity is unimpeded by a relatively low cost per coin. Users who see Bitcoin primarily as a store of value and want to take advantage of increasingly deflationary prices over time are more likely to sit out during these periods and trade less often, especially if their bitcoin were purchased at a higher USD (or other fiat currency) Bitcoin exchange rate.

Overall, the nature of the relationship of average dormancy and the Bitcoin exchange rate seems to indicate that users who have held coins for long periods without trading are more likely to trade these coins as the value of Bitcoin versus the USD rises. This reflects not only the store of value use of bitcoin but also the primacy of exchanges as dominant venues of bitcoin trading and transactions. Thus average dormancy is increased by the "emergence" of coins that are being traded in various off-chain transactions such as being stored and traded on exchanges, coins being removed from exchange cold storage to enable withdrawals or other trades, or those that had been obtained via private transactions such as surrendering a private key. On balance, it seems a high price for Bitcoin relative to fiat seems to encourage less hoarding, not more. It is likely then, since long dormant coins are entering circulation, that higher prices entice long-term holders of Bitcoin to sell part of their holdings. This is similar

to an analysis of the transfer of Bitcoin from long term holders to short term speculators described by the cryptocurrency analytics firm Chainalysis.[16]

4. Active Monetary Base in Bitcoin Analyzed by Little's Law

A short discourse on Little's Law, despite being largely inapplicable to long-term bitcoin trading data, adds an additional detail to days destroyed as well. Little's Law is a commonly used and basic equation in queuing theory. Though it has existed in different forms throughout time in different fields being applied to more narrow problems, its most general and widely used form was first proposed, without proof, by Philip Morse[17] in 1958 and given a rigorous proof by John Little[18] in 1961. Little's Law relates the average number of items in a queue, L (bank queue line customers, cars at a toll booth, even Drake's equation for the estimated number of intelligent species[19]) to the average arrival rate at the queue, λ, and the average wait time in the queue, W:

$$L = \lambda W. \tag{5}$$

To apply Little's Law to Bitcoin trading we can reinterpret its variables where the average wait time, W, is replaced by $\langle t \rangle$, the arrival rate, λ, is replaced by B, the average or median transaction volume over a given period of time with the same base unit as $\langle t \rangle$, and the average number of items in the queue, L, is replaced by V which is defined as the average size of the actively traded monetary base of Bitcoin.

To understand this perspective, one must abstract the basic spend activity of on-chain transactions as trades between two addresses where the recipient, on average, does not trade the newly created bitcoin for $\langle t \rangle$ days. In this conceptualization, the average size of the monetary base of bitcoin actively used in transactions is equal to the average or median on-chain transaction volume of bitcoin spent during a time horizon equal to the average dormancy. This active monetary base of bitcoin turns over once on average during the average dormancy period.

This interpretation, however, has its flaws and is not realistic for long-term bitcoin trading patterns. This is primarily because Little's Law requires the underlying random processes, in particular the bitcoin transaction volume and the dormancy rate, to be stationary: having the same distribution and moments (mean, standard deviation, etc.) over time. Financial market data is almost never stationary, even under short time periods. It would require a relatively level trading volume and constant dormancy rate for Little's Law to work. Therefore measurements of the pool of bitcoins used in on-chain transactions by virtue of days destroyed may be approximate only for limited time series, such as the period of average dormancy under minimal exchange rate price volatility, but definitely not for months or years.

5. Non-normality of Bitcoin-Days Destroyed

Previously, we have discussed bitcoin-days destroyed and trading volume in terms of aggregate sums over time related by the average dormancy. While this analysis is mathematically accurate, using the mean or sum of any of the variables requires caution due to the nature of the data. Like all financial markets,[20, 21, 22, 23] the transactions in Bitcoin, both in volume and days destroyed, show a heavily skewed character where large transactions can be of an almost arbitrarily large size, implying a huge variance. This is an issue not unique to

Bitcoin, but a well-known issue dealing with financial market data. In fact, the skewed nature of the distribution of days destroyed is shown in Fig. 4 where the proportion of daily bitcoin-days destroyed accounted for by the largest transaction value in days destroyed can be as high as 80 - 90% while rarely dipping below 10%. The median proportion of total daily days destroyed accounted for by the largest transaction for 2017 through November is 17%—almost one-fifth of days destroyed on average is accounted for by the largest transaction measured by days destroyed.
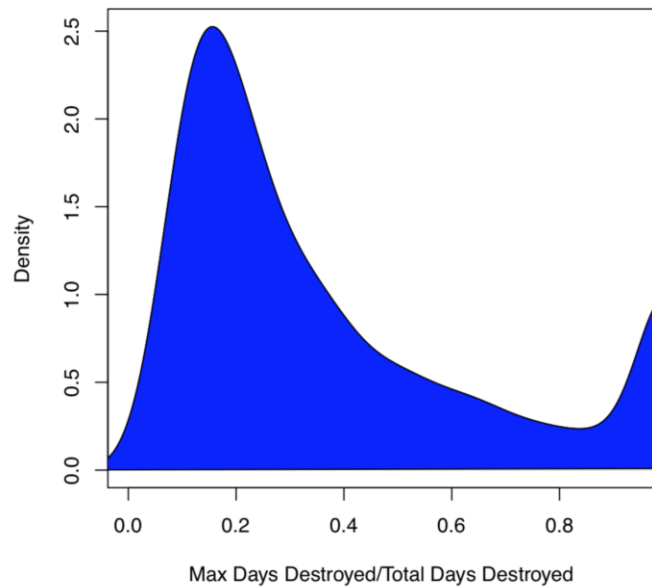
Fig. 4. Proportion of the daily days destroyed that is accounted for by the largest transaction.

The actual distribution of days destroyed or transaction volume is outside the scope of this paper but is possibly a power law, skewed exponential, or another such long tail, which can be verified by the appropriate statistical tests. While this does not invalidate the analysis it shows that averages, such as dormancy rate, can be affected by large transactions in days destroyed or bitcoin transaction volume that are not accompanied by large increases in the other variable. This can be large transaction volumes of coins that have moved recently or huge days destroyed transactions based on relatively small transfers of aged coins.

Aggregation, while smoothing out daily fluctuations, does not remove these effects. Removing the largest values, while it may provide some balance, also cannot totally remove the skew. If the size distributions of days destroyed or transaction volume hold a power law character, the nature and proportion of skewed transactions will always exist no matter which proportion of the top values are removed.

6. Conclusion

The average dormancy of actively traded bitcoin, easily generalizable to almost any cryptocurrency, is a valuable new variable that ties together previous concepts of transaction

volume into a coherent picture. In particular, some new information is uncovered regarding the spending of bitcoin depending on the USD/BTC exchange rate which seems to confirm the widespread use of Bitcoin as a store of value.

While average dormancy and turnover may help us understand how bitcoin transactions relate to bitcoin's use and circulation, neither measure should be mistaken for an exact analogue of monetary velocity. Monetary velocity, while often defined as the number of transactions per currency unit per unit time, is a relation that connects the money supply, economic activity, and the price inflation. Monetary velocity also sees money primarily as a unit of exchange rather than store of value which conflicts with the previous findings.

The unique nature of Bitcoin and its current and future uses as a currency or store of value make it an ideal candidate for research from a variety of perspectives from economics, to computer science, to sociology. It is hoped that the metrics introduced in this paper will become better understood and researched in order to enhance our understanding of this wonderful innovation and its future evolution.

Acknowledgement

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