Cointime Economics

A New Framework for Bitcoin On-chain Analysis

Author: James Check
Lead Analyst at Glassnode

Co-Author: David Puell
Research Associate at ARK Invest

23 August 2023

Disclaimer

FOR INFORMATIONAL PURPOSES. This is not a recommendation in relation to any named securities/cryptocurrencies and no warranty or guarantee is provided. Any references to particular securities/cryptocurrencies are for illustrative purposes only. There is no assurance that ARK Invest will make any investments with the same or similar characteristics as any investment presented. The reader should not assume that an investment identified was or will be profitable.

All of the charts shown in this material are meant to illustrate the points made in the text. They are for informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security or cryptocurrency. Any past performance depicted in the charts is not indicative of future results.

Table of Contents

Executive Summary vi

Introduction ... vi
Key Innovations ... vi
Definitions ... vii

Chapter 1: Introduction 1

The Origins of Bitcoindays ... 1
Why Analyze Cointime Economics? ... 1
The Foundations of Cointime Economics ... 3
Introducing Coinblocks ... 3
Data Engineering Implications ... 5
Traditional UTXO Analysis Framework ... 5
Cointime Economics Framework ... 6
Comparison between UTXO and Cointime Analysis Frameworks ... 7
On-Chain Analysis Implications ... 8

Chapter 2: The Primitives of Cointime Economics 10

Three States of Cointime ... 10
Coinblocks Created (CBC) ... 11
Coinblocks Destroyed (CBD) ... 13
Coinblocks Stored (CBS) ... 14
Cumulative Total Coinblocks ... 16

Chapter 3: Network Liveliness & Vaultedness 18

Liveliness....18
Vaultedness....19
A Brief History of Bitcoin (Told by Its Liveliness and Vaultedness)....20
Activity-to-Vaulting Ratio (A2VR)....21
Concurrent Liveliness....23
Liveliness Incremental Change....24

Chapter 4: Supply Dynamics 27

Vaulted Supply....27
Active Supply....30
The Symmetry of Cointime Economics....34
Supply Region Analogies....36
Changes Between Supply Regions....38
Change in Active Supply....39
Change in Vaulted Supply....40
Coinblocks Destroyed as an Economic Primitive....42
Supply Net Position Change....43
Nuances in Relating Cointime Supply Regions Back to a UTXO Framework....44
Change to Circulating Supply: Newly Minted Coins....44
Change to Active Supply: Transactions and Destruction....45
Changes to Vaulted Supply: UTXOs and Storage....45
Asymptotic Network States....45

Chapter 5: Economic Models 49

Economic Weight of Active Supply ... 49
Economic Weight of Vaulted Supply ... 49
Cointime-Adjusted Inflation Rate ... 50
Cointime-Adjusted Stock-to-Flow Ratio ... 53
Cointime-Adjusted Velocity ... 54
Vaulting Rate ... 55

Chapter 6: Re-Evaluating UTXO Realized Value 58

Reassessing the Realized Price ... 60
Active Realized Price and Active MVRV ... 61
Vaulted Realized Price and Vaulted MVRV ... 66
Decomposition of the MVRV Ratio ... 70
The True Market Mean or Active-Investor Price ... 71
AVIV Net Unrealized Profit/Loss (AVIV-NUPL) ... 75
The AVIV Relationship, ‘Investorness’, and ‘Producerness’ ... 76

Chapter 7: Cointime Valuation Models 83

Cointime Value Created, Destroyed, and Stored ... 83
Cointime Price ... 85
Cointime Capitalization ... 87
Cointime MVRV Ratio ... 88
Cointime NVT and RVT Ratios ... 91
Cointime Distributions ... 94

Chapter 8: Case Studies & Economic Applications 98

Analysis of On-Chain Entities ... 98
Estimation of Lost Coins ... 101
Upper Bound Estimates (UB) ... 102
Lower Bound Estimates (LB) ... 105
Best Estimates ... 106
Concluding Estimates of Lost Coins ... 108
Cointime and Supply in Profit/Loss ... 108
Application to Other Crypto-asset Networks ... 111

About the Authors 115

Live Chart Suite for Cointime Economics

All charts and metrics developed in the Cointime Economics framework are available live in Glassnode Studio.

View Live Charts

Acknowledgments

The authors would like to thank Tuur Demeester, Dylan LeClair, Will Clemente, Murad Mahmudov, Luke D, and Zi Vizart for their review of this piece. We would also like to thank Tamás Blummer for his pioneering work inventing the Liveliness and HODLed or Lost Coins metrics—both crucial primers for this paper.

Executive Summary

In 2022 and 2023, Glassnode and ARK Invest collaborated to develop a new economics framework for analyzing Bitcoin on-chain metrics—Cointime Economics. Our work together now offers two companion pieces: this white paper, which is written for on-chain specialists, market analysts, and academics, as well as an alternate, shorter version found at ARK's website, written for a broad investor audience.

Introduction

Cointime Economics is an analytical framework for Bitcoin, which efficiently discounts the influence of inactive supply.

- We define a new analytical framework for the study of Bitcoin economics, which considers only the lowest fungible level of volume and time, the coinblock, as the principle measurement of economic activity.
- Cointime Economics allows for a robust, computationally efficient, and mathematically consistent toolkit to validate, adjust, and improve upon UTXO derived models and metrics. Cointime adjustment allows for the accurate weighting and discounting of coin volumes across the full spectrum of investor holding times, better accounting for economic relevance.
- A comprehensive suite of Bitcoin economic metrics, correction factors, and valuation models are proposed, of which the majority can be trivially derived using only the following list of inputs: blockheight, circulating supply, coinblocks destroyed, and spot price.

Key Innovations

- A mathematically symmetrical framework is developed which relates the dimension of time, expressed via investor holding periods (coin age, lifespan), to an equivalent dimension of coin volume. This allows for improved tools for assessing the economic weight of any subset of the coin supply or transactions, and efficient discounting of lost and dormant coins.
- Renewed appreciation of the UTXO-derived Realized Price, alongside corrections to its interpretation, and adjustments to better reflect the true market cost basis. A new Bitcoin valuation model is proposed (AVIV Ratio and derivatives), which has demonstrated exceptional mean reversion properties for the Bitcoin market to date.
- Derivation of new Bitcoin economic metrics such as cointime-adjusted inflation rate, Market-Value-to-Realized Value (MVRV) Ratio, and the Network-Value-to-Transactions (NVT) Ratio. We also propose cointime-derived pricing models, all of which do not require data engineering or heavy analysis at a per-UTXO level to compute.

Definitions

The following key terms are defined:

- **UTXO:** An 'Unspent Transaction Output'. UTXOs are the foundational unit of account within the Bitcoin blockchain, which contain coin units (analogy of a dollar bills, however without any constraint on BTC denomination).
    - **UTXO Set:** The entire Bitcoin supply is held within the UTXO set, which is a set of append-only ledger entries which are append-only updated every block. Updates occur based on transactions (spending) and newly minted coins (via mining).
    - **UTXO Creation:** The Bitcoin protocol creates new UTXOs and updates the existing UTXO set in response to spending and newly minted coins at each blockheight.
    - **UTXO Destruction:** The spending of a coin necessitates the destruction of the input UTXO that contained it. The destroyed input UTXOs are removed from the UTXO set and replaced with new set of outputs (new UTXOs) reflecting the updated ownership of the coins that were transferred.
    - **Input:** A UTXO which is destroyed as an input to a transaction.
    - **Output:** A UTXO which is created as an output from a transaction.

The concepts of UTXO, creation, and destruction can be difficult to fully grasp at first. We recommend reviewing this analogy to gold coins on Glassnode Academy [1] **for an additional reference.**

- **Coin:** The volume of BTC held within a specific UTXO (units of BTC).
- **Coin Supply (or, simply, Supply):** An aggregate volume of coins (units of BTC).
- **Unspent:** A UTXO which has been created but has not yet been destroyed as of the blockheight being analyzed. The contained coins are referred to as Unspent.
- **Spent:** When a UTXO is destroyed in a transaction, the coins contained within are referred to as Spent.
- **Lifespan:** The length of time between UTXO creation and destruction (in the event of a spend) or the current blockheight (if unspent). Lifespan has units of time.
- **Cointime:** The product of coin volume (BTC) and Lifespan (time held) with units 'coin-time' (e.g., 'coin-block', 'coin-day').
- **Value:** The fiat denominated value of a coin volume, supply region, or volume of cointime.

[1] *Source: Glassnode. "Understanding UTXOs-The Gold Coin Analogy", Glassnode Academy.*
https://academy.glassnode.com/concepts/understanding-utxos-the-gold-coin-analogy

Introduction

The Origins of Bitcoindays

One of the very first on-chain metrics introduced for Bitcoin was the concept of **bitcoindays destroyed**. It was originally posted on a BitcoinTalk forum in 2011[2] as a methodology to assess the time-weighted value of spent bitcoin, and gauge network health and economic participation.

This concept has since developed, with **Coindays Destroyed (CDD)** being established as a foundational metric within the on-chain analytics discipline. By assessing the timestamps applied to each UTXO, we can measure how long any specific coin has remained dormant and use this information to inspect aggregate supply and demand dynamics of the network, investor behaviour and sentiment, and market trends.

In a December-2018 post[3], Tamás Blummer introduced Liveliness, which is a macro indicator for the relative volumes of Coinday Destruction relative to Coinday Creation. This elegant metric is a foundational tool for understanding the aggregate behavior patterns of Bitcoin holders.

In this suite of research, we progress the concept of both Coindays Destroyed and Liveliness, and re-introduce them within a robust and mathematically-consistent analysis framework called Cointime Economics.

In this suite of research, we progress the concept of both Coindays Destroyed and Liveliness, and re-introduce them within a robust and mathematically-consistent analysis framework called Cointime Economics.

Why Analyze Cointime Economics?

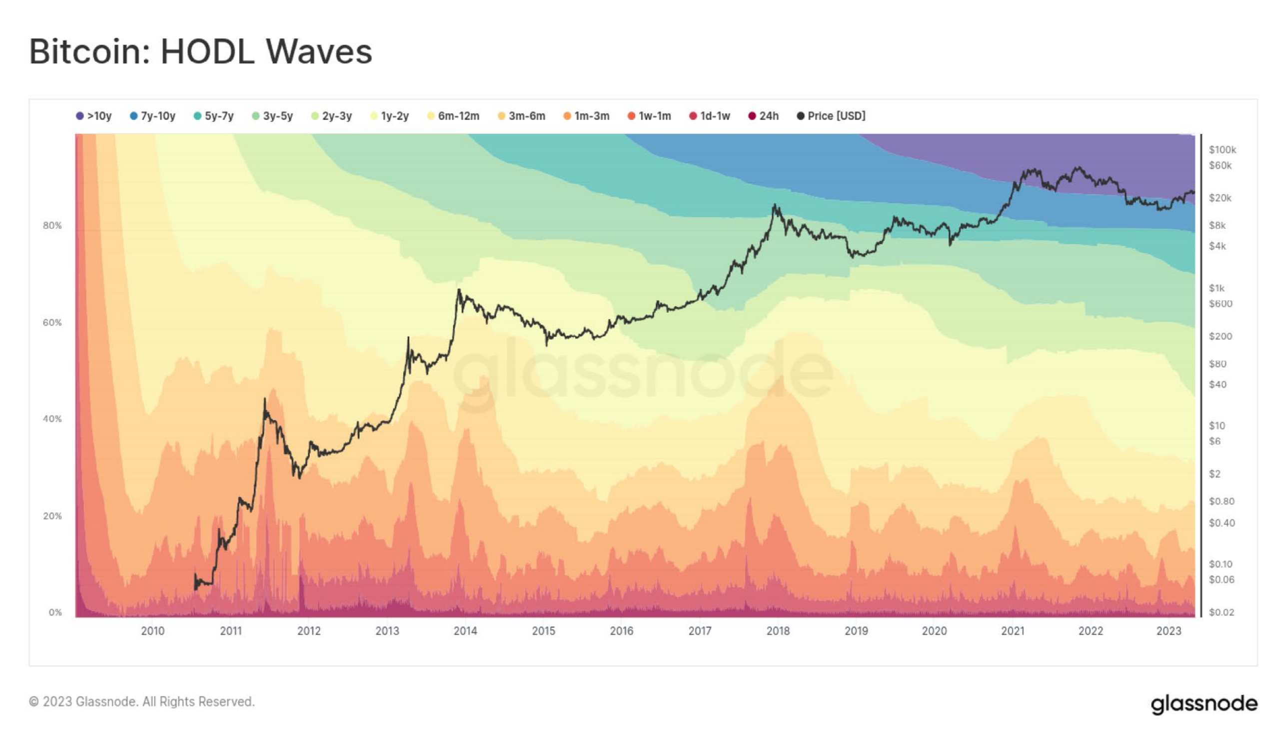
Assessing time-weighted coin volumes at a macro scale provides information on the underlying trends in investor spending and holding patterns.

There are several valuable insights which may be drawn from such a study, many of which underpin the foundations of on-chain analysis at large:

- **Coins with long accumulated lifespans** are increasingly likely to be either lost or held by very strong-handed investors, many of whom are experienced with Bitcoin's infamous volatility.
- **Coins with short accumulated lifespans** are typically more sensitive to near-term volatility, as their owner's cost basis is typically closer to the current market price. These coins are statistically more likely to be spent. (Please read further research here)[4].

- **Macro trends of cointime being accumulated or destroyed** tends to correlate with periods of lower and higher volatility, respectively. Aggregate cointime accumulation is historically associated with periods where price-insensitive investors accumulate coins and increasingly hold them, we assume, in cold storage. Cointime destruction is more commonplace in bull markets and in high volatility bear markets, where investors take profits into market strength or capitulate in panic during sell-off events, respectively.

By way of example, one of the most popular on-chain metrics are the HODL waves, a tool that visualises the evolving age of the coin-supply over time. Cooler colours reflect coins that have remained unspent for years, whilst warmer colours were more recently spent, and are thus more active, mobile, and influential on day-to-day trade. Macro market and investor trends can then be visualised as coins are spent, mature, and migrate between various age brackets.



Data as of 8-May-2023. Past performance is not indicative of future results.

The Foundations of Cointime Economics

Cointime is a unit of measurement describing the holding time of the UTXO set. Today, this unit is commonly referred to as the **coinday**, being a portmanteau of **coin** and **day**, and it is a unit of measurement with two components, **coin volume (BTC)** and **time (UTXO lifespan)**:

- **Coin Volume** has a unit of BTC (or satoshis), and is measured directly from the UTXO which contains it.
- **UTXO Lifespan** has a unit of time, and is measured as the duration between UTXO creation and UTXO destruction (or at the point of evaluation where the coin remains unspent).
    - The length of time that a UTXO has remained unspent is defined as ***accumulated lifespan***.
    - When this UTXO is spent, we can then assess the magnitude of ***destroyed lifespan***.

Thus, we can define the cointime of a specific UTXO as the product of coin volume and the accumulated or destroyed lifespan. Cointime can then be aggregated across the entire UTXO set to establish the complete economic state at each blockheight.

Cointime has units of BTC-time (e.g., BTC-days, BTC-blocks, BTC-years, sat-weeks, etc).

At a macro scale, we can evaluate changes in cointime accumulation and destruction across the entire network and establish the market analysis framework called **Cointime Economics**.

Introducing Coinblocks

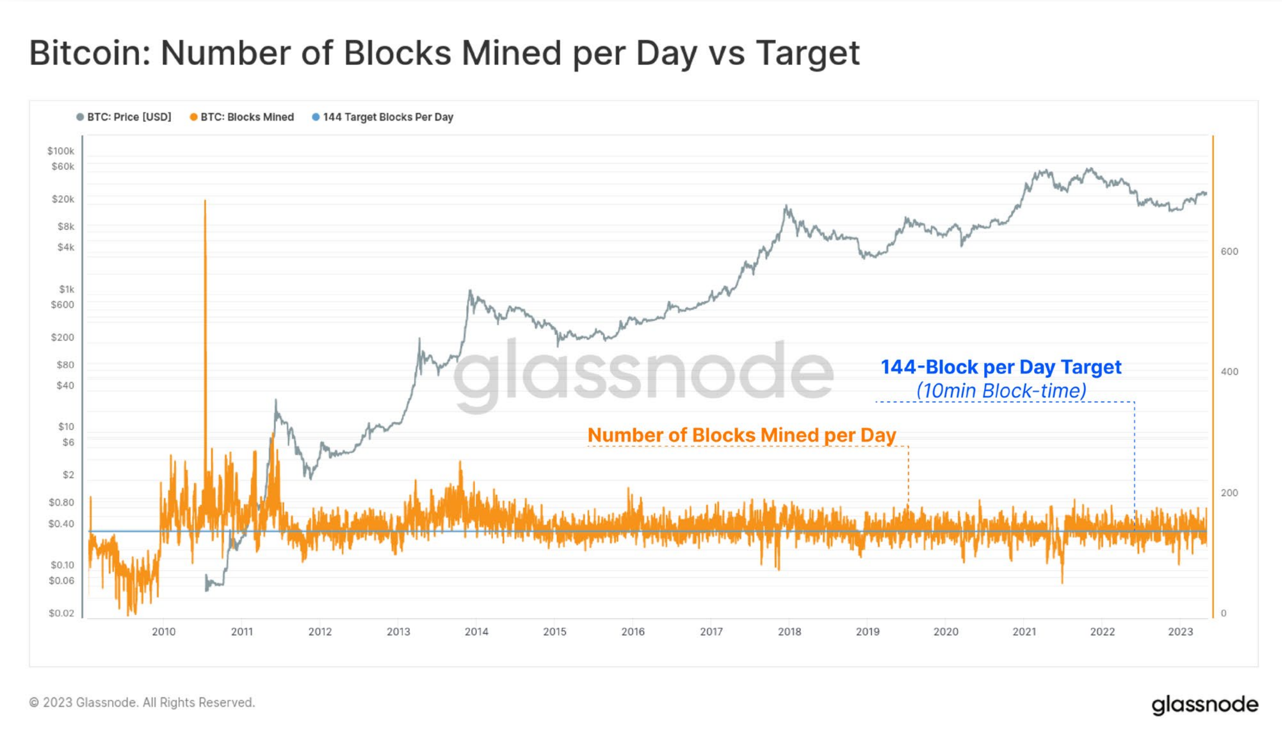
As noted, cointime is the product of **coin volume** and **lifespan**. The first part of this equation, coin volume, can be measured directly from the UTXO set. However, the second component of time, requires the definition of a standard unit which is appropriate in a Bitcoin context.

At a technical level, the Bitcoin protocol is aware of two versions of 'time':

1. **Clock-time** as defined by the **timestamps** added by miners to each block-header and used by the Bitcoin protocol to calibrate the difficulty adjustment.
2. **Block-time** as defined by **blockheight and number of confirmations** of a UTXO. Blocktime is often quoted in the number of blocks mined in a given day or as the blockheight when an event occurred.

The process of miners finding new blocks is probabilistic in nature and, as a result, there is a natural variance in the number of blocks mined each day. Furthermore, periods where miners apply an increasing (or decreasing) magnitude of hash rate to the network will result in blocks being found faster (or slower) until the difficulty adjusts upwards (or downwards).

The chart below shows this natural variability with the number of blocks mined per day displaying notable deviation around the target of 144-blocks per day.



Data as of 8-May-2023. Past performance is not indicative of future results.

As a result, every window of clock-time (day, hour, or 10 minutes) contains a variable number of Bitcoin blocks. This means that clock-time is non-fungible and any analysis considering clock-time as the base unit of time measurement will be influenced by this natural variability in what is effectively an error-carried-forward.

In order to remove this variance, we propose block-time as the lowest level and non-divisible unit of measurement of time in Bitcoin. Thus, we introduce the concept of a coinblock:

A coinblock is the lowest level and fully fungible unit of measurement of cointime. A UTXO containing 2.1 BTC (coin volume), and with 400 confirmations (lifespan) will have accumulated a cointime of 2.1 ∗ 400 = 840 coinblocks.

Conversion of coinblocks back into the more widely known coindays is non-trivial. It requires additional steps to account for variance in the number of blocks mined per day and the exact time in the day that each block was mined.

- **Each coinday (clock-time domain)** contains a variable number of coinblocks, and with blocks mined at variable timestamp intervals within it. Thus, each coinday will internally differ to all other coindays. Coindays are therefore a unique and non-fungible unit of cointime measurement. As such, each coinday must be associated with, and measured from, the timestamps of the UTXO set, increasing computational load.

- **Each coinblock (block-time domain)** is equivalent to any other coinblock and is thus a fungible unit of measurement. Calculations may consider all coinblocks as uniform and therefore tracking the originating UTXO is not required during analysis, lowering computational load.

For these reasons, all analysis henceforth in a Cointime Economics framework will be based solely on coinblocks as the foundational unit of account.

Data Engineering Implications

The discipline of on-chain analysis requires a minimum degree of node-level engineering, as well as data exporting and parsing software, such as that operated by Glassnode. For clarity, we can split this process into two steps:

1. **Data Science Engineering**—which describes the process of extracting and parsing the UTXO set from the node database and into a structured database.

2. **On-Chain Analysis**—which describes the process of taking this structured database and converting it into metrics, visualizations, and insights to explain economic activity.

All forms of on-chain analysis require the first step as a minimum level of infrastructure. However, a principle advantage of the Cointime Economics framework is that the computational efficiency of the second stage of this process can be significantly reduced.

Traditional UTXO Analysis Framework

Under the **traditional UTXO level analysis framework**, an On-Chain Analyst must consult the following minimum inputs in order to calculate economic flows through the Bitcoin network:

- Database of the UTXO set at each blockheight.

- Timestamp of each UTXO on creation and destruction.

- Pricestamp of each UTXO on creation and destruction.

- Spot price.

This approach ingests and processes a large dataset (Bitcoin blockchain size ~470 GB), however allows for the explicit application of heuristics and the monitoring of entities (e.g., exchanges and miners). The applied assumptions and heuristics are often proprietary which can lead to different outcomes between various data providers in the industry.

Cointime Economics Framework

Under a **Cointime Economics framework**, the On-Chain Analyst may consult only the following minimum inputs in order to calculate economic flows through the network:

- Blockheight.
- Coinblocks destroyed.
- Coinblocks created (obtained directly from circulating supply).
- Spot price.

This dataset can be trivially contained within a text file or CSV, however it can still be used to compute a wide array of metrics describing the supply and demand dynamics of the Bitcoin network (discussed throughout this paper).

All input parameters are easily replicated between data providers and no proprietary spending heuristics are required, since coinblocks are fully fungible. Thus, the conclusions drawn by any analysis will be consistent, allowing Cointime Economics to be used as a computationally efficient, complimentary verification toolbox alongside UTXO analyses.

Comparison between UTXO and Cointime Analysis Frameworks

A summary comparison between the two frameworks is provided in the table below.

Concept	UTXO Analysis	Cointime Analysis
Unit of account (UoA)	UTXOs	Coinblocks
Fungibility of UoA	Non-fungible	Fully-fungible
Timestamp	Explicit timestamps associated with each UTXO at creation and destruction.	Aggregate volumes of coinblocks created, destroyed, or stored.
Pricestamp	Explicit pricestamps associated with each UTXO at creation and destruction.	Aggregate coinblock volumes valued against spot price.
Computational overhead	Calculating economic flows requires parsing large data sets (entire blockchain) via data-science engineering.	Calculating economic flows requires trivially-sized data sets (text file or CSV).
Necessary assumptions and heuristics	Application of spending heuristics regarding UTXO status and ownership (i.e. change-adjustments, entity analysis, assumptions of lost vs. dormant coins).	No heuristics required due to fungibility of unit of account.
Quality of insight	Explicit observation of spending and holding patterns, and ability to perform specific analysis of entities.	Implied macro observations which are mathematically verifiable, but with lower resolution and incapable of tracking specific entities.
Capacity to verify	Discrepancies between on-chain data providers arise as a result of applied proprietary heuristics and methods.	Trivially replicated between data providers due to unit-of-account fungibility and lack of necessary heuristics.

On-Chain Analysis Implications

As will be explored further in this paper, there are several potential benefits to analysis of Bitcoin from within a Cointime Economics framework:

1. A self-correcting toolkit that enables the efficient discounting of the influence of long-dormant or lost coins on shorter-term economic models.
2. A framework for the filtering of 'churned coins', being those that are spent several times in a short time period, inflating transfer volumes.
3. Correction (or iteration) of several traditional economic models for Bitcoin economic models which have experienced drift or signal deterioration over time.
4. New appreciation of the traditional Realized Price, as well as the development of several new on-chain pricing, valuation, and economic models derived from cointime principles.

Overall, Cointime Economics provides a suite of new principles and primitives that allow for the computationally efficient adjustment of economic models for Bitcoin. These models act to accounting for the varying degrees of coin activity and inactivity across the network.

[2] *Source: ByteCoin. "Re: Bitcoin Transaction Volume", Bitcoin Talk.org, 2011.*
https://bitcointalk.org/index.php?topic=6172.msg90789#msg90789

[3] *Source: Blummer, Tamás. "Liveliness of Bitcoin", Medium, 2018.*
https://medium.com/@tamas.blummer/liveliness-of-bitcoin-174001d016da

[4] *Source: Schultze-Kraft, Rafael, et al. "Breaking Up On-Chain Metrics for Short- and Long-Term Investors", Glassnode, 2020.*
https://insights.glassnode.com/sth-lth-sopr-mvrv/

The Primitives of Cointime Economics

In this section we will establish the fundamental building blocks of Cointime Economics.

Three States of Cointime

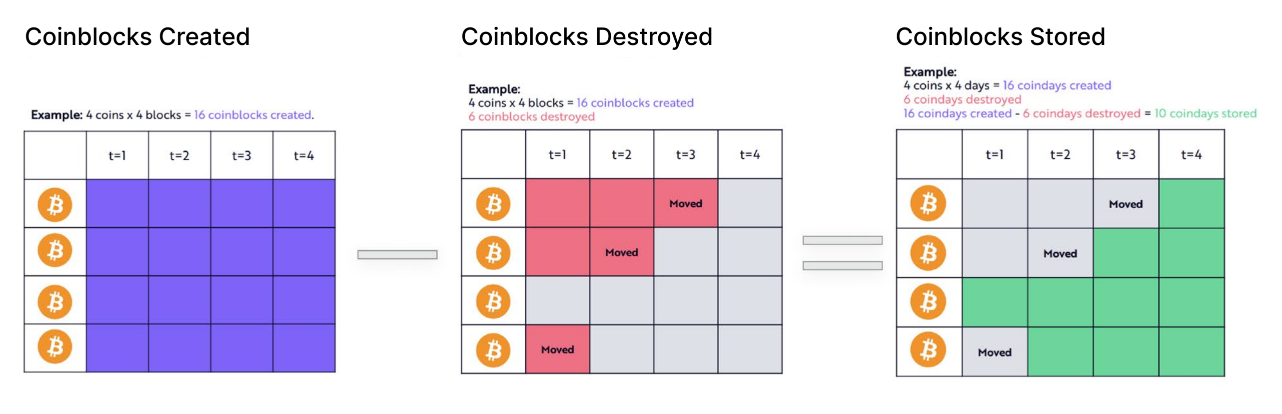
The overall economic state of the Bitcoin network will change each time a new block is found by miners—and all transactions within it are confirmed. At all times, individual coinblock volumes can only exist in one of three states at the time when the next block is found:

- Created.
- Destroyed.
- Stored.

The graphic below summarizes this considering a sample model network with the following properties:

- Coin supply of 4 coins, all minted at genesis.
- Total network time of 4 blocks since genesis.
- Total cointime created of 4 coins x 4 blocks = 16 coinblocks.
- Total cointime destroyed of 6 coinblocks, distributed across three coins spent (moved) at different times.
- Total cointime stored of 10 coinblocks, calculated by subtracting coinblock destruction from coinblock creation.

Note that all coinblocks are considered equivalent and keeping track of which specific coin or UTXO it is associated with is unnecessary.



Coinblocks Created (CBC)

Every coin (of any denomination) in the existing coin supply creates an equivalent volume of coinblocks per block. The maximum number of coinblocks that can be created each block is therefore limited by and equal to the existing coin supply, which itself is bounded by the pre-defined Bitcoin supply curve.

As such, the volume of coinblocks created at block N is equal to the circulating supply at blockheight N (including newly minted coins).

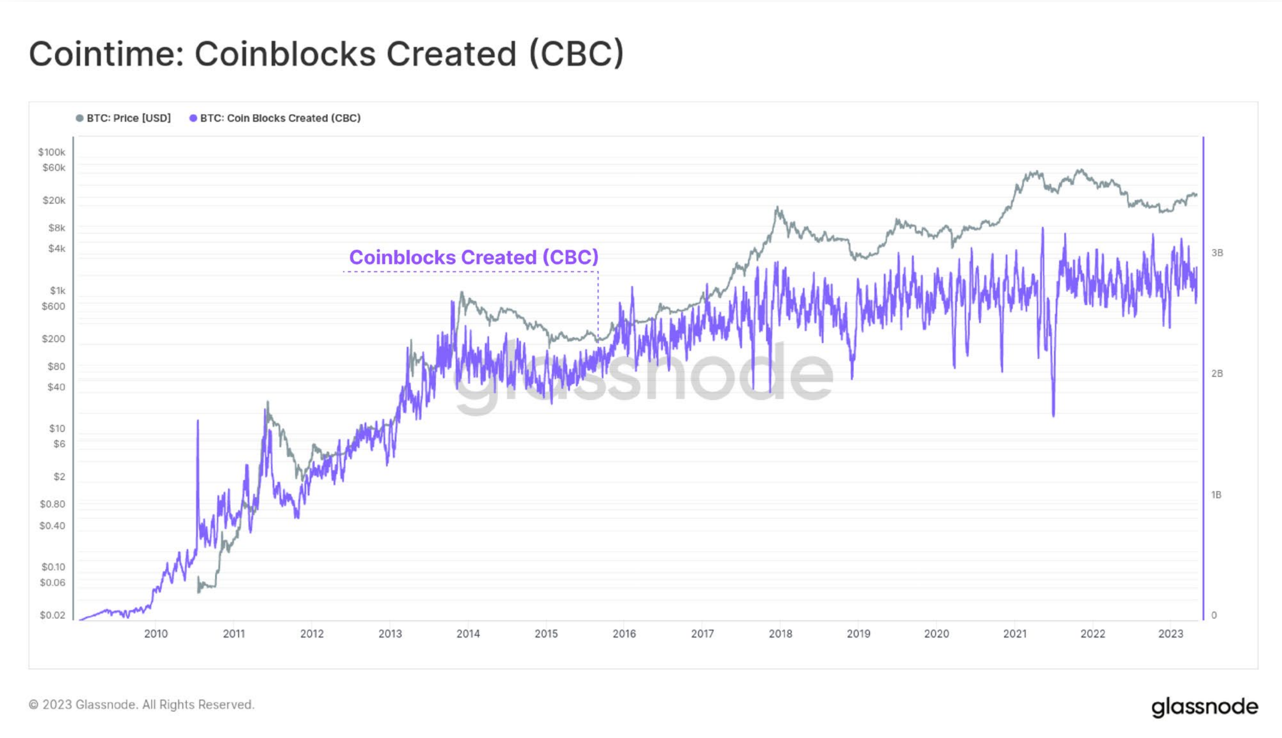
$$\begin{aligned} Coinblocks\ Created_N &= CBC_N \\ &= Circulating\ Supply_N \\ Total\ Coinblocks\ Created &= \sum_{i=0}^{N} CBC_i \end{aligned}$$

Coinblocks created (CBC) are the volume of additional coinblocks added to the Bitcoin economy with each new block, which is equivalent to the circulating supply at each blockheight.

- **Example:** A UTXO containing 3.25406 BTC will create exactly 3.25406 coinblocks for every confirmation on that UTXO.

Coinblock creation for newly minted coins commences immediately. Upon confirmation of the block containing the coinbase transaction, new coinblocks are created which are associated with newly minted coins via the block subsidy.

- **Example:** The miner who finds the next block rewards themselves with a coinbase transaction providing revenue of 6.25 BTC in block subsidy, and 0.20 BTC in fees, which creates 6.45 coinblocks immediately upon confirmation.



Data as of 8-May-2023. Past performance is not indicative of future results.

Note how the coinblock created chart demonstrates a reactive response to market pricing. This is a result of changes in mining market dynamics as more or less hash rate is applied to the network following price performance—and thus profitability of the mining industry.

Coinblocks Destroyed (CBD)

For every mined block, a subset of UTXOs is usually spent, destroying any accumulated coinblocks held within those UTXOs. The number of coinblocks that can be destroyed is therefore bounded by the accumulated coinblocks contained within the UTXO set at each blockheight.

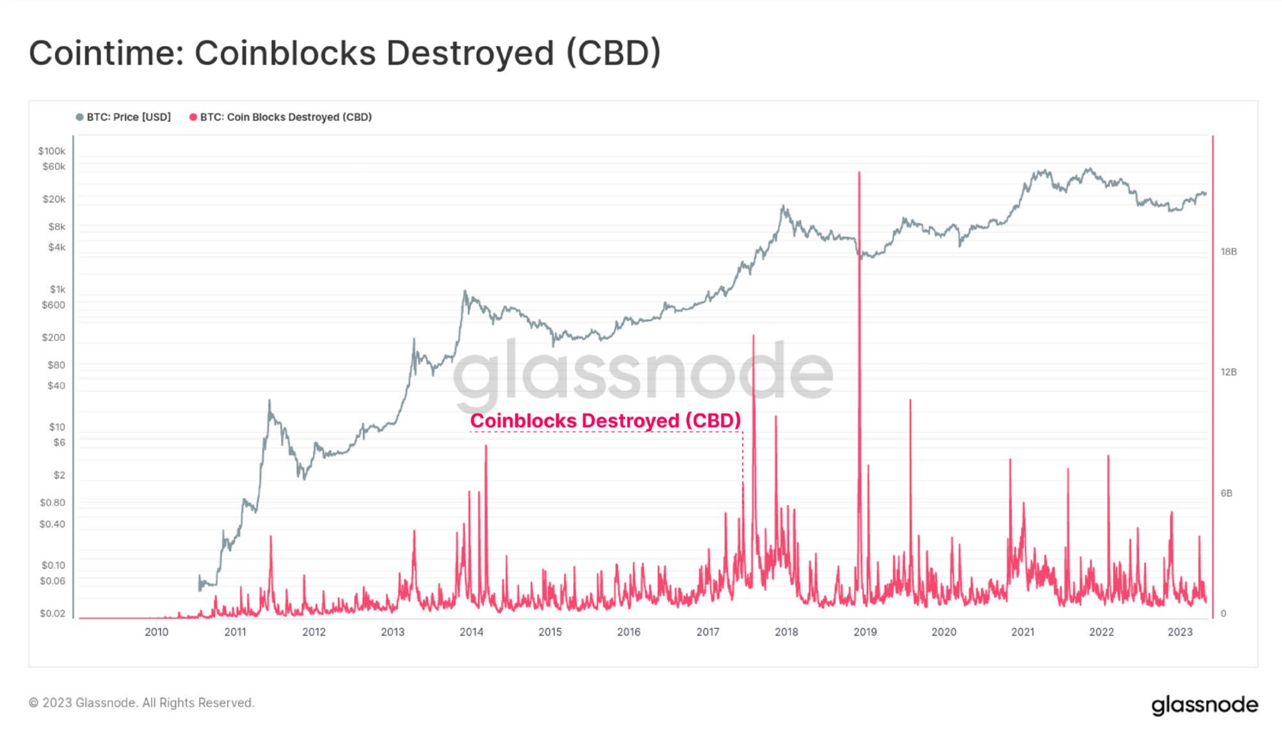
$$\begin{aligned} Coinblocks\ Destroyed_N &= CBD_N \\ &= \sum(Coins[BTC] * Lifespan\ [blocks]) \\ &\quad [for\ all\ spent\ outputs\ in\ block\ N] \\ Total\ Coinblocks\ Destroyed &= \sum_{i=0}^{n} CBD_i \end{aligned}$$

Coinblocks destroyed (CBD) are the volume cointime destroyed in each confirmed block via transactions (which destroy UTXOs).

When an output is spent, a set of new UTXOs are created and the coins within them will restart the accumulation of cointime immediately following block confirmation.

- **Example:** A UTXO containing 3.254 BTC and with 1,025 confirmations is spent and mined into a block. This destroys exactly 3.254 * 1025 = 3335.35 coinblocks. The result of the transaction is that the coins are now contained within a new set of output UTXOs and have their lifespan reset to zero. Upon confirmation, these coins will create 3.254 coinblocks.

The chart below shows how coinblocks destroyed tends to peak alongside high volatility market events such as bull markets, and major sell-off events in bear market. This is a result of greater market incentives (profit or fear) for coin holders to spend.



Data as of 8-May-2023. Past performance is not indicative of future results.

Coinblocks Stored (CBS)

At each blockheight, we can evaluate the difference between coinblocks created (CBC) and coinblocks destroyed (CBD) to assess the net change in overall network cointime stored.

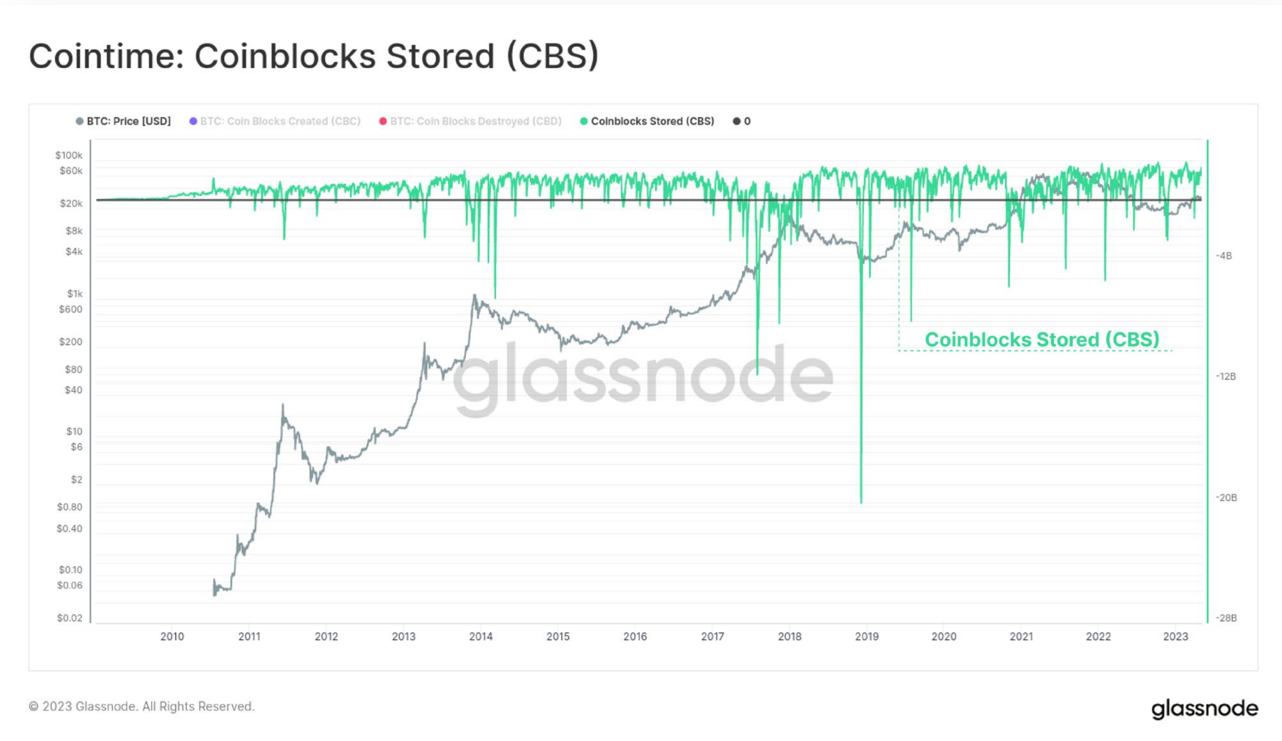
$$
\begin{aligned}
Coinblocks\ Stored_N &= CBS_N \\
&= CBC_N - CBD_N \\
Total\ Coinblocks\ Stored &= \textstyle\sum_{i=0}^{n}(CBC - CBD)_i
\end{aligned}
$$

Coinblocks stored (CBS) are the net volume of coinblocks which are added to the aggregate at each blockheight.

- **Example (first assumption):** A network mints 50 BTC each block, no UTXO has ever been spent, and the network is currently at blockheight 5. As the coin supply increases by 50 each block, the total coinblocks stored equals total coinblock creation at block = 50 + 100 + 150 + 200 + 250 = 750 total coinblocks stored.

- **Example (second assumption):** This same network now has a coin supply of 250 BTC and a reserve of 750 stored coinblocks. In the next mined block, the following events occur:
    - 50 BTC are minted, making the total supply 300 BTC.
    - All 300 BTC in the supply create 300 coinblocks.
    - A UTXO containing 50 BTC, and having 5 confirmations is spent, leading to 5 * 50 = 250 coinblocks destroyed.
    - The net coinblock storage at N = 6 is CBS_6 = 300-250=50 coinblocks stored.
    - The total cointime stored reserve is now 750 + 50 = 800 total coinblocks stored.

Note that over time, the network can generate a 'surplus total reserve' of coinblocks stored, and thus coinblock destruction can exceed creation at times. This leads to negative coinblock stored values at times.



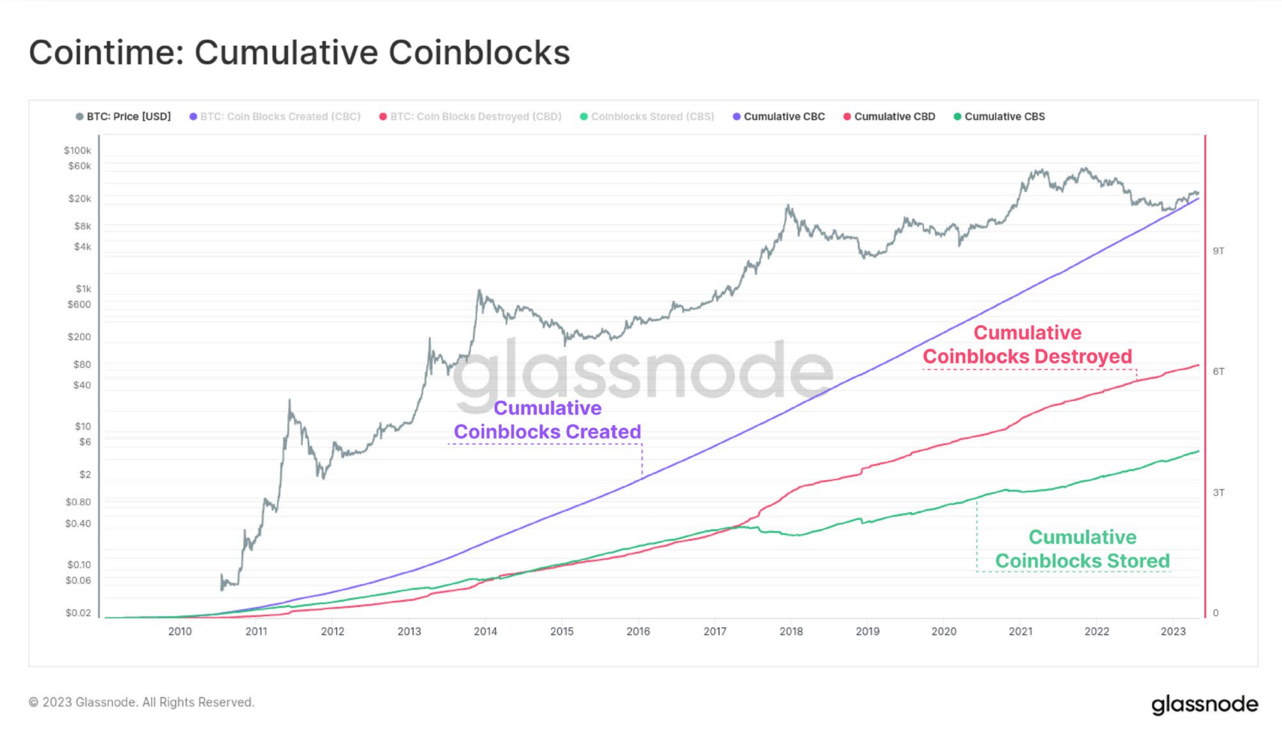
Data as of 8-May-2023. Past performance is not indicative of future results.

Cumulative Total Coinblocks

These three states of cointime may then be evaluated over time to establish an aggregate economic state of the network. The chart below shows the cumulative sum of all coinblocks created, destroyed, and stored. Analysis of net changes between these three cointime states allows us to assess macro behaviour of network participants, without explicitly tracking the UTXOs that contain each coinblock.

As of 8-May-2023, the economic state of each coinblock group is:

- Total CBC: 10.429 Trillion Coinblocks.
- Total CBD: 6.281 Trillion Coinblocks (60.2% of CBC).
- Total CBS: 4.147 Trillion Coinblocks (39.8% of CBC).



Data as of 8-May-2023. Past performance is not indicative of future results.

Network Liveliness & Vaultedness

Liveliness

The concept of Liveliness [3] was first introduced in 2018 by Tamás Blummer as a measure of how 'active' a blockchain network is (cumulative cointime destruction) relative to its aggregate age and size (cumulative cointime creation). Liveliness was a breakthrough innovation in on-chain analytics and is a remarkably elegant, yet information dense, concept.

Liveliness moves between the extremes of 0 (where no coin has ever been spent) and is asymptotic to a value of 1 (possible only theoretically in a block where every coin in the supply is spent). Liveliness is calculated as the cumulative sum of coinblocks destroyed, divided by the cumulative sum of coinblocks created:

$$Liveliness = \frac{\sum CBD}{\sum CBC}$$

A general framework of interpretation for Liveliness is as follows:

- **Liveliness will decrease** when a high proportion of the coin supply is dormant and the global coinblock accumulation outpaces coinblock destruction via on-chain spending activity.
- **Liveliness will trend sideways** where the volume of coinblock destruction is equal to the volume of coinblock creation within the circulating supply.
- **Liveliness will increase** as investors begin spending long-dormant coins which have accumulated and stored large volumes of coinblocks which exceeds the rate of coinblock creation.

Liveliness can also be used to assign relative weight and confidence for comparing valuations between digital assets. Liveliness will be closer to zero for assets with low liquidity, highly concentrated supplies and poor adoption (and vice versa).

Cointime: Liveliness

glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

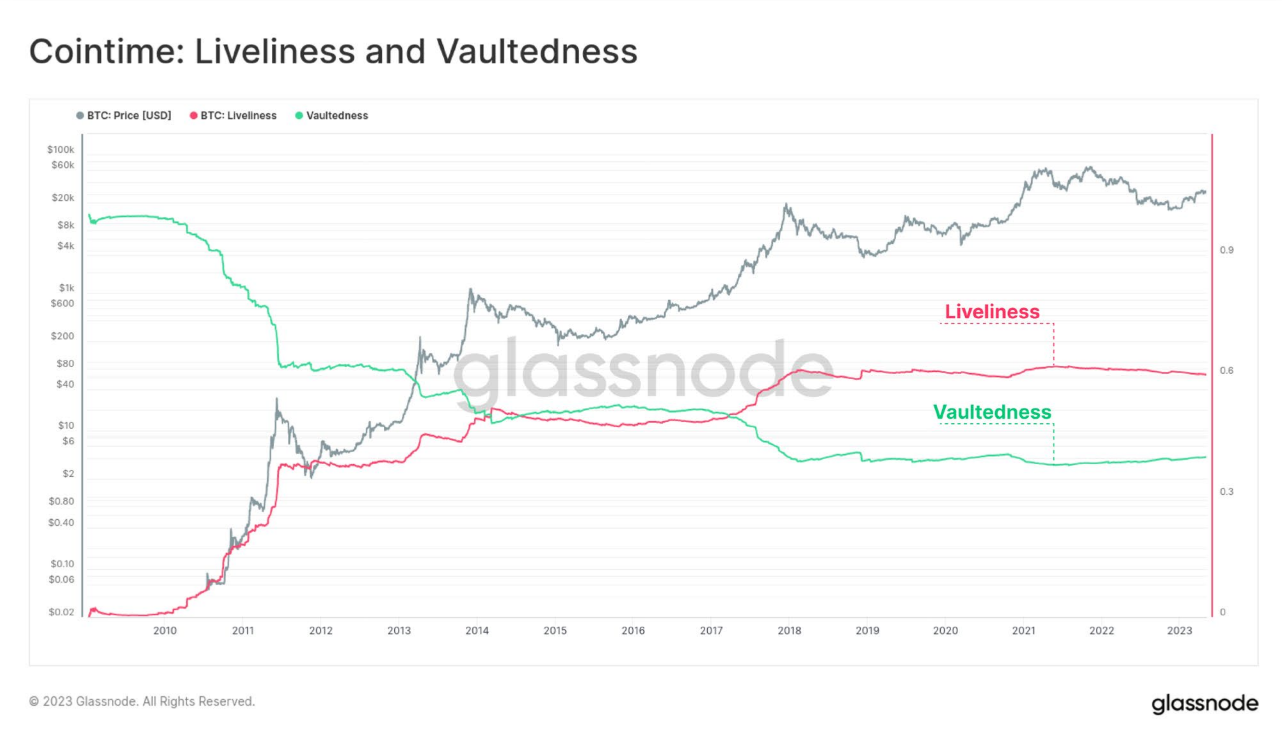
Vaultedness

Where Liveliness describes the relative proportion of ‘activity’ in a network, we introduce the opposing metric, describing the relative ‘inactivity’ or relative coinblock storage within the Bitcoin network: **Vaultedness.**

$$\begin{aligned} Vaultedness &= (1 - Liveliness) \\ &= \frac{\sum CBC}{\sum CBC} - \frac{\sum CBD}{\sum CBC} \\ &= \frac{\sum CBS}{\sum CBC} \end{aligned}$$

The combination of **Liveliness** and **Vaultedness** provides a complete macro view of the economic state of the Bitcoin network. Together, they account for both the relative proportion of cointime expenditure (coinblock destruction), as well as cointime accumulation that results from investors holding coins in a dormant state (coinblock storage).

The chart below shows Liveliness and Vaultedness for Bitcoin, with these metrics trading inverse to each other between the extremes of 0 and 1.



Data as of 8-May-2023. Past performance is not indicative of future results.

A Brief History of Bitcoin (Told by Its Liveliness and Vaultedness)

The evolution of Liveliness and Vaultedness over time elegantly describes the changing perception and utilization of the Bitcoin asset and network by the market.

- **During the early years of Bitcoin (2009-2012)**, Vaultedness was very high (> 0.6), largely a result of Satoshi and other early miners primarily leaving their coins unspent (or lost). These coins continue to create, but not destroy, coinblocks to this day. At this time, bitcoin had few trading venues, little financial value, and many coins were subsequently lost as owners misplaced their private keys.

- **As the market started to value Bitcoin (2010-2013)**, it experienced its first major market bubble in 2011, and transaction activity picked up. As a result, more coinblocks were destroyed, causing Liveliness to increase, and Vaultedness to decay. The influence of lost coins remained a relatively large influence, and thus continued to favour coinblock creation, which kept Vaultedness higher than Liveliness.

- **Following the collapse of Mt. Gox (late 2013)**, a transitional period occurred between mid 2014 and early 2017. Liveliness and Vaultedness started to converge between values of around 0.47 to 0.53. This reflects a near equal balance of aggregate network activity (buyers and sellers during a bear market), the impact of lost coins, and long-term investor accumulation. By this time, early adopters had gained an appreciation of the potential of Bitcoin as a monetary network/asset, and thus spending behaviours started to become more cyclical in nature.

- **After the second halving (9-July-2016)**, 75% of the total 21M coin supply had been mined and the market commenced its 2016-2017 parabolic bull run. The relative influence of Satoshi and early adopter lost coins had by this time decayed and many investors found a renewed reason to spend and liquidate their coins as the market rallied. A significant jump in Liveliness can also be seen in early August 2017, as Bitcoin holders spent their coins to acquire the additional Bitcoin Cash (BCH) coins after the hardfork.

- **Through the 2018 to 2022 period**, the Bitcoin market had reached a new level of financial maturity, with the emergence of derivatives markets, usage as lending collateral, early institutional adoption, and an increasing role within a macroeconomic framework. The demand for Bitcoin as a long-term store of value had emerged as a dominant use case, and this is reflected in a relatively stable plateau in Liveliness and Vaultedness, despite the market reaching significantly higher prices.

Note that Liveliness tends to reach local peaks around bull market tops, reflecting a point of maximum incentive for investors to spend coins, liquidate, and take profits. Over time, the probability increases that the total cointime stored (unspent) over successive market tops is associated with the truly lost coin volume.

We will explore this further in Chapter 8 and how the principles of Cointime Economics can therefore be used to better estimate the volume of truly lost and truly active coins.

Activity-to-Vaulting Ratio (A2VR)

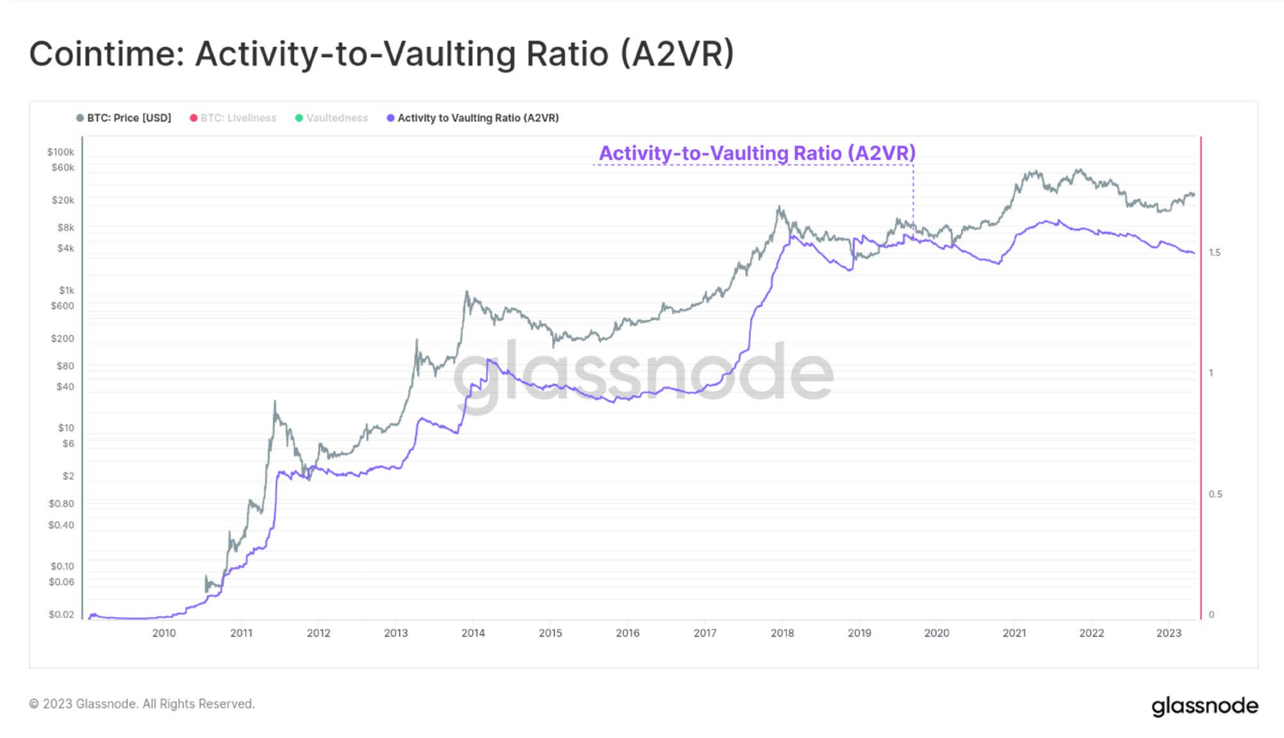
The relative macro shifts between Liveliness and Vaultedness can also be surmised into a single metric: the Activity-to-Vaulting Ratio (A2VR), calculated as the ratio between Liveliness and Vaultedness.

$$Activity\ to\ Vaulting\ Ratio\ (A2VR) = \frac{Liveliness}{Vaultedness} = \frac{\sum CBD}{\sum CBS}$$

The A2VR metric can be considered as a weighting function, or multiplier, useful for calculations where analysts seek to discount the influence of dormant, inactive coins and amplify the influence of more mobile and active supply.

A2VR also provides a more sensitive view on shifts in coin owner behaviour, however retains a similar interpretation framework to Liveliness [5]:

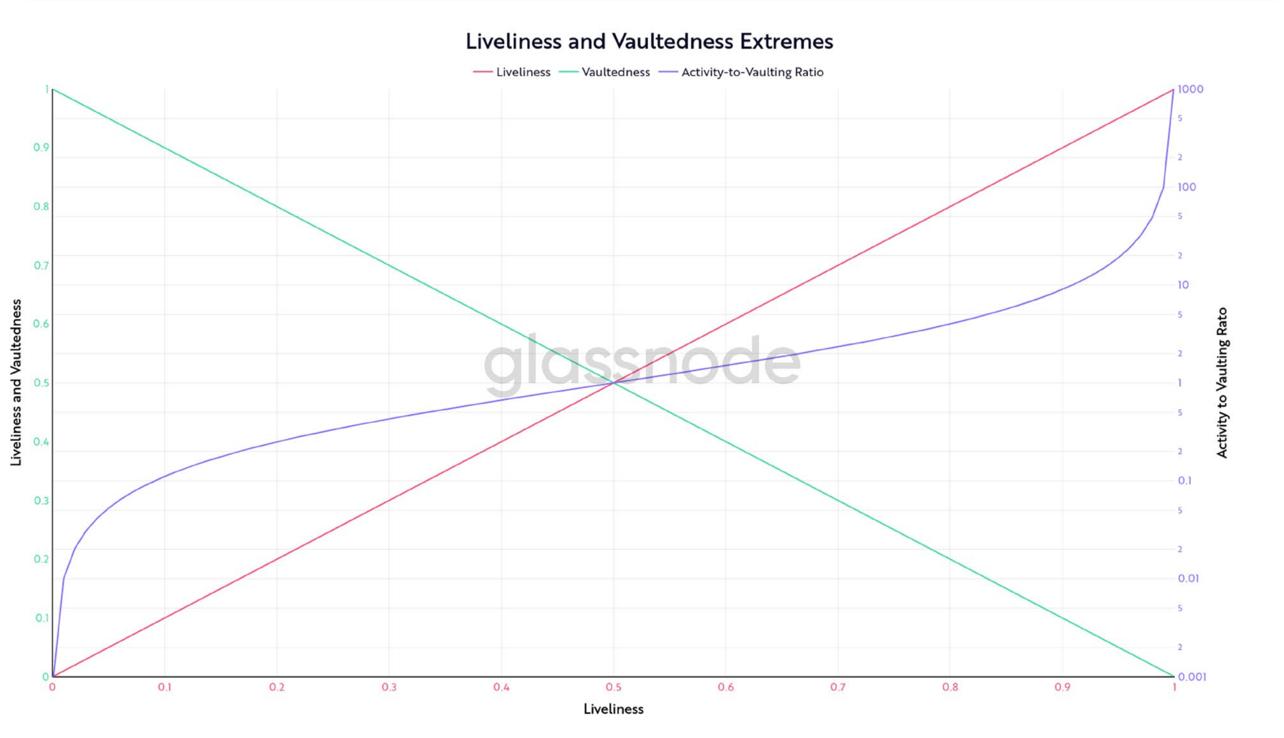
- **Uptrends** signal that aggregate coinblock destruction is greater than aggregate coinblock creation. This is typical of bullish markets as older coins are liquidated for profit, but also during periods of high volatility and panic such as major sell-off events.
- **Downtrends** signal that aggregate coinblock creation is greater than aggregate coinblock destruction. This is typical of bearish markets, when longer-term investors accumulate and HODL at elevated rates (e.g., due to increasing demand for Bitcoin as a store-of-value asset).
- **Steepness** of the metric signals the relative magnitude of the above two points. Steeper uptrends indicate more aggressive coinblock destruction, whilst steeper downtrends signal the converse, that the coin supply is increasingly dormant.



Data as of 8-May-2023. Past performance is not indicative of future results.

A2VR is not bounded by the extreme limits of 0 and 1, and instead has a S-curve profile in log space with respect to Liveliness. The chart below shows this relationship between Liveliness (x-axis, LHS y-axis, red), Vaultedness (LHS y-axis, green), and A2VR (RHS y-axis, purple).

- As Liveliness approaches 0, Vaultedness approaches 1, and A2VR approaches 0.
- As Liveliness approaches 1, Vaultedness approaches 0, and A2VR approaches infinity.



Data as of 8-May-2023. Past performance is not indicative of future results.

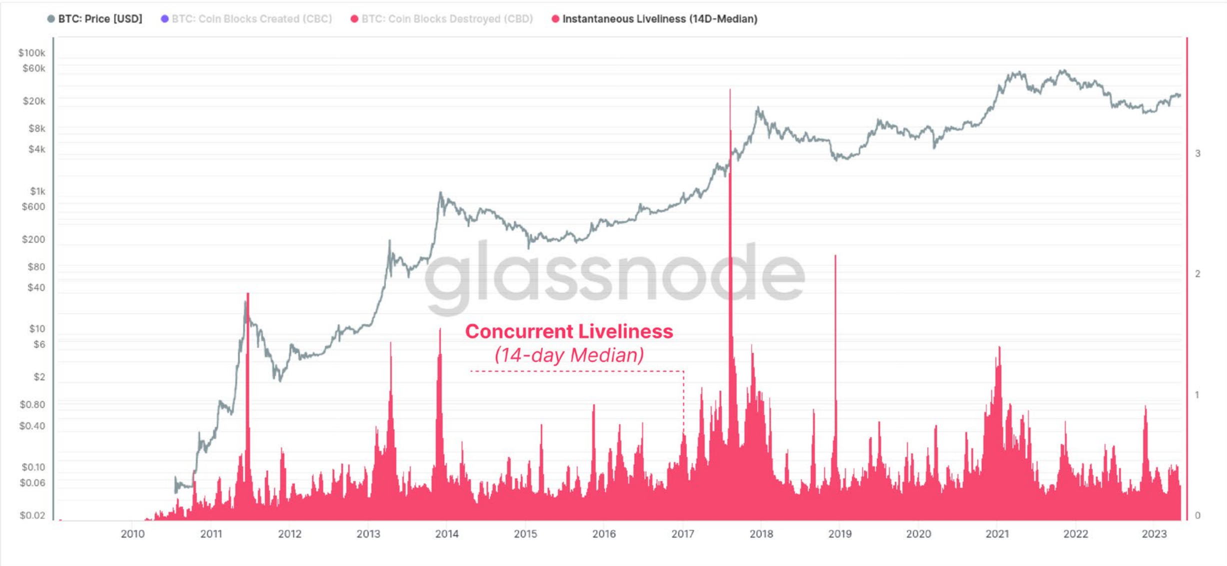
Concurrent Liveliness

The ratio between cointime destroyed and cointime created at any blockheight can be described as **Concurrent Liveliness**. Concurrent Liveliness will trade above a value of 1 when coinblock storage is negative, and vice-versa.

$$Concurrent\ Liveliness = \frac{CBD}{CBC}$$

Concurrent Liveliness can be considered in a similar way to the traditional Coindays Destroyed (CDD) metric, and in fact is synonymous with Supply Adjusted Coindays Destroyed [6] (given CBC each block equals Circulating Supply). Concurrent Liveliness will peak during periods of high expenditure by older, previously dormant coins, and decline during periods of aggregate long-term accumulation and investor preference for HODLing.

Cointime: Concurrent Liveliness



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results. Note the chart above has a 14-day moving median applied to better visualize macro trends.

Liveliness Incremental Change

We may also calculate the incremental change in Liveliness between each mined block, which describes the change in network state at each blockheight.

$$Liveliness\ Incremental\ Change = Liveliness_N - Liveliness_{N-1}$$

$$= \frac{CBD_N}{CBC_N} - \frac{CBD_{N-1}}{CBC_{N-1}}$$

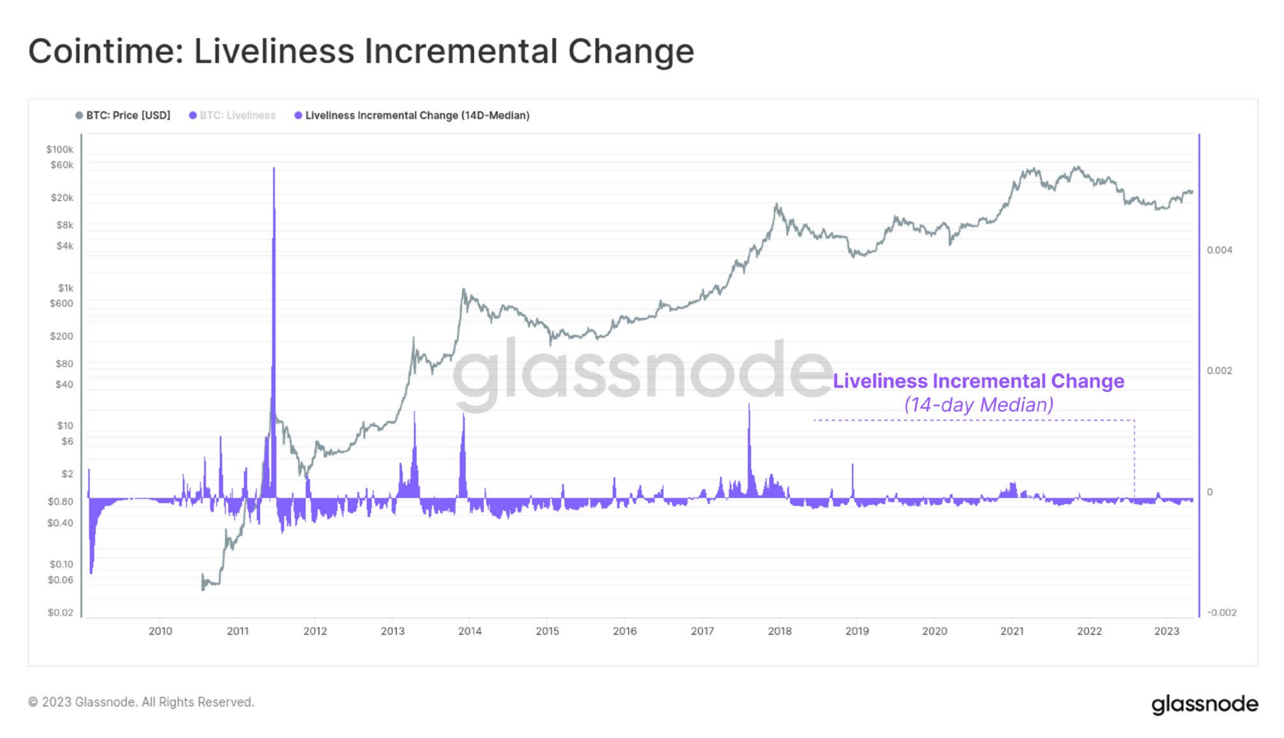
$$= \frac{CBD_N * CBC_{N-1} - CBD_{N-1} * CBC_N}{CBC_N * CBC_{N-1}}$$

- **Values greater than 0** signal that, on net, coinblock destruction across the network is dominant, and uptrends indicate that coinblock destruction is occurring at a greater magnitude than the prior observation.

- **Values less than 0** signal that, on net, coinblock storage across the network is dominant, and downtrends indicate that coinblock storage is occurring at a greater magnitude than the prior observation.

This oscillator will experience positive spikes when there is a large scale expenditure of cointime. Such events are typically associated with high volatility market environments such as late-stage bull markets (as long-term investors take profits) or during capitulation events (as investors spend in panic).

Conversely, deep negative values describe periods of heavy coin dormancy, and are typical of later stage bear markets, and periods of accumulation and/or lack of market interest.



Data as of 8-May-2023. Past performance is not indicative of future results. Note the chart above has a 14-day moving median applied to better visualize macro trends.

[3] *Source: Blummer, Tamás. "Liveliness of Bitcoin", Medium, 2018.*
https://medium.com/@tamas.blummer/liveliness-of-bitcoin-174001d016da

[5] *Source: Glassnode Academy. "Liveliness", Glassnode.*
https://academy.glassnode.com/indicators/liveliness/liveliness

[6] *Source: Glassnode. "Bitcoin: Supply Adjusted CDD".*
https://studio.glassnode.com/metrics?a=BTC&category=&m=indicators.CddSupplyAdjusted&zoom=all

Supply Dynamics

In the sections above, we established the following cointime primitives that form the foundation of the Cointime Economics analysis framework:

- **Cointime Economics** is an analytical framework that considers units of 'cointime' as a uniform unit of measurement within the Bitcoin network. Cointime is defined as the product of coin volume and UTXO lifespan, and may exist in one of three states: created, destroyed, or stored.
- **Coinblocks** are the lowest level unit of cointime within the Bitcoin network. Each coinblock is considered fully fungible with all other coinblocks and removes the need to associate a unit of cointime with a source UTXO.
- **Liveliness** is the ratio between cumulative coinblock destruction and cumulative coinblock creation, reflecting a measure of how 'active' the network coin supply is.
- **Vaultedness** is the ratio between cumulative coinblock storage, and cumulative coinblock creation, reflecting a measure of how 'inactive' or 'vaulted' the network coin supply is.

The following chapter will demonstrate how cointime can be used as a tool for the evaluation of network coin supply dynamics.

Vaulted Supply

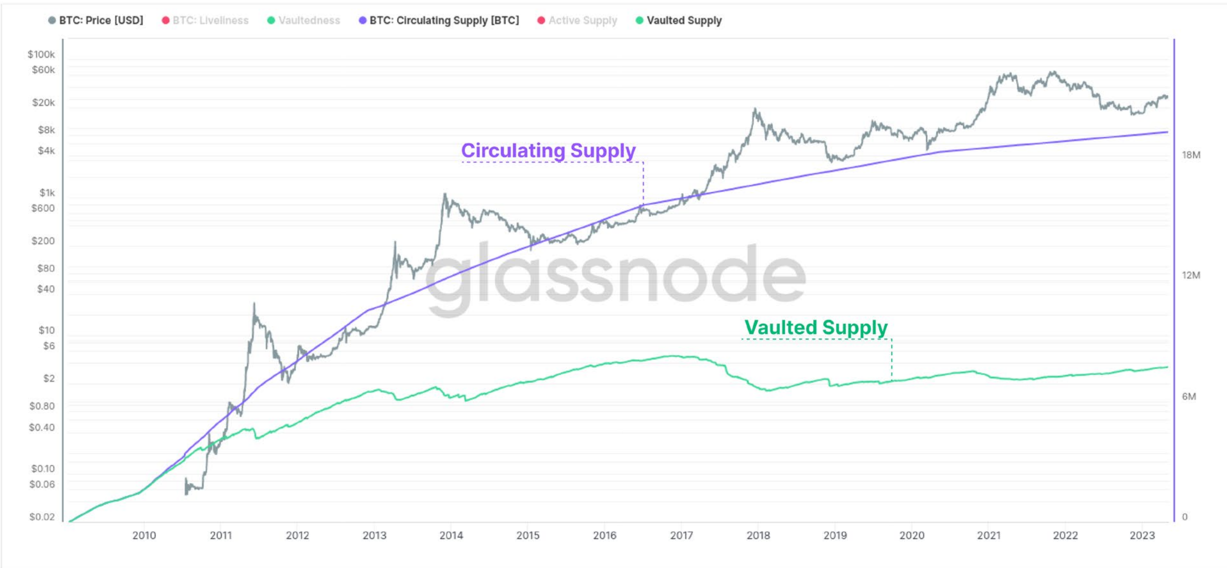
Tamás Blummer and Adamant Capital first proposed the interchangeable nature of cointime and coin supply with a paper released in 2019 [7]. Herein, it was shown how units of cointime could be transferred into the coin supply (BTC) domain by introducing a metric called, at the time, **HODLed and Lost Coins**.

We re-introduce this metric as **Vaulted Supply**.

$$
\begin{aligned}
HODLed\ and\ Lost\ Coins &= Circulating\ Supply * (1 - Liveliness) \\
&= Circulating\ Supply * Vaultedness \\
&= Circulating\ Supply * \frac{\sum CBS}{\sum CBC} \\
&= Vaulted\ Supply
\end{aligned}
$$

Vaulted Supply describes an equivalent sum of Bitcoin which has never been spent and represents the unspent coin volume required to generate the cumulative sum of coinblocks stored within the network. Vaulted Supply may be considered as the equivalent coin volume which is completely dormant and is not actively participating in the Bitcoin economy.

Cointime: Vaulted Supply



glassnode

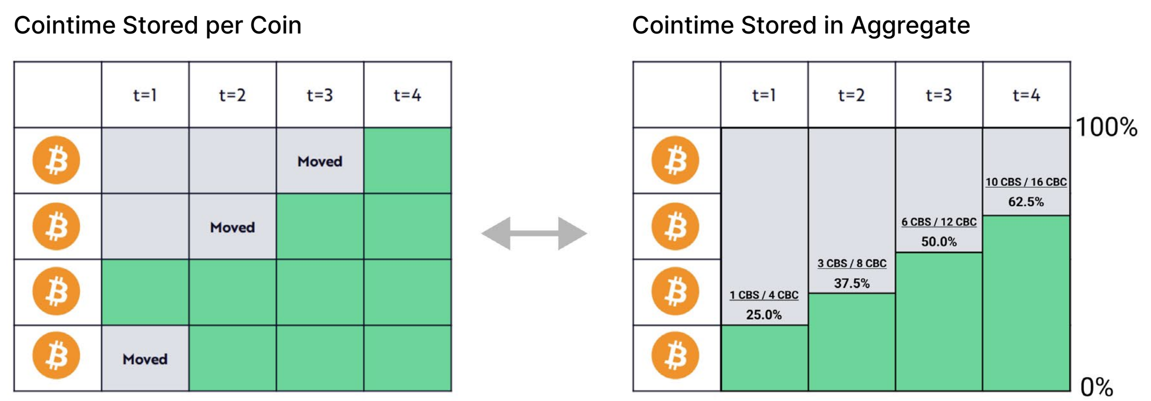
Data as of 8-May-2023. Past performance is not indicative of future results.

Revisiting our 4x4 model network, we can arrange the total coinblocks stored across the network via two analytical frameworks as a demonstration:

- **Model Network:** 3 coins have been spent (moved) at different blockheights, whilst 1 coin remains unspent. Each coin has a unique percentage of its total lifespan destroyed at each blockheight and therefore each must be monitored individually for analysis.

- **Aggregate Network:** At each blockheight, Vaultedness is to be computed according to the cumulative aggregate volumes of cointime created and stored across all coins.

The aggregate network model allows for superior computational efficiency by equating cointime stored to an equivalent unspent BTC volume. This capitalizes on the fungibility of cointime units and allows economic calculations to proceed without knowing the specific path dependency of any particular UTXO relative to the overall network supply.

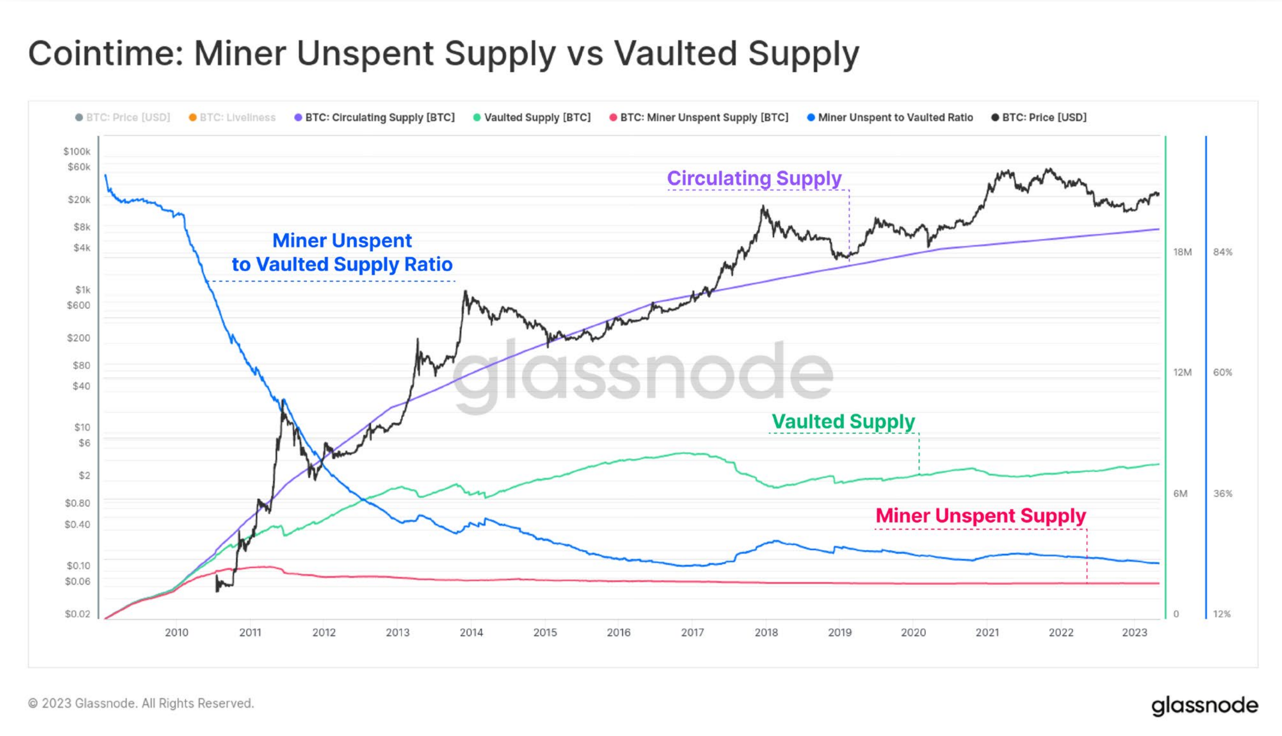


Vaulted Supply does not necessarily need to align with UTXO derived metrics such as Miner Unspent Coins. Vaulted Supply is effectively consolidating all stored cointime into an equivalent supply of 'never moved' coins. This compresses coinblocks with relative inactivity levels grading from lost to deep cold storage, to recently acquired, into a homogeneous 'unspent' supply region.

To illustrate the relationship between Miner Unspent Coins and Vaulted supply, the chart below shows the following curves:

- Circulating Supply (RHS-1).
- Vaulted Supply (RHS-1).
- Miner Unspent Supply (RHS-1) coins that have never been spent from the coinbase UTXO.
- Miner Unspent to Vaulted Supply Ratio (RHS-2) presenting the relative proportion of vaulted supply contributed by Miner Unspent Supply.

It can be seen that the proportion of Vaulted supply represented by Miner Unspent supply has steadily descended from 100% (Satoshi era) to 23.06% as of 8-May-2023.



Data as of 8-May-2023. Past performance is not indicative of future results.

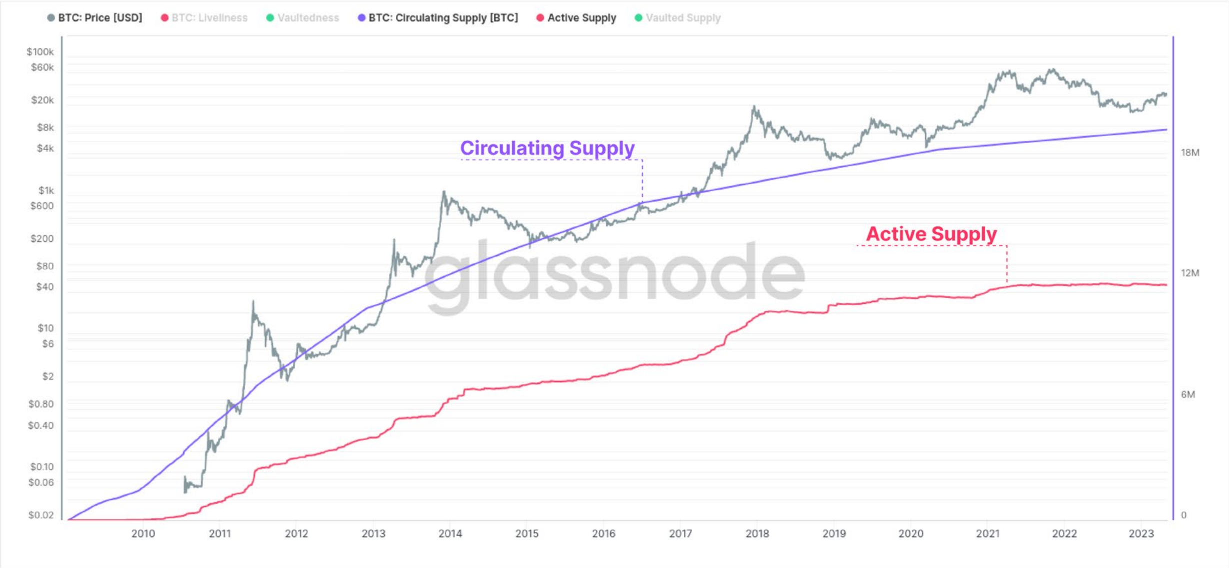
Active Supply

It therefore follows that multiplication of Circulating Supply by Liveliness will yield the opposing region of the supply: **the Active Supply**.

$$
\begin{aligned}
Active\ Supply &= Circulating\ Supply - Vaulted\ Supply \\
&= Circulating\ Supply * (1 - (1 - Liveliness)) \\
&= Circulating\ Supply * Liveliness \\
&= Circulating\ Supply * \frac{\sum CBD}{\sum CBC}
\end{aligned}
$$

Active Supply describes an equivalent sum of Bitcoin which has experienced a complete expenditure of all its accumulated cointime. Active Supply can be considered to be the economically meaningful coin volume which is actively participating in the Bitcoin economy.

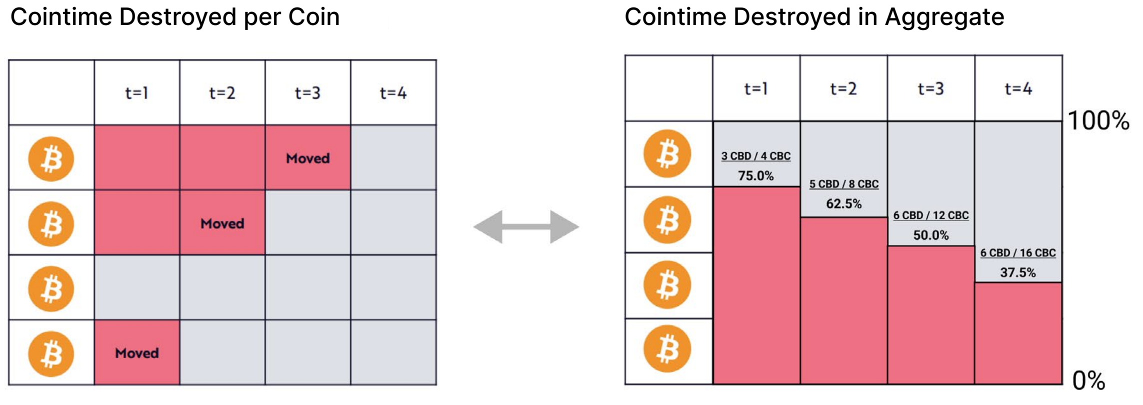
Cointime: Active Supply



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

Revisiting our 4x4 model network, we can rearrange the total coinblocks destroyed in a similar manner, with the aggregate result reflecting network Liveliness.



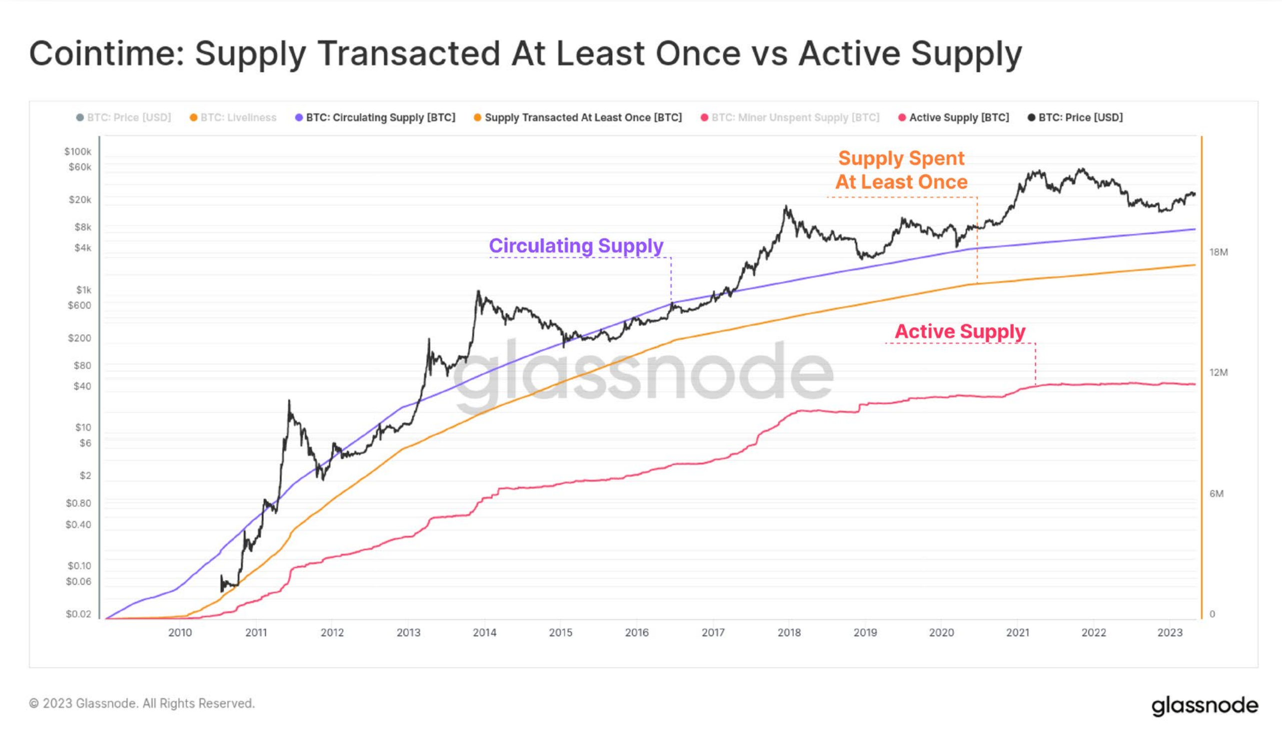
Active Supply does not necessarily need to align with UTXO-derived metrics such as Coins Transacted at Least Once. Active Supply is effectively consolidating all destroyed cointime and returning an equivalent supply volume of 'economically active and mobile' coins. This compresses coinblocks with relative activity levels grading from just spent to recently stored, to moved only once, into a homogeneous 'spent' supply region.

For example, a UTXO from 2011 may have transacted only once soon after it was minted, but has never moved since. Thus it has primarily contributed to Vaulted Supply and minimally to Active Supply.

To illustrate the relationship between Supply Transacted at Least Once and Active Supply, the chart below shows the following curves:

- Circulating Supply.
- Active Supply.
- Supply Transacted at Least Once—coins which have experienced at least one spending transaction after minting by miners.

It can be seen that Supply Transacted at Least Once is significantly higher than Active Supply, which is the result of the latter metric consolidating all cointime expenditure into the densest volume of fully expended coins (effectively a binary system of supply never spent or spent).

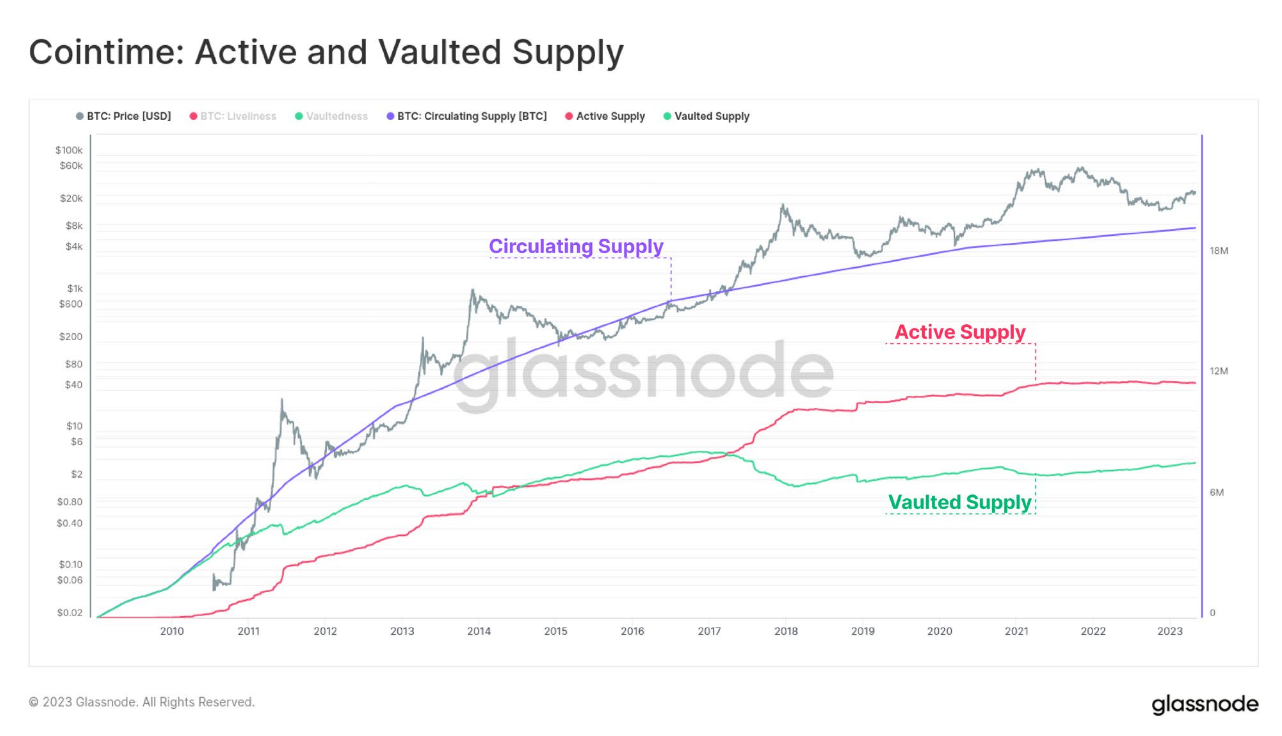


Data as of 8-May-2023. Past performance is not indicative of future results.

The Symmetry of Cointime Economics

And thus we have a complete description of the Circulating Supply segmented into an 'economically active portion' (Active Supply) and an 'economically inactive portion' (Vaulted Supply). These three supply curves are presented in the chart below.

$$Circulating\ Supply = Active\ Supply + Vaulted\ Supply$$



Data as of 8-May-2023. Past performance is not indicative of future results.

If we rearrange the equations above, we can establish that the ratio between Vaulted Supply and Circulating Supply is equal to the ratio of cumulative coinblocks stored and cumulative coinblocks created (a.k.a. Vaultedness).

$$\frac{Vaulted\ Supply}{Circulating\ Supply} = \frac{\sum CBS}{\sum CBC}$$
$$= Vaultedness$$

By completing the same rearrangement for Active Supply, we arrive to an elegant symmetry between the three supply domains and their associated cumulative coinblock primitive.

$$\frac{\sum CBC}{Circulating\ Supply} = \frac{\sum CBD}{Active\ Supply} = \frac{\sum CBS}{Vaulted\ Supply}$$

Furthermore, our three principle metrics of Liveliness, Vaultedness, and A2VR can also be seen to describe ratios between these three supply regions.

$$Liveliness = \frac{\sum CBD}{\sum CBC} = \frac{Active\ Supply}{Circulating\ Supply}$$

$$Vaultedness = \frac{\sum CBS}{\sum CBC} = \frac{Vaulted\ Supply}{Circulating\ Supply}$$

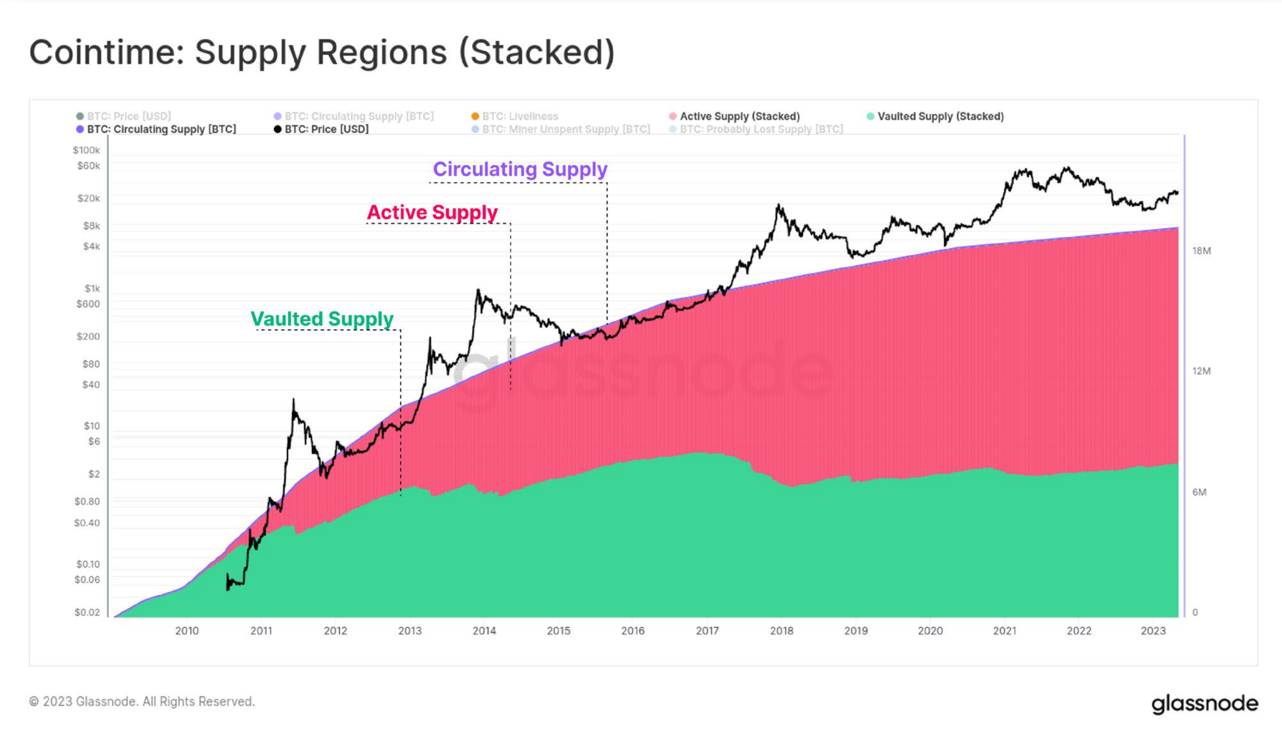
$$Activity\ to\ Vaulting\ Ratio = \frac{\sum CBD}{\sum CBS} = \frac{Active\ Supply}{Vaulted\ Supply}$$

Supply Region Analogies

By way of analogy, imagine a closed system containing water and a lower layer of sand. Consider Circulating Supply as the total volume of both sand and water. Active Supply is the water (spent volume) and Vaulted Supply is the sand (unspent volume) that precipitates to the bottom during any inactivity (upon block confirmation). The chart below presents a stacked supply region view of:

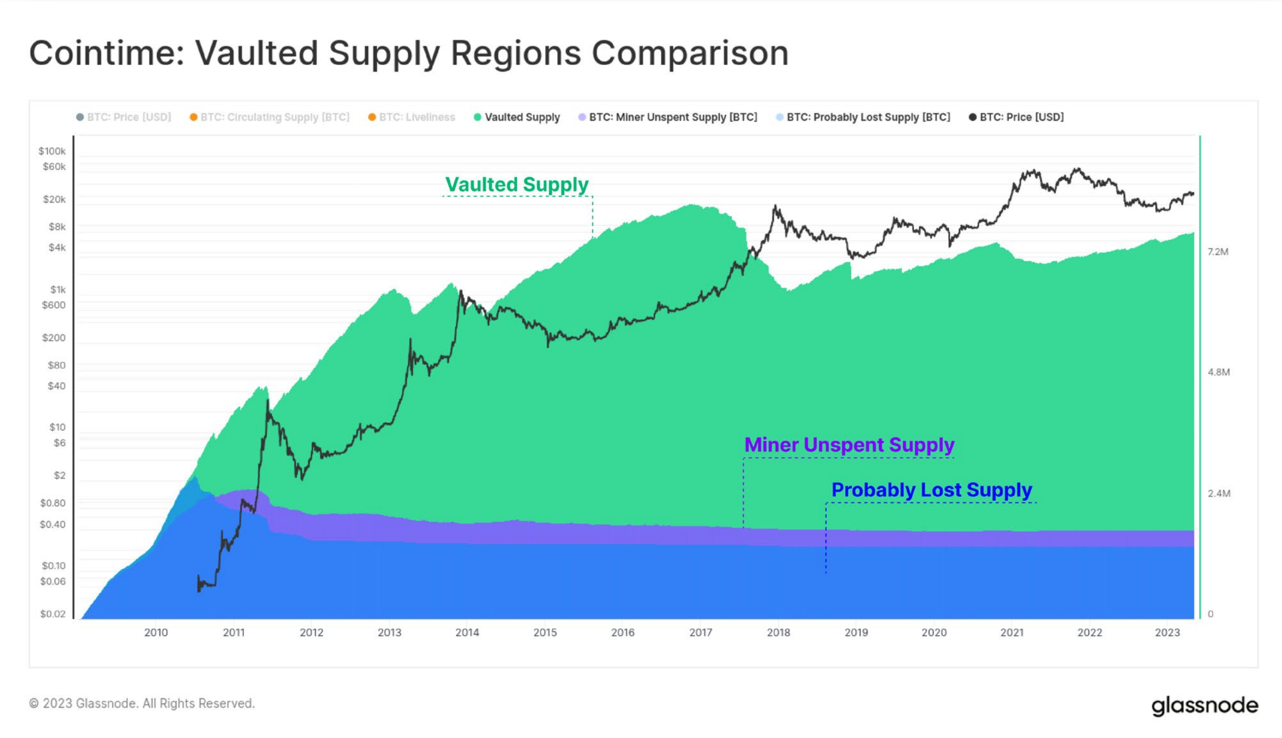
- Circulating Supply (line trace).
- Active Supply (area trace).
- Vaulted Supply (area trace).

The lowest levels of Vaulted Supply are the densest and least mobile sand grains (i.e. lost or unspendable coins), whilst grading higher up towards looser sand (i.e. HODLed but still accessible coins). The chart below presents a stacked supply region view of:



Data as of 8-May-2023. Past performance is not indicative of future results.

- Vaulted Supply.
- Miner Unspent Supply—coins which have never been spent after minting by a miner.
- Probably Lost Supply—coins which have not moved since the first traded BTC price in July 2010.

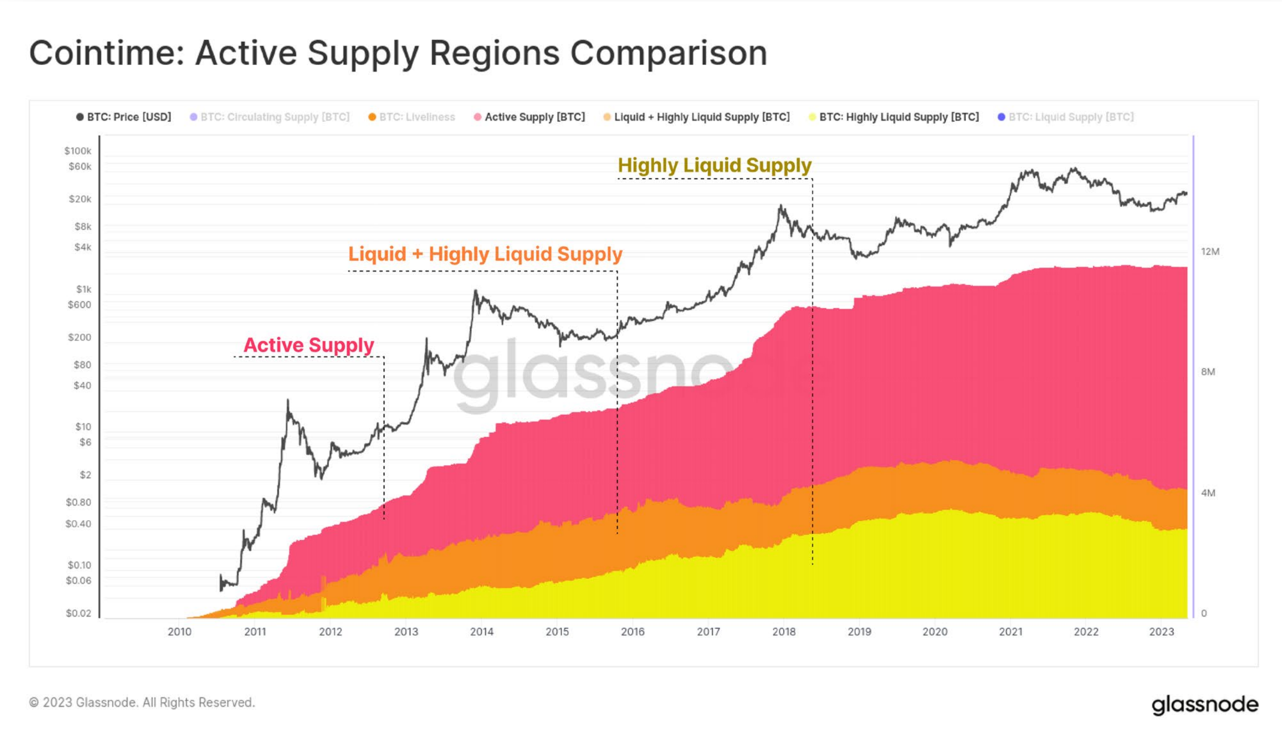


Data as of 8-May-2023. Past performance is not indicative of future results.

Whilst the calculation methodology differs, it is possible to appreciate the grading of Active Supply using a comparison to Highly Liquid and Liquid supply regions as determined by Glassnode prior work [8]. These two metrics describe coins that are held within wallets that are extremely to moderately active and thus regularly destroying all accumulated cointime (e.g., exchange hot wallets).

The chart below presents a stacked supply region view of:

- Active Supply.
- Liquid plus Highly Liquid Supply.
- Highly Liquid Supply—coins held in wallets which are extremely active.



Data as of 8-May-2023. Past performance is not indicative of future results.

Changes Between Supply Regions

The size of these two supply regions will change with every new block added to the chain as a result of three mechanisms:

1. **Change to Circulating Supply:** New coin issuance increasing the coin supply.
2. **Change to Active Supply:** Transactions destroying UTXOs and thus destroying cointime.
3. **Change to Vaulted Supply:** Unspent coins in the UTXO set creating and storing cointime.

Within the context of Bitcoin market cycles, there is generally a cyclical dominance in investor spending patterns whereby supply domain growth favours either Active or Vaulted Supply.

Change in Active Supply

Active Supply growth dominates when the volume of cointime destruction exceeds cointime creation (negative coinblock storage). This has historically been observed around periods of elevated market volatility such as bull markets (where longer-term investors take profits) and during major bear market selloff events (as investors panic).

If we consider the incremental change in Active Supply between blockheight N-1 and N, we can establish a relationship between changes in cointime and the change in Active Supply.

$$\begin{aligned} d(Active\ Supply)_N &= AS_N - AS_{N-1} \\ &= (CS_{N-1} + I_N) * \frac{\sum CBD_N}{\sum CBC_N} - CS_{N-1} * \frac{\sum CBD_{N-1}}{\sum CBC_{N-1}} \\ &= CS_{N-1} * (\frac{\sum CBD_N}{\sum CBC_N} - \frac{\sum CBD_{N-1}}{\sum CBC_{N-1}}) + I_N * \frac{\sum CBD_N}{\sum CBC_N} \\ &= [CS_{N-1} * (L_N - L_{N-1})] + [I_N * L_N] \\ &= [Circulating\ Supply_{N-1} * Concurrent\ Liveliness] \\ & \quad +[Issuance_N * Liveliness_N] \end{aligned}$$

$where;$
$AS_N, AS_{N-1}\ is\ Active\ Supply\ at\ block\ N,\ and\ N-1, respectively$
$CS_{N-1}\ is\ Circulating\ Supply\ at\ block\ N-1$
$I_N\ is\ Issuance\ at\ block\ N$
$L_N, L_{N-1}\ is\ Liveliness\ at\ block\ N,\ and\ N-1,\ respectively$

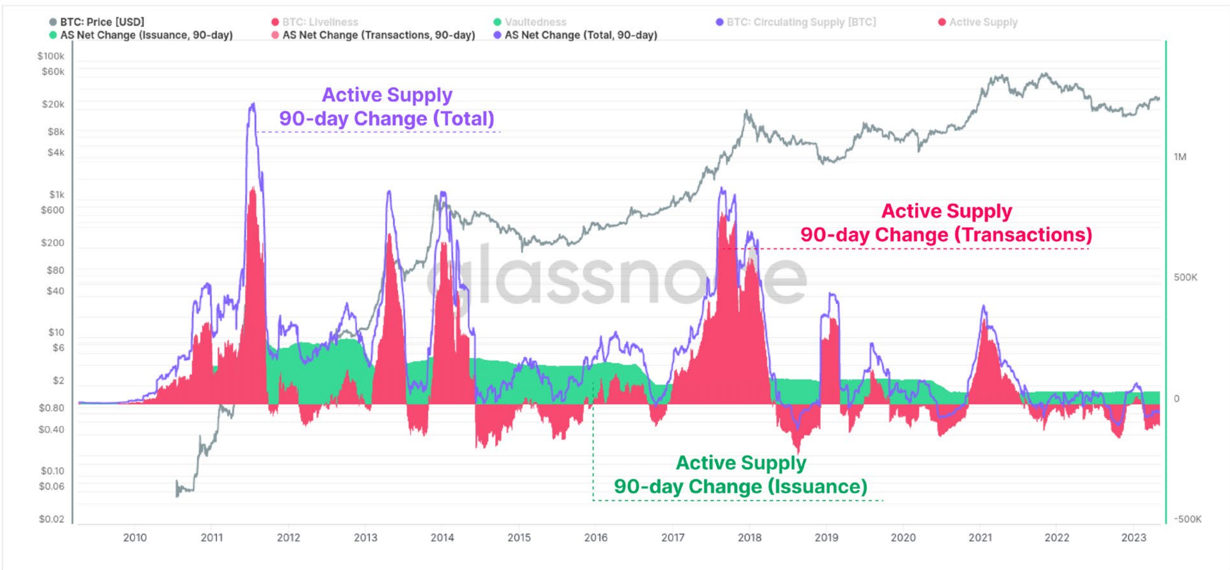
It can be seen that changes in Active Supply are a function of two components:

1. **Transactions** which change the Active-to-Vaulted cointime balance of the existing supply between blockheights N and N-1. This is **regulated by Liveliness Incremental Change**.

2. **New issuance** which is sorted into Active and Vaulted Supply corresponding to the newly adjusted liveliness at blockheight N. This is **regulated by Liveliness**.

The chart below shows a 90-day change in Active Supply, decomposed into the Issuance component and Transaction component, compared to the sum total. The influence of bull markets become quite clear, as Active Supply growth is sourced primarily from transactions, a result of elevated incentives for investors to spend and take profits on older coins. Conversely, the transaction component of Active Supply change tends to turn negative during bearish trends as expenditure slows and greater accumulation takes place.

Cointime: Active Supply Net Change Decomposition (90-day)



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

Change in Vaulted Supply

Vaulted Supply growth dominates when the volume of cointime creation exceeds cointime destruction (positive coinblock storage). This is typically observed during periods of reduced market interest, volume, and general activity. Such structure is more commonplace in bear markets and early phase bull markets, as long-term investors accumulate and coins migrate into cold storage.

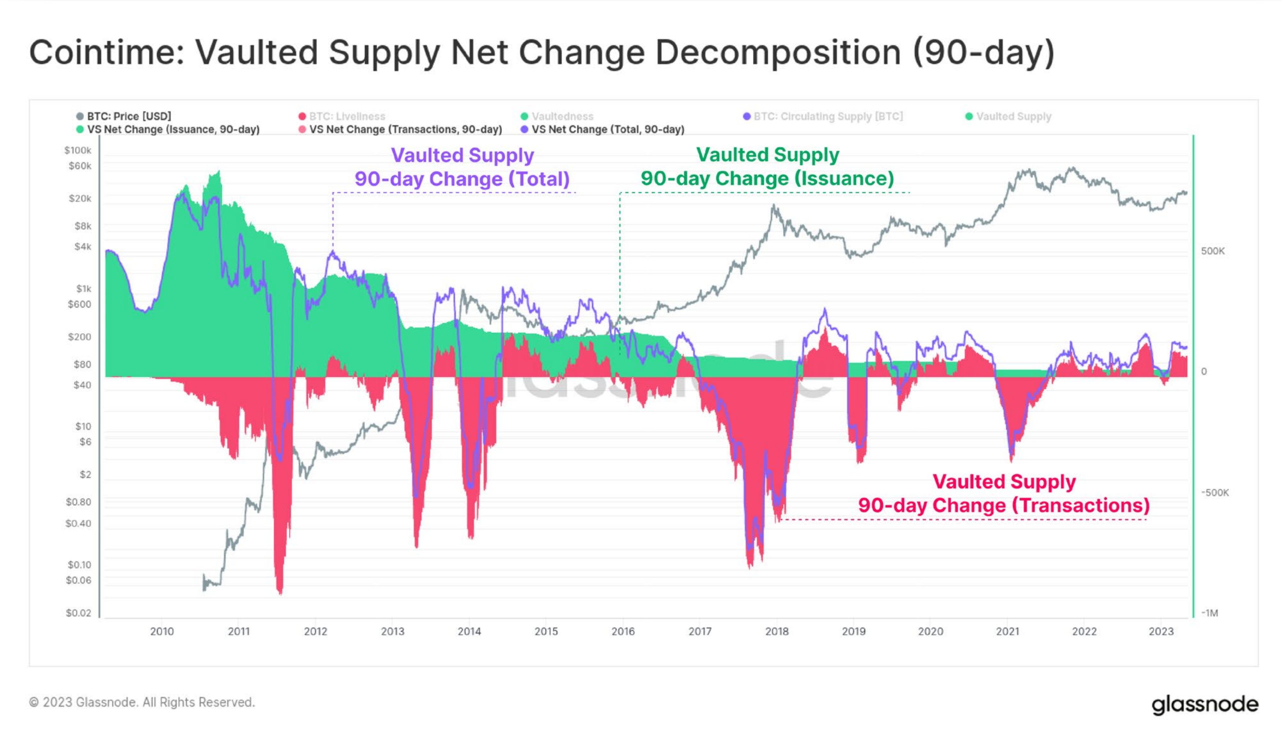
If we consider the incremental change in Vaulted Supply between blockheight N-1 and N, we can establish a similar relationship between changes in cointime and Vaulted Supply.

$$
\begin{aligned}
d(Vaulted\ Supply)_N &= VS_N - VS_{N-1} \\
&= (CS_{N-1} + I_N) * \frac{\sum CBS_N}{\sum CBC_N} - CS_{N-1} * \frac{\sum CBS_{N-1}}{\sum CBC_{N-1}} \\
&= CS_{N-1} * (\frac{\sum CBS_N}{\sum CBC_N} - \frac{\sum CBS_{N-1}}{\sum CBC_{N-1}}) + I_N * \frac{\sum CBS_N}{\sum CBC_N} \\
&= [CS_{N-1} * (V_N - V_{N-1})] + [I_N * V_N] \\
&= [Circulating\ Supply_{N-1} * Concurrent\ Vaultedness] \\
&\quad + [Issuance_N * Vaultedness_N]
\end{aligned}
$$

$where;$
$VS_N, VS_{N-1}\ is\ Vaulted\ Supply\ at\ block\ N,\ and\ N-1, respectively$
$CS_{N-1}\ is\ Circulating\ Supply\ at\ block\ N-1$
$I_N\ is\ Issuance\ at\ block\ N$
$V_N, V_{N-1}\ is\ Vaultedness\ at\ block\ N,\ and\ N-1,\ respectively$

Again we can identify these two components, with **Issuance regulated by Vaultedness** and **Transactions are regulated by Incremental Vaultedness**.

The chart below shows the 90-day change in Vaulted Supply, decomposed into the Issuance component and Transaction component, compared to the sum total. The heavy influence of early miner issuance into Vaulted supply is evident during the Satoshi era, as well as marked reductions in Vaulted Supply during bull markets as longer-term investors take profits.



Data as of 8-May-2023. Past performance is not indicative of future results.

Coinblocks Destroyed as an Economic Primitive

From the above studies, we can see that changes in Active and Vaulted Supply, and thus shifts in the economic balance of Bitcoin are a function of two sets of variables:

1. **Known and deterministic variables:** Issuance, Circulating Supply, and Coinblock Creation which are known with respect to blockheight given Bitcoin's pre-determined supply curve (with some nuance regarding miners who choose not to mint their allocated issuance).

2. **Unknown variables:** Coinblock destruction (expressed via Liveliness and inverse Vaultedness), which is related to market transactional activity, investor behavior patterns, and economic throughput.

Thus, Coinblocks Destroyed (CBD) can be argued to be the foundational variable when describing Bitcoin market activity within the Cointime Economics framework. We thus consider CBD to be one of the lowest level and most distilled measurement of shifting economic trends for Bitcoin.

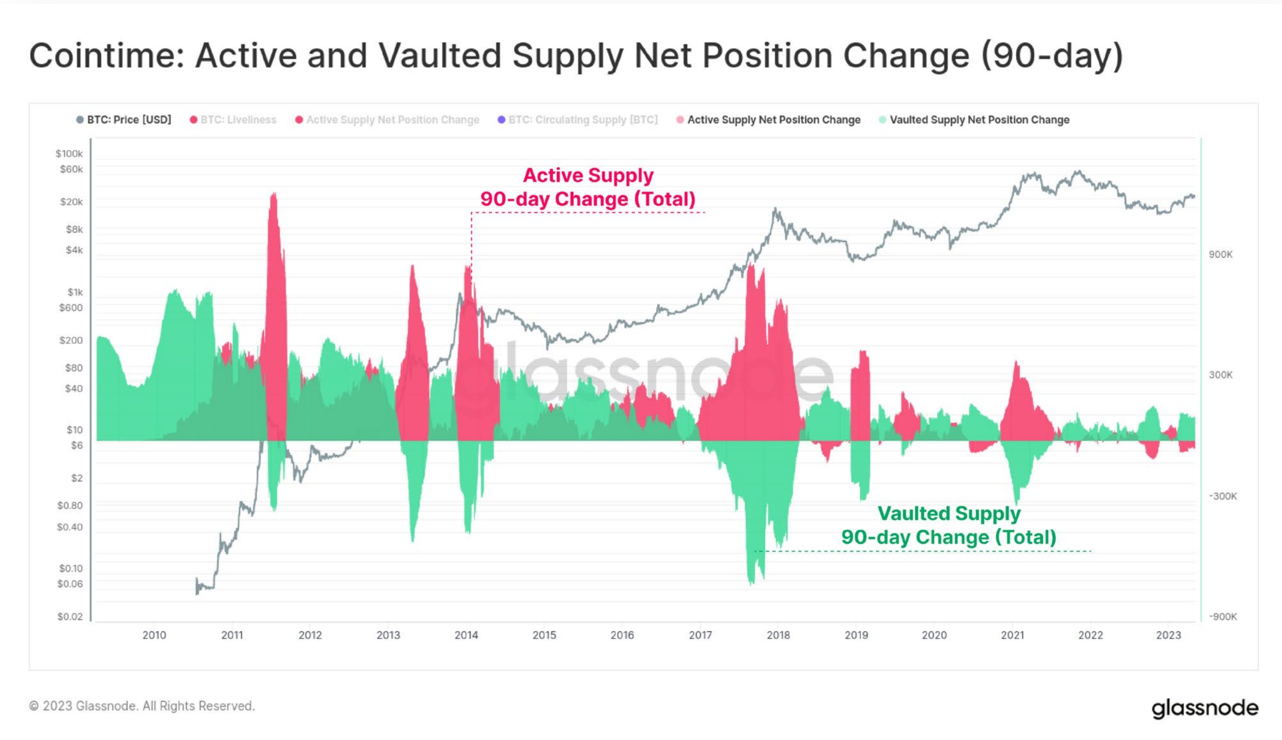
Supply Net Position Change

With the underlying drivers of change to cointime supply regions established, we can compute a Net Position change metric for each region.

$$Active\ Supply\ Change_{90} = Active\ Supply_N - Active\ Supply_{N-90}$$

$$Vaulted\ Supply\ Change_{90} = Vaulted\ Supply_N - Vaulted\ Supply_{N-90}$$

The 90-day Net Position Change traces below demonstrates how changes in Active and Vaulted Supply are inversely correlated. However, the absolute values are not necessarily equal and opposite. Active Supply can increase more than Vaulted Supply decreases (and vice-versa) due to the influence of newly minted coins (issuance), and changes in both supply regions can be positive (but not negative) at the same time.



Data as of 8-May-2023. Past performance is not indicative of future results.

Nuances in Relating Cointime Supply Regions Back to a UTXO Framework

The following section details the nuances and intricacies when relating cointime supply regions back into a UTXO framework. It is important to remember that, whilst all cointime is fungible, observations relating to the specific UTXO level can be useful to illustrate the underlying mechanics yet are not necessary for application of the framework in practical analysis.

The following section is quite technical and discusses many fine mechanical details. Some readers may chose to pass over this section, as it will appeal more to analysts considering implementation of the Cointime Economics framework in their practice.

Reminder: the term 'coin' is used here to describe the BTC volume held within a UTXO.

By definition:

- Every coin which has never been spent has only contributed to and is entirely contained within Vaulted Supply (i.e., Satoshi's coins, Miner Unspent coins, etc).
- Every coin that was included in the last mined block (block N), has destroyed all accumulated cointime up to blockheight (N-1), which is now contained within Active Supply.
- The exception is the newly created coinblocks that are created by these spent coins upon block confirmation (this will be explored further in Section 5).
- All remaining coins which do not fit within these two extremes have contributed, in part, to both Active and Vaulted Supply, as follows:
    - All cointime accumulated since the containing UTXO was confirmed in a block is contained within Vaulted Supply.
    - All cointime accumulated between the coinbase transaction that the coin was minted in and the block height of its last confirmation is contained within Active Supply.

Change to Circulating Supply: Newly Minted Coins

The Bitcoin protocol design prevents miners from spending coins minted in a coinbase UTXO until they reach a maturity of 100 blocks. After the 100-block threshold, miners may choose to spend these coins or leave them unspent within the coinbase UTXO. As such:

Newly minted coins issued to miners will initially contribute cointime entirely to Vaulted Supply for a minimum period of 100-blocks.

Perhaps unintuitively, whilst this 100-block Vaulted Supply threshold is occurring in reality (at UTXO level), under a Cointime Economics framework, Active and Vaulted Supply regions will change in line with the newly adjusted network Liveliness/Vaultedness values upon block confirmation. Thus, newly mined coins in block N are immediately sorted into Active and Vaulted Supply by the updated Liveliness value at block N.

Change to Active Supply: Transactions and Destruction

At mined block N, all confirmed transactions will destroy the input UTXOs and all accumulated cointime stored within them up to blockheight N-1.

Destroying a UTXO (spending it) destroys all accumulated cointime up to, but not including, the blockheight of confirmation. This cointime is transferred from Vaulted Supply into Active Supply.

Additionally, the moment the transaction is confirmed, the new set of created UTXOs will generate cointime, which are added back into Vaulted Supply.

Changes to Vaulted Supply: UTXOs and Storage

At the time when block N is mined, the entire coin supply will create cointime. This includes newly mined coins and spent coins which are confirmed in block N.

Every unit of coin in the supply will generate an equivalent unit of coinblocks per block. This volume of cointime is assigned entirely to Vaulted Supply.

Asymptotic Network States

A nuance of these observations is that a network state where Liveliness is equal to 1 cannot exist (i.e., where Active Supply is equal to Circulating Supply).

Imagine a theoretical scenario where all UTXOs (containing the entire Circulating Supply) are spent, and are awaiting confirmation in block N. The following sequence of states will occur:

- Unconfirmed transactions will enter the mempool, but as yet no cointime has been destroyed, as no block confirmation has taken place. Thus the existing balance of Active and Vaulted Supply remains unchanged from block N-1.
- Upon confirmation of block N, all accumulated cointime up to blockheight N-1 is destroyed and transferred to Active Supply. This theoretically makes Vaulted Supply equal to zero.
- Simultaneously, the entire circulating supply will now be contained in a set of new UTXOs, that will immediately create cointime upon confirmation of block N. This cointime will be added to Vaulted Supply.

As such, we have the following asymptotic network states:

- **Liveliness is asymptotic to a value of 1** as is it impossible to achieve a network state where cumulative coinblocks stored is equal to 0. The maximum possible value of total coinblocks destroyed is equal to all-time coinblock creation, minus Circulating Supply.

$$\begin{aligned} \sum CBD_{max,N} &= \sum CBC_N - Circulating\ Supply_N \\ Liveliness_{max,N} &= \frac{\sum CBC_N - Circulating\ Supply_N}{\sum CBC_N} \\ &= 1 - \frac{Circulating\ Supply_N}{\sum CBC_N} \end{aligned}$$

- **Vaultedness is asymptotic to a value of 0**, as the entire Circulating Supply will create coinblocks immediately upon block confirmation. The minimum value of total coinblocks stored is therefore equal to Circulating Supply divided by all-time coinblock creation.

$$\begin{aligned} \sum CBS_{min,N} &= Circulating\ Supply_N \\ Vaultedness_{min,N} &= 1 - Liveliness_{max,N} \\ &= 1 - (1 - \frac{Circulating\ Supply_N}{\sum CBC_N}) \\ &= \frac{Circulating\ Supply_N}{\sum CBC_N} \end{aligned}$$

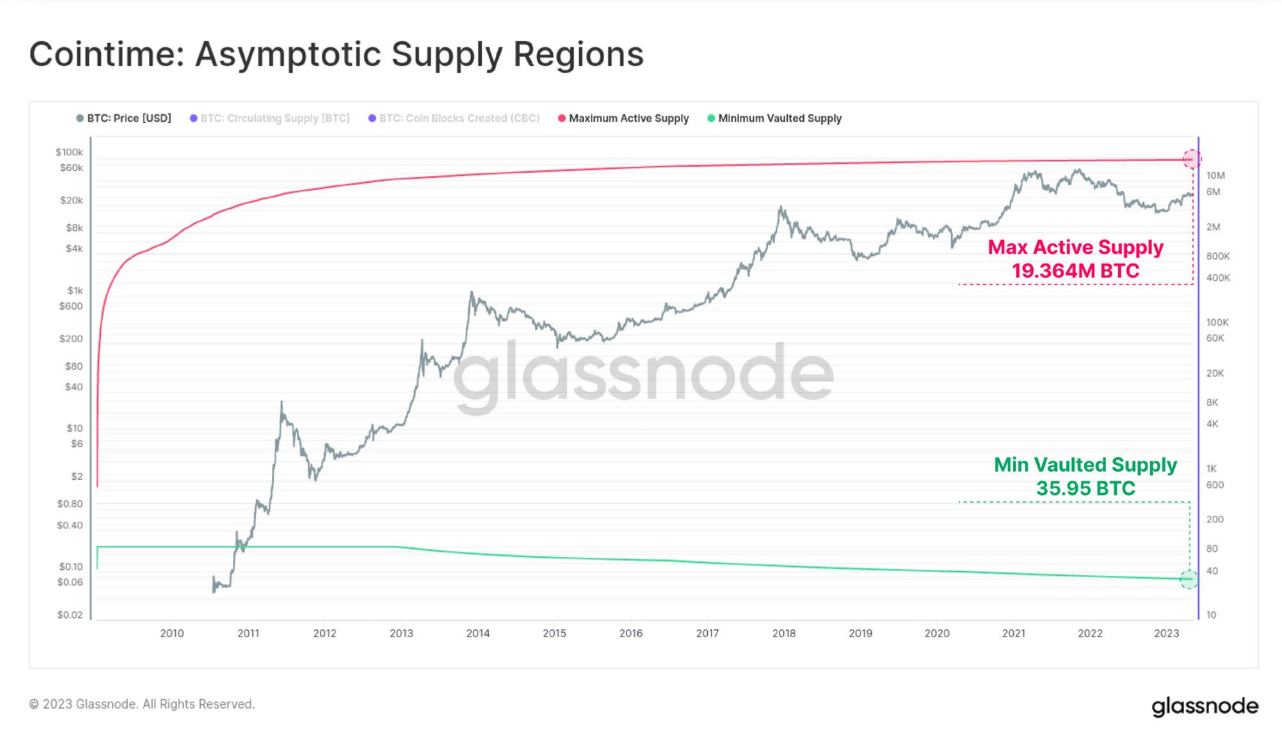
- **The maximum volume of Active Supply is therefore asymptotic to Circulating Supply** at each blockheight.

$$\begin{aligned} Active\ Supply_{max,N} &= Circulating\ Supply_N * Liveliness_{max,N} \\ &= Circulating\ Supply_N * (1 - \frac{Circulating\ Supply_N}{\sum CBC_N}) \end{aligned}$$

- **The minimum volume of Vaulted Supply is therefore asymptotic to 0**, reflecting the equivalent minimum volume of unspent BTC required to store coinblocks created by the Circulating Supply at each blockheight.

$$\begin{aligned} Vaulted\ Supply_{min.N} &= Circulating\ Supply_N * Vaultedness_{min,N} \\ &= Circulating\ Supply_N * \frac{Circulating\ Supply_N}{\sum CBC_N} \end{aligned}$$

As of 8-May-2023, the maximum Active Supply is more than 19.364M BTC, whilst the minimum Vaulted Supply is just 35.95 BTC.



Data as of 8-May-2023. Past performance is not indicative of future results.

[7] *Source: Blummer, Tamás, et al. "A Primer on Bitcoin Investor Sentiment and Changes in Saving Behavior", Medium, 2018.*
https://medium.com/@adamant_capital/a-primer-on-bitcoin-investor-sentiment-and-changes-in-saving-behavior-a5fb70109d32

[8] *Source: Schultze-Kraft, Rafael, et al. "78% of the Bitcoin Supply Is Not Liquid", Glassnode, 2020.*
https://insights.glassnode.com/bitcoin-liquid-supply/

Economic Models

The foundations of Active and Vaulted Supply offer us an opportunity to better characterize and quantify economic activity within the Bitcoin network, accounting for, and discounting, relative coin mobility. The following suite of metrics use a **Cointime adjustment** to discount the influence of long dormant coins, whilst amplifying the impact on the economically active supply.

Economic Weight of Active Supply

Active Supply reflects an equivalent volume of BTC which has **spent all accumulated cointime** and is thus **economically active**. As such, Active Supply is the supply region that has primarily contributed to monetary velocity, has an immediate impact on day-to-day trade in the market and contributes to metrics such as velocity and realized value.

Active Supply is akin to Economic Kinetic Energy, representing coins that are liquid, mobile, and actively contributing to daily trade in the market. Expenditure of these coins is essentially an expected outcome, and thus holders spending these coins does not meaningfully disrupt the prevailing economic equilibrium.

Economic Weight of Vaulted Supply

Vaulted Supply reflects an equivalent volume of BTC which is unspent and has only ever accumulated cointime, and is thus economically inactive. Vaulted Supply is the supply region which stores the network's economic energy. The market gradually discounts the impact of these coins re-entering liquid circulation, but experiences an outsized net impact if/when they do.

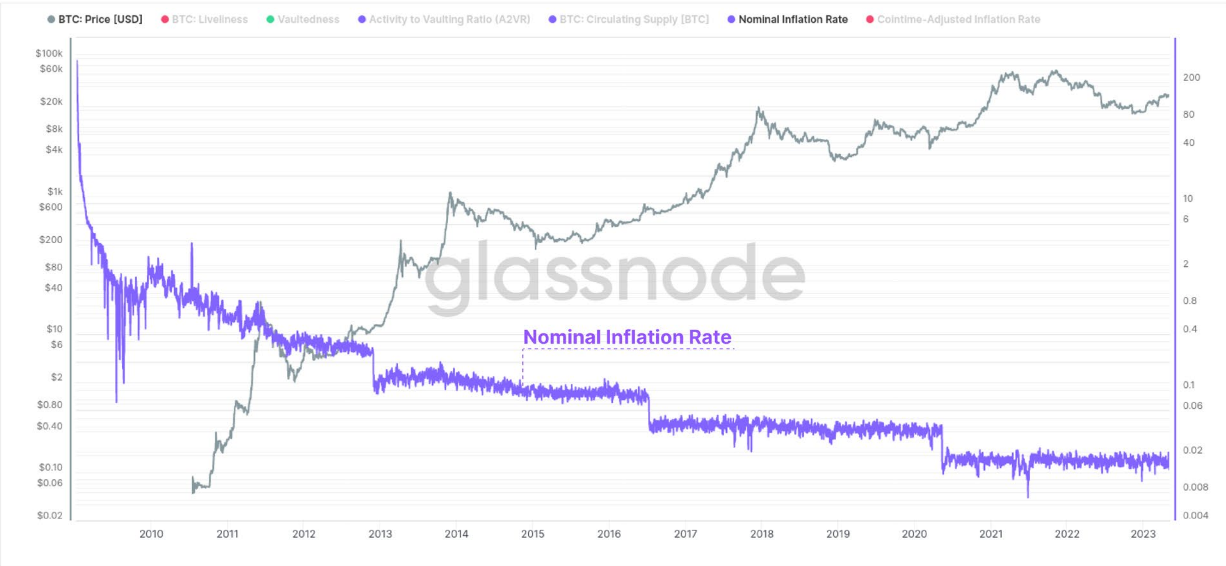
Vaulted Supply is akin to Economic Potential Energy, representing coins that are illiquid, tightly held by investors, or lost. These coins have low day-to-day mobility, however, in the event of spending, release an outsized amount of economic energy. As such, these coins can significantly alter the prevailing economic equilibrium (e.g., oversupplying bull market demand near tops).

Cointime-Adjusted Inflation Rate

We can now re-evaluate the influence of supply dilution by new issuance. The inflation rate of Bitcoin is traditionally measured in nominal terms, reflecting the annualized dilution of the circulating supply. Here, the issuance of newly minted coins to miners represents an effective dilution of all existing coin holders.

$$Nominal\ Inflation\ Rate = \frac{Issuance_{\ Annualized}}{Circulating\ Supply}$$

Cointime: Nominal Inflation Rate



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

However, this raises the question as to whether newly minted coins dilute all holders equally. For example, it could be argued that newly mined coins hardly dilute lost coins, as the holders cannot react, and the market has discounted the influence of lost coins over time. If this axiom is accepted, then it also means that by contrast, newly mined coins will instead impose a heavier dilution on the non-lost supply. Similarly, should previously discounted 'lost' coins be recovered, the market would likely consider this event to have a short-term dilution effect, despite the circulating coin supply remaining unchanged.

Given Bitcoin mining is a highly competitive industry, miners are generally required to distribute the vast majority of the mined coins to cover CAPEX and OPEX expenses. Following the above thought experiment, we can consider Active Supply to be the supply region which is most immediately impacted by issuance dilution.

By application of the **Active-to-Vaulting Ratio (A2VR)** weighting function as seen in section 3, we can achieve two objectives:

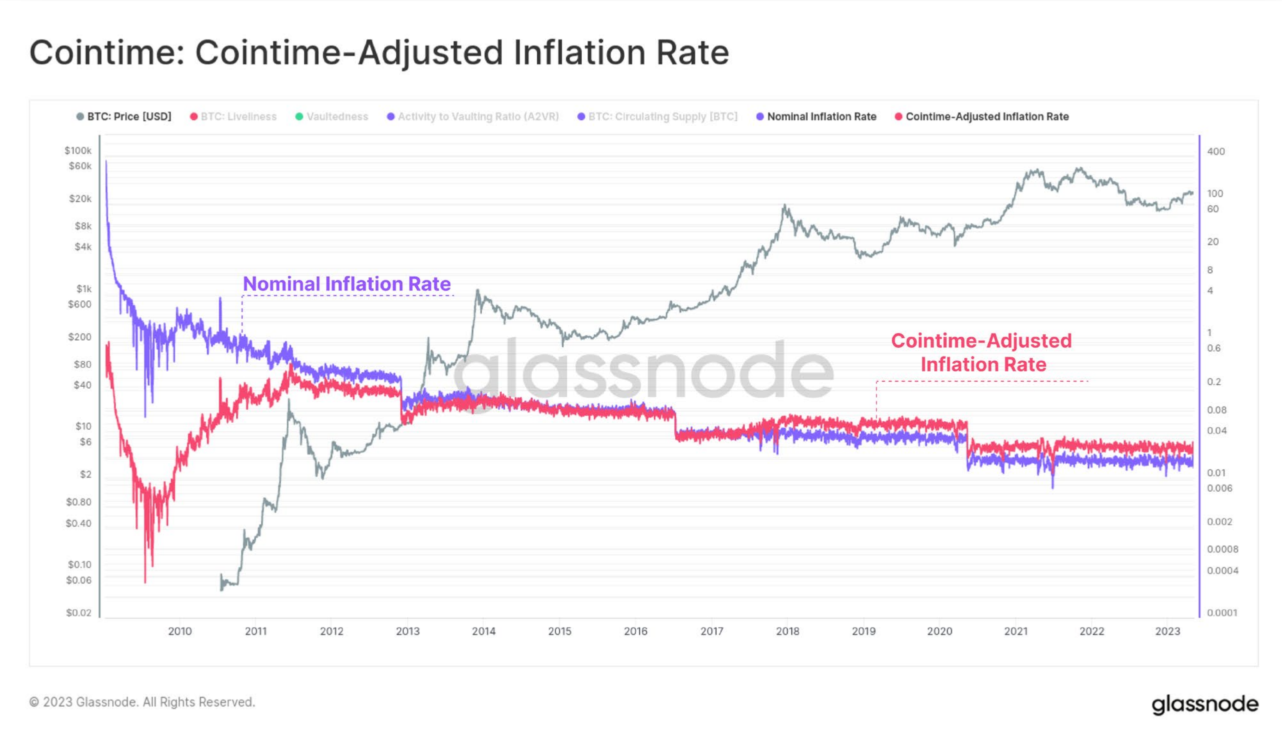
- Discount the dilution impact of new issuance on Vaulted Supply.
- Amplify the dilution impact of new issuance on Active Supply.

Thus we define the Cointime-Adjusted Inflation Rate which better captures the immediate market impact of coin issuance dilution on the economically active portion of the coin supply.

$$Cointime\ Adjusted\ Inflation\ Rate = \frac{Issuance_{\ Annualized}}{Circulating\ Supply} * A2VR$$

The chart below shows Nominal Inflation Rate and the **Cointime-Adjusted Inflation Rate**. A general framework for interpretation is as follows:

- As coinblock destruction increases, Active Supply increases, and the net impact of additional issuance reaching the market results in a larger Cointime-Adjusted Inflation Rate.
- As coinblock storage increases, Vaulted Supply increases, and the net impact of additional issuance diminishes, as coins are absorbed off the market, resulting in a lower Cointime-Adjusted Inflation Rate.



Data as of 8-May-2023. Past performance is not indicative of future results.

We can observe three distinct phases, with Cointime-Adjusted Inflation Rate providing what we view as a superior explanation of the relative market impact of newly issued coins, compared to the nominal inflation rate:

- **The Great Inflation (Genesis to 2013):** Despite a relatively high 50 to 25 BTC per block issuance, a large proportion of early miners (including Patoshi) lost, or never spent their coins. As such, the liquid supply that was available for acquisition in the market was far smaller than nominal terms would suggest. This led to Cointime-adjusted inflation rates starting at all-time-lows, and likely contributed to the extraordinary price appreciation from $0 to over $1,130 by late 2013.

- **The Convergence (2013 to 2017):** Nominal and Cointime-adjusted Inflation Rates converge as the fallout from the collapse of the Mt. Gox exchange and the loss of darknet market Silk Road is processed by the market. Industry infrastructure develops significantly during this period, including superior wallet technology, the growth of the longstanding exchanges like Bitstamp and Coinbase, the build out of ASIC mining operations, and the emergence of altcoin markets. Lost coins become more infrequent and a wider appreciation of the potential of Bitcoin as a monetary asset takes root.

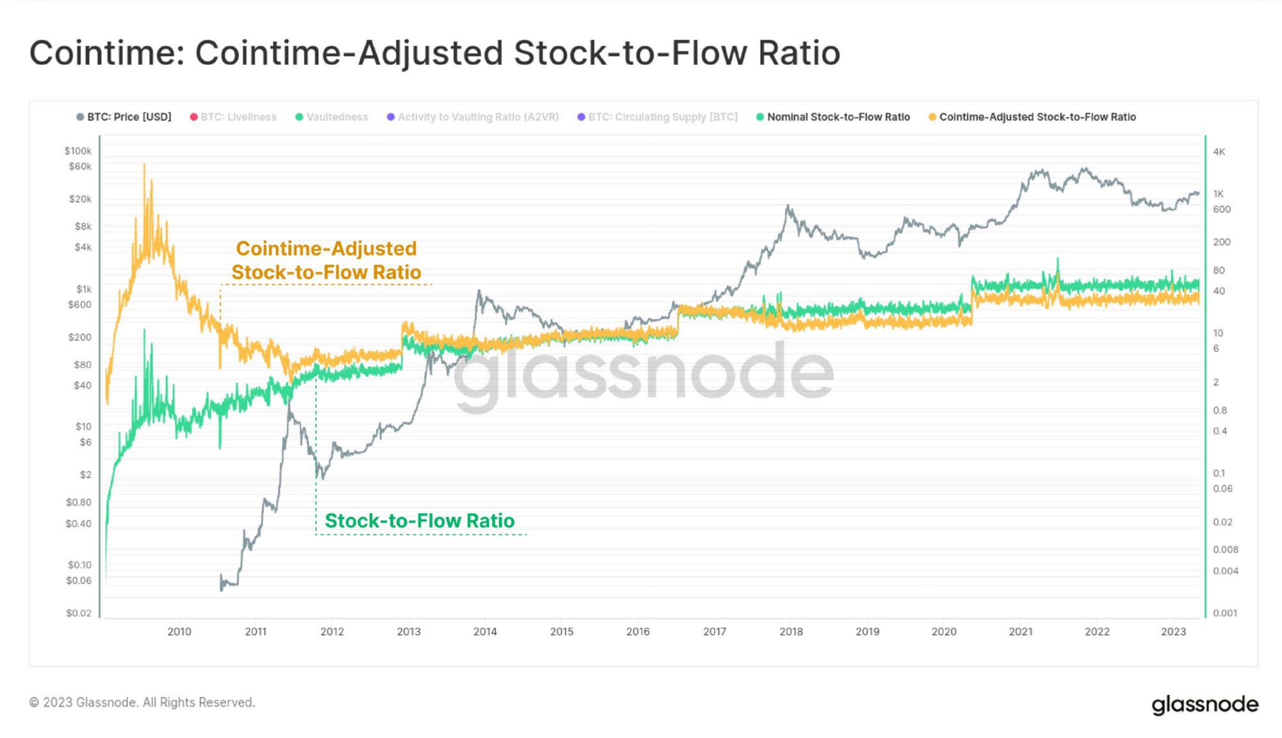
- **The Divergence (2017 to present)**: With the infamous parabolic bull market of 2017 came exponentially greater awareness and adoption of Bitcoin. Liquidity in markets deepened, derivatives markets were established, and a larger proportion of the coin supply remains economically active. Also of note was the Bitcoin Cash (BCH) hard-fork in August 2017, which motivated the spending of many long dormant coins to take advantage of and sell the perceived dividend coins on the BCH fork. Cointime-adjusted Inflation Rate trended higher than Nominal Inflation rate, reflecting a diminishing discount applied to lost Satoshi-era coins. This suggests an increasing influence of dilution, despite the 6.25 BTC/block issuance being comparatively smaller.

Bitcoin Era	Circulating Supply	Nominal Inflation Rate	Cointime-Adjusted Inflation Rate
The Great Inflation: Genesis to 2013	0 to 12M BTC	200% declining to 12%	0.004% climbing to 12%
The Convergence: 2013 to 2017	12M to 16M BTC	12% declining to 4.2% post-halving no. 2	12% declining to 4.2% post halving no. 2
The Divergence: 2017 Onwards	16M+ BTC	4.2% declining to 1.6% post-halving no. 3	4.2% climbing to 8.0% in 2018 before declining to 2.5% post-halving no. 3

Cointime-Adjusted Stock-to-Flow Ratio

By taking the inverse of the Cointime-adjusted inflation rate above, we can visualize this as a stock-to-flow ratio (S2F). Nominal S2F Ratio is seen to perpetually increase, whilst the Cointime-Adjusted S2F Ratio is extremely high at first, but diminishes relative to Nominal S2F.

This effectively describes an extreme scarcity during the era where early miners were not releasing mined coins into the economy. Conversely, we see a relatively lower scarcity rate in modern times, as fewer investors lose their coins and trading markets mature, resulting in a more mobile coin supply and a preference amongst investors trading for fiat denominated returns.



Data as of 8-May-2023. Past performance is not indicative of future results.

Cointime-Adjusted Velocity

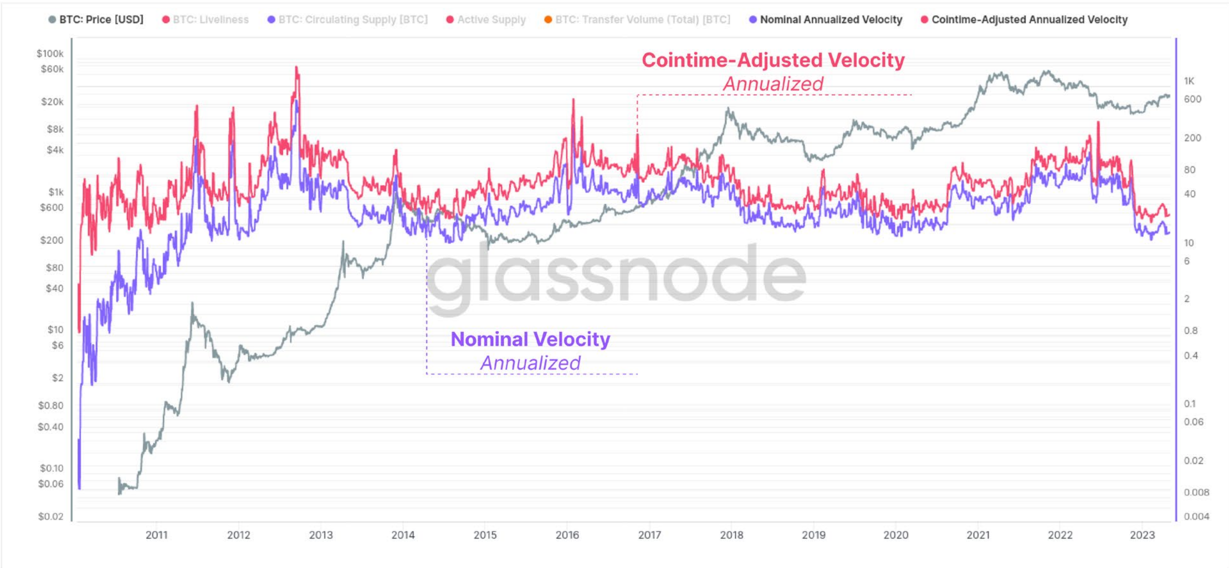
In a similar vein to inflation rates, we can apply a cointime-adjustment to Bitcoin's monetary velocity by substituting total circulating supply for active supply in the denominator of its calculation. This acts to account for the relative scale of economic volume throughput relative to the economically active proportion of the supply.

$$Nominal\ Velocity = \frac{TxVolume\ [BTC, Annualized]}{Circulating\ Supply}$$

$$Cointime\ Adjusted\ Velocity = \frac{TxVolume\ [BTC, Annualized]}{Active\ Supply}$$

It can be seen that cointime-adjustment signals a higher monetary velocity than the nominal case. Intuitively, this makes sense, as lost coins are effectively discounted from this model, thus indicating that observed transfer volumes are larger relative to the non-lost monetary base, and suggesting that the actual churn of coins in the network is larger than previously estimated.

Cointime: Cointime-Adjusted Monetary Velocity



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

Vaulting Rate

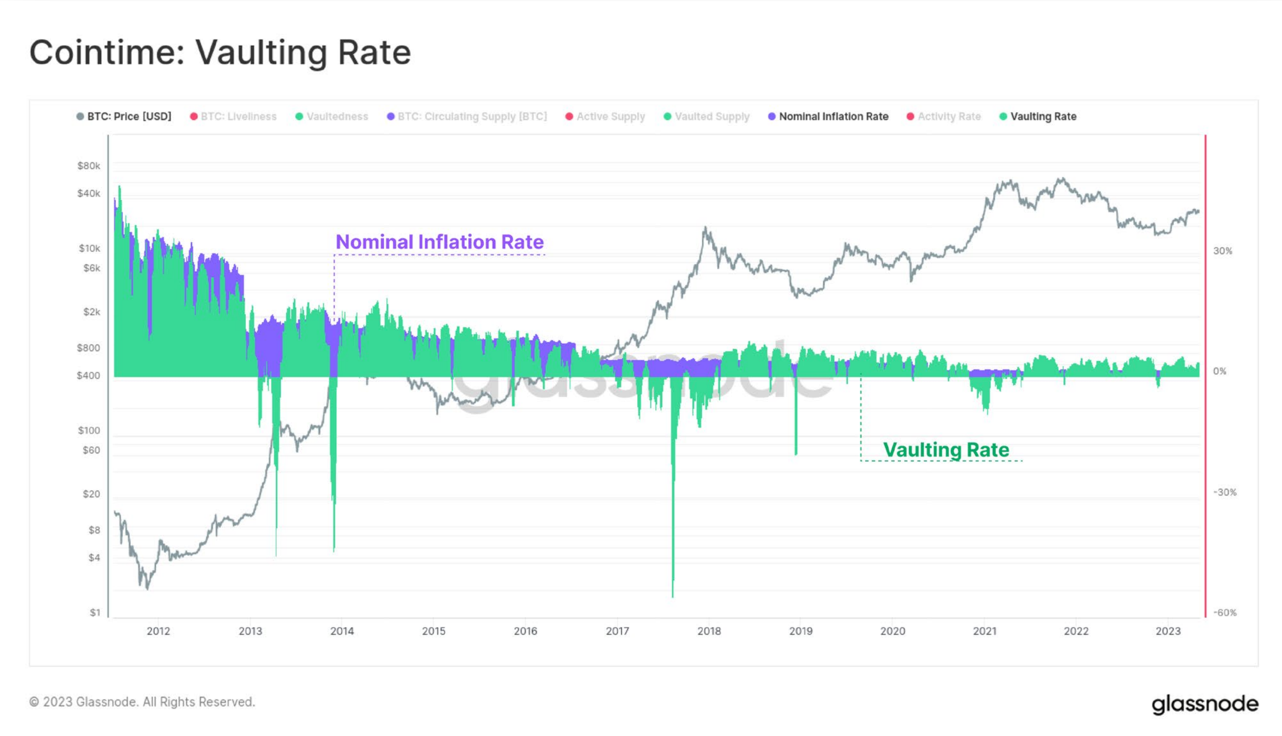
Further expanding on how cointime-derived primers can be used to extract the economic information of Bitcoin, we can calculate the rate at which users of the network vault supply. Instead of comparing network issuance to total supply, we comparing the daily rate of change of vaulted supply to total supply, otherwise named here as **Vaulting Rate**.

$$Vaulting\ Rate = \frac{d(Vaulted\ Supply)_{1-day} * 365}{Circulating\ Supply}$$

As shown in the chart below, two key takeaways emerge:

1. For the most part, the vaulting rate of the network is larger than its inflation rate. This makes sense from first principles given Bitcoin's price appreciation since its inception. Conversely, the vaulting rate drops below the inflation rate—and even below zero—during periods of exuberance at historical market tops, suggestive of the unusual rate of profit-taking and distribution by participants in the network.

2. Just as Bitcoin's inflation rate drops over time, its vaulting rate drops as well—and seemingly proportionally so. Inflation drops given Bitcoin's ever decreasing new issuance due to the deflationary nature programmed into the asset's monetary policy; the vaulting rate drops, we believe, because, over time, less coins are being permanently lost.



Data as of 8-May-2023. Past performance is not indicative of future results.

Re-Evaluating UTXO Realized Value

A foundational component of on-chain analysis is the **Pricestamping** of UTXOs. This involves the assignment of a USD denominated price at the time of each UTXOs creation and destruction. This enables the evaluation of realized and unrealized profit and loss, considering the change in value between when a coin was acquired and when it is spent (or at the time of evaluation if unspent).

The Realized Cap is one of the most important and influential Bitcoin valuation models and is a foundational metric within the on-chain analysis discipline. Originally published by Coin Metrics in 2018 [9], the Realized Cap reflects the cumulative sum of each unit of BTC in the supply, multiplied by the USD pricestamp of the containing UTXO at the time of creation.

$$Realized\ Cap = \sum(UTXO\ Value\ [BTC] * UTXO\ Pricestamp\ [USD])$$

In other words, the Realized Cap represents the USD denominated valuation of the entire coin supply, valued at the time each coin was last spent (and bought) on-chain. The following components contribute to the magnitude of the Realized Cap:

1. **Coins mined and spent before there was a recorded BTC market price have** an effective Realized value of $0.

2. **Coins which were mined after a market price was available** are valued at the pricestamp of the block N when they were minted. This is often referred to as the **Thermocap**.

$$Thermocap = \sum_{N=1}^{blk} Issuance_N * Price_N$$

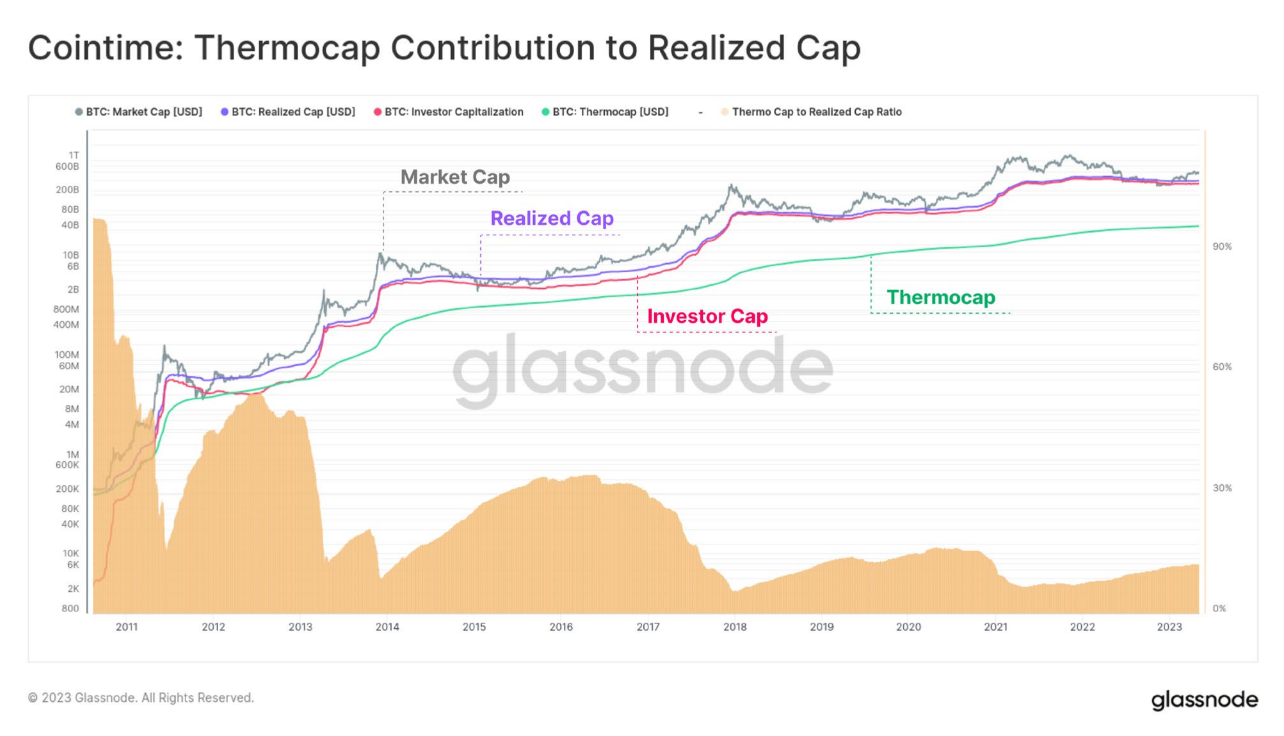
3. **Coins are then revalued each time they are spent on-chain**, creating an evolving realized valuation as owners realize profits, losses, or spend at break-even. This metric was previously defined by ARK Invest as the Investor Cap, calculated by summing the realized value across all Transactions (T) across all blockheights (N) (excluding miner coinbase transactions).

$$Investor\ Cap = \sum_{N=1}^{i}(\sum_{T=1}^{j} Input\ Value_T\ [BTC] * (Price_{spent} - Price_{created})_T[USD])_N$$

The Realized Cap can therefore be redefined as the sum of the Thermocap and the Investor Cap components.

$$Realized\ Cap = Thermocap + Investor\ Cap$$

The chart below shows the relative scale of the Thermocap and Investor Cap relative to the Realized Cap. We can see that the contribution of the Thermocap has steadily declined from 99% in 2010 to just 11% as of 8-May-2023. This is similar in scale to the 9.2% of the circulating coin supply which has never been spent by miners. Over time, we can see that the Investor Cap has become the dominant factor influencing the Realized Cap.



Data as of 8-May-2023. Past performance is not indicative of future results.

This raises one of the more interesting questions arising from the Cointime Economics framework, which we propose requires a reassessment of the Realized Price, and its popular positioning as an 'aggregate cost basis' of the market.

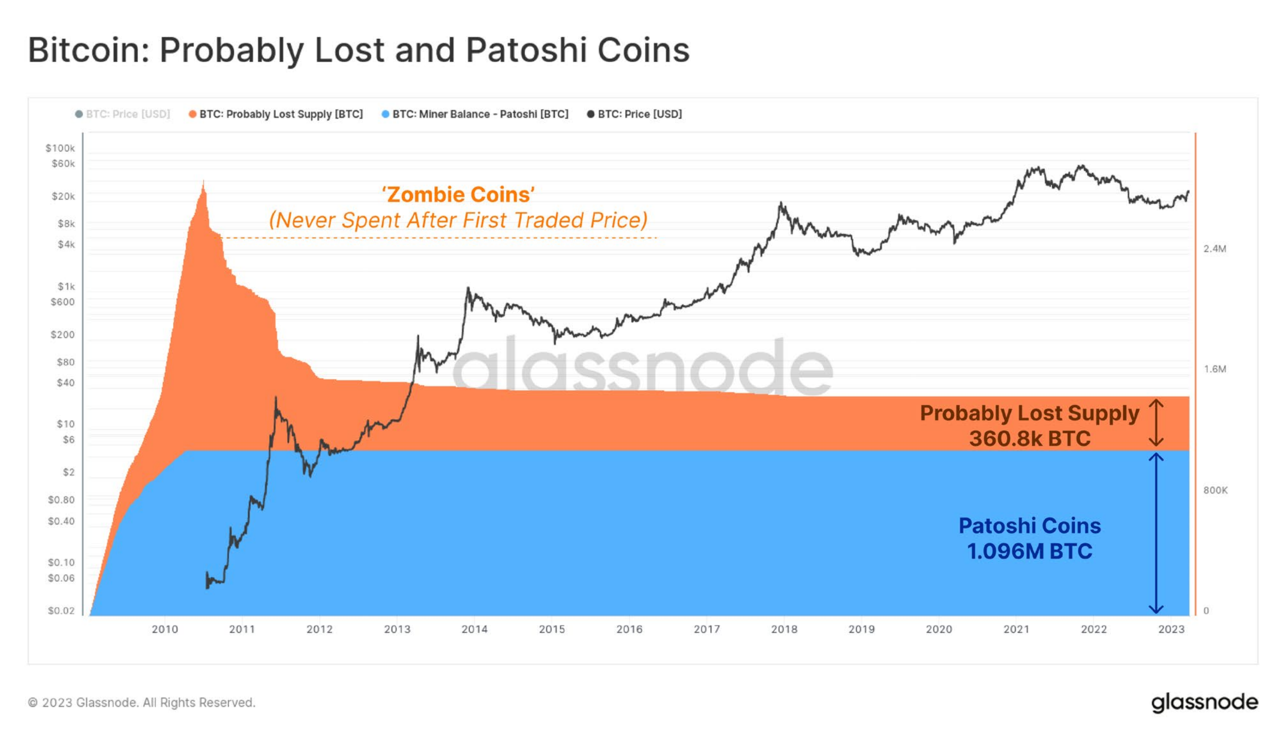
Reassessing the Realized Price

The Realized Price is traditionally calculated by dividing the Realized Cap by the Circulating Supply. This is often considered to be the average on-chain cost basis of the market.

$$Realized\ Price = \frac{Realized\ Cap}{Circulating\ Supply}$$

However, as we have established above, not all coins within the Circulating Supply have contributed a meaningful, non-zero value to the Realized Cap.

By way of example, the Patoshi coins (estimated to be some 1.096M BTC [10]) remain unspent to this day, and were mined before a market price was available. In fact, a total of 1.457M BTC [11] are considered 'zombie coins', which were mined prior to the first exchange traded price on 17-July-2010, but have not been spent since. These coins are most likely lost and have contributed zero value to both the Thermocap and Investor Cap, and thus contributed zero value to the Realized Cap.



Data as of 8-May-2023. Past performance is not indicative of future results.

As such, inclusion of these coins in the denominator to establish the Realized Price can be reasonably argued to unfairly dilute our estimate of the economically meaningful market cost basis. In the event these coins are spent, their realized value would be marked-to-market, and their inclusion in the denominator becomes valid (and is automatically computed by data providers).

Using the Cointime Economics framework, we will now propose a suite of alternative definitions for the 'Realized Price', which seek a superior estimation of the average on-chain acquisition price of the Bitcoin network via its market participants.

Active Realized Price and Active MVRV

Cointime Economics provides us with a robust methodology for calculating an equivalent volume of coin supply which can be considered to be economically active (Active Supply). This Active Supply has thus meaningfully contributed to the **Investor Cap**, which is the dominant influence over changes in the Realized Cap.

Thus, we propose that Active Supply provides an appropriate denominator compared to Circulating Supply, which both accounts for the economic contribution of coins whilst also discounting the influence of long-dormant and/or lost coins.

Active Realized Price is a first iteration towards a more representative estimate of the average cost basis for the Bitcoin market, which accounts only for coins which are economically active and automatically discounts as coin supply inactivity increases.

$$\begin{aligned}
Active\ Realized\ Cap &= \frac{Realized\ Cap}{Liveliness} \\
Active\ Realized\ Price &= \frac{Realized\ Cap}{Active\ Supply} \\
&= \frac{Realized\ Cap}{Circulating\ Supply} * \frac{1}{Liveliness} \\
&= \frac{Realized\ Price}{Liveliness}
\end{aligned}$$

Active Realized Price can also be described in terms of Investor and Thermocap components. This metric construction also better suits an interpretation as a cost basis model, effectively mapping the market ***Acquisition Cost divided by the Economically Active Supply***.

$$Active\ Realized\ Price = \frac{Thermocap + Investor\ Cap}{Active\ Supply}$$

$$Active\ Realized\ Price = \frac{Thermocap + Investor\ Cap}{Circulating\ Supply} * \frac{1}{Liveliness}$$

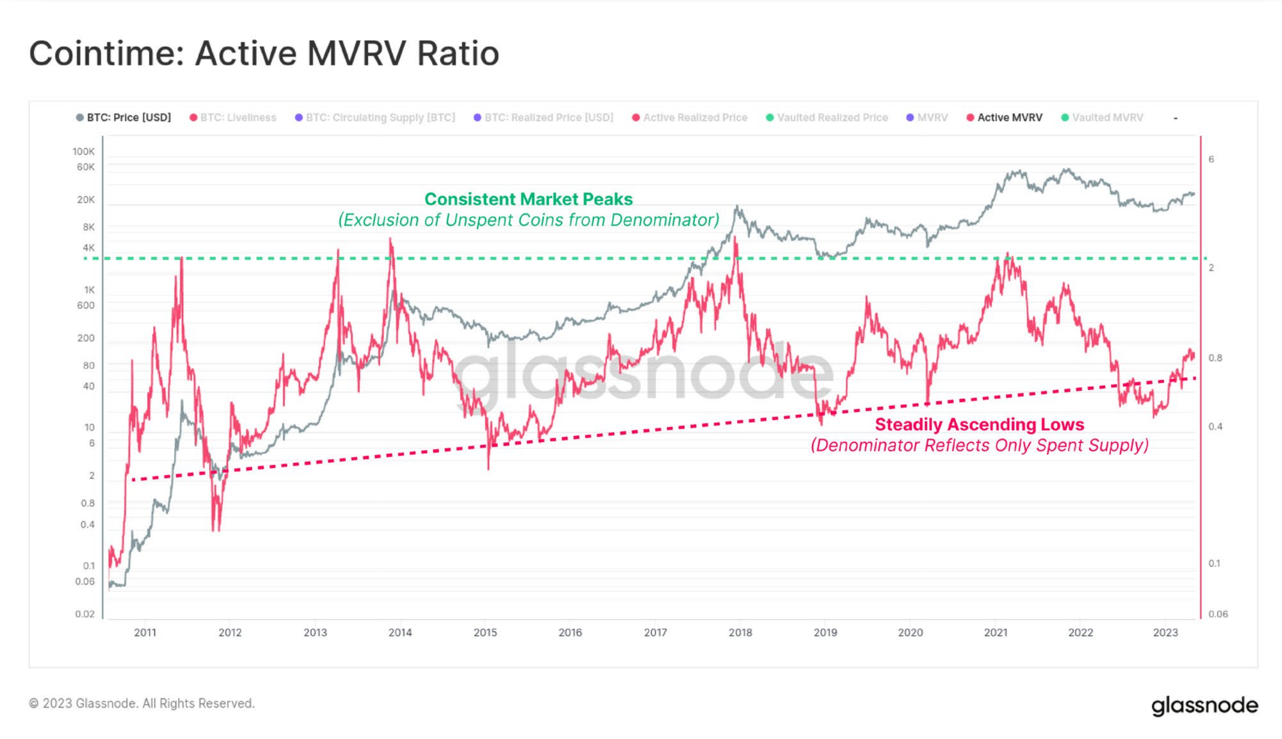
$$Active\ Realized\ Price = \frac{Thermocap + Investor\ Cap}{Circulating\ Supply} * \frac{\sum CBC}{\sum CBD}$$

Thus the Active Realized Price may be considered as the aggregate BTC 'acquisition price' (by hash power or in secondary markets), divided by the economically active supply (Active Supply). It is a self correcting model that will automatically adjust in the event that long-dormant coins are spent and re-enter circulation.

A natural extension of this result is to establish the Active MVRV Ratio as a measure of price deviation from the Active Realized Price and to gauge the unrealized profit/loss held within the economically active coin supply.

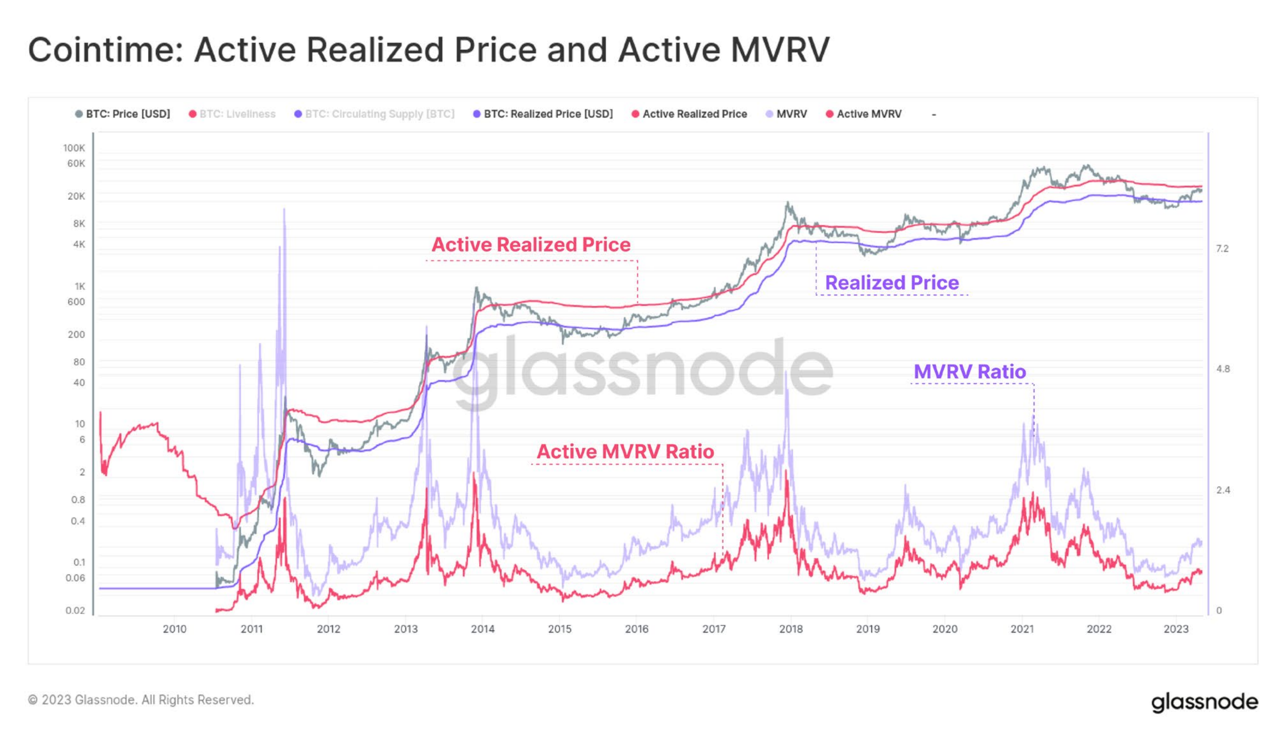
$$Active\ MVRV = \frac{Market\ Price}{Active\ Realized\ Price} = \frac{Market\ Cap}{Active\ Realized\ Cap}$$

Active MVRV accounts only for coins which are actively contributing to revaluing the Realized Cap through market cycles. By excluding inactive supply, Active MVRV has shown to be a more consistent and stable maximum value near historical cycle peaks. By discounting inactive Vaulted Supply, market lows are less reliably identified, as the accumulation behaviour, and thus cointime accretion that eventually establishes market floors, is discounted.



Data as of 8-May-2023. Past performance is not indicative of future results.

The chart below plots out the traditional Realized Price and MVRV Ratio, and the Active Realized Price and Active MVRV Ratio.

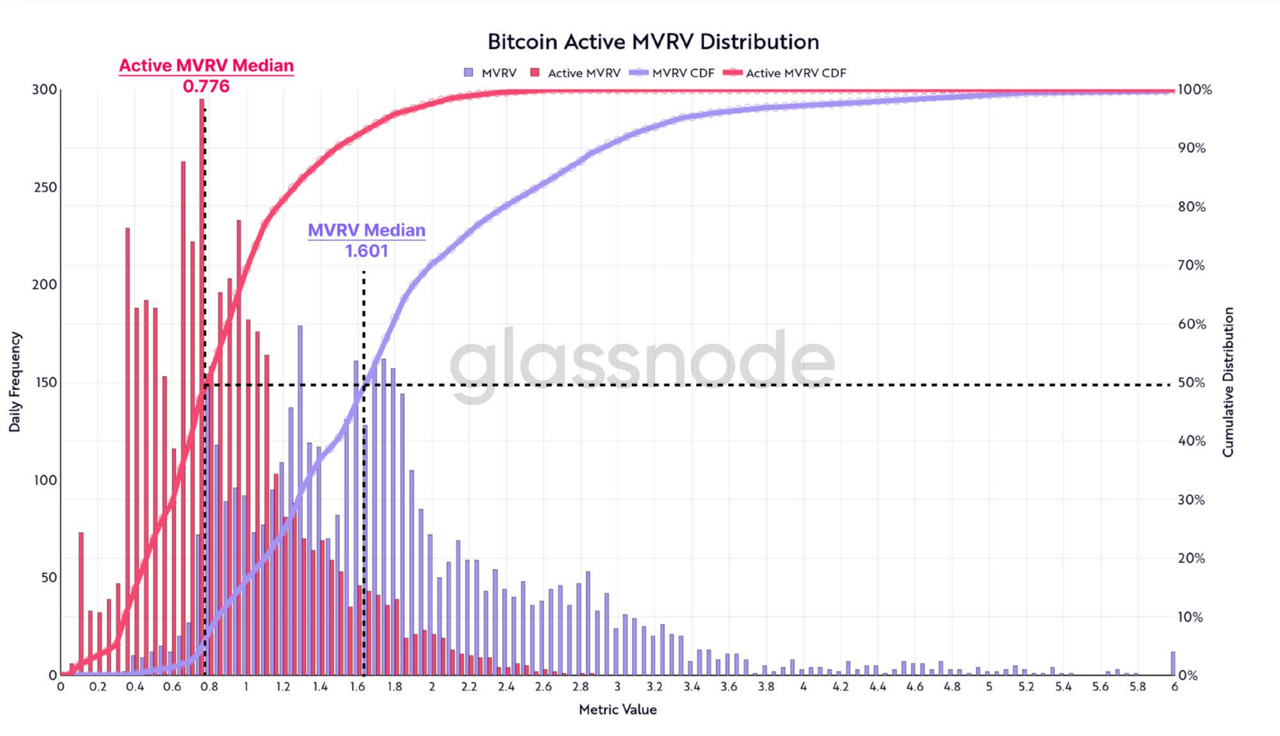


Data as of 8-May-2023. Past performance is not indicative of future results.

We can compare the relationship of each pricing model relative to previous market cycles through observations of both the shape of the MVRV curves, and also the histogram distribution of historical values. Note that an MVRV value of 1.0 signifies parity between price and the respective realized pricing model (the point where the aggregate market is at break even). This break-even level of 1.0, for a true cost basis model, should, in theory, function as a reference point of mean reversion.

- **Traditional MVRV** tends to trade well above a value of 1.0 for the majority Bitcoin trading history (75.88% of trading days as of 8-May-2023), falling below 1.0 during extended bearish trends. The median historical value is around 1.60, indicates that the typical condition is spot prices trading at a premium to the Realized Price (suggesting an aggregate unrealized profit).

- **Active MVRV** tends to oscillate around mean and median values of 0.804 and 0.776, respectively. This indicates that the coin supply is typically held a slight unrealized loss in aggregate. The median historical value of 0.80 is much closer to break even compared to the traditional MVRV (median of 1.60). Given the majority of daily transaction volume is held for less than a few months (please see prior research here [12]) this indicates Active Realized Price may indeed be providing a more representative market cost basis for the economically active supply.



Data as of 8-May-2023. Measured since inception. Past performance is not indicative of future results.

Metric	Median	Mean	Standard	Skew	History Trading > 1
MVRV	1.601	1.638	1.016	0.887	75.88%
Active MVRV	0.776	0.804	0.514	0.543	30.91%

The comparative distributions of MVRV and Active MVRV suggest that spreading the Realized Cap across the entire Circulating Supply, likely leads to excessive dilution when seeking an estimate of the market average on-chain acquisition price. It suggests that the traditional Realized Price model may be more appropriately considered as lower bound cost basis estimate, rather than a market average cost basis model.

If we price the 1.457M [11] BTC 'zombie coins' at the first exchange traded price of $0.4951, we can estimate an unrealized profit held in these lost coins. As of 13-January-2023, when the MVRV value was 1.0, this unrealized profit is around $28.945B. Whilst MVRV would indicate the aggregate market is at breakeven, the underlying reality is that the tremendous unrealized profits held within lost and ancient coins is offsetting large unrealized losses held by coins which were recently transacted within the 2020-2023 cycle.

This implies that today, a 'breakeven' MVRV value of 1.0 is in fact masking a large proportion of economically active BTC that is held at a significant unrealized loss.

Vaulted Realized Price and Vaulted MVRV

Naturally, a Vaulted variant of the Realized Price and MVRV may also be established, reflecting a spreading of all network realized value over the Vaulted coin supply (a.k.a. the 'HODLed and Lost' supply).

$$Vaulted\ Realized\ Cap = \frac{Realized\ Cap}{Vaultedness}$$

$$\begin{aligned} Vaulted\ Realized\ Price &= \frac{Realized\ Cap}{Vaulted\ Supply} \\ &= \frac{Realized\ Cap}{Circulating\ Supply} * \frac{1}{Vaultedness} \\ &= \frac{Realized\ Price}{Vaultedness} \end{aligned}$$

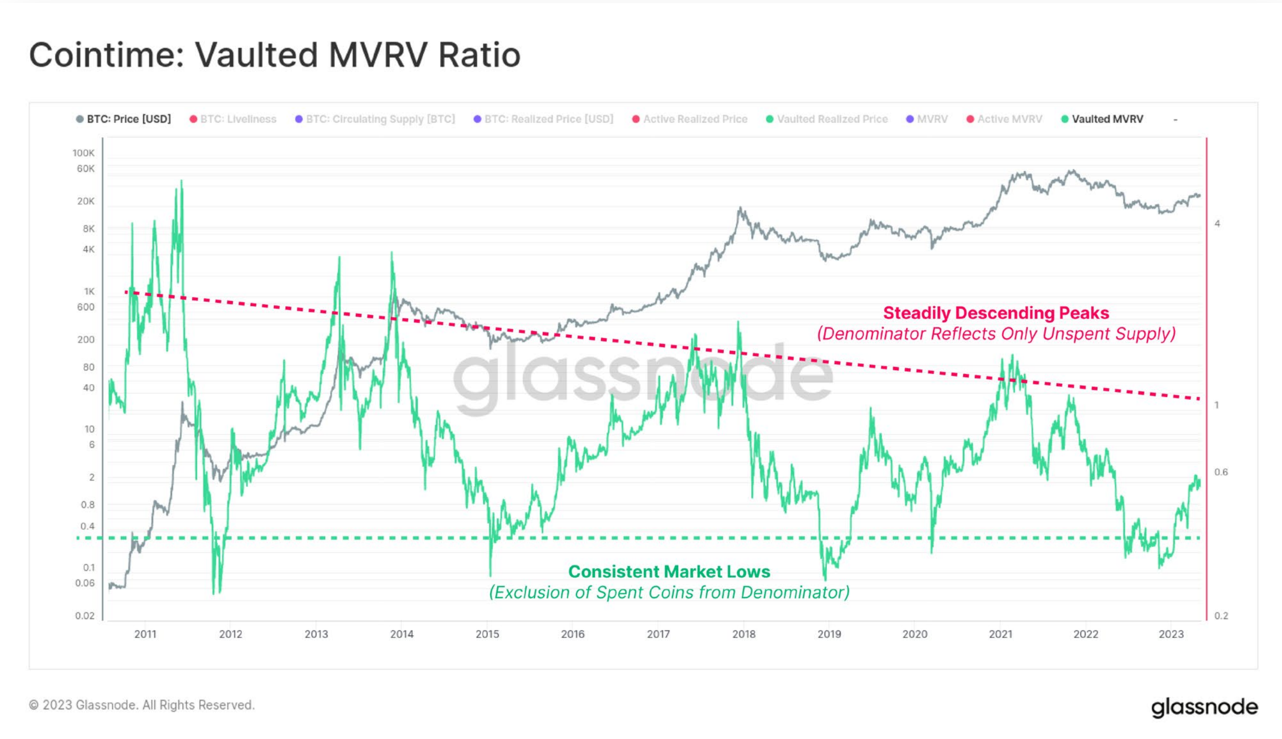
$$Vaulted\ MVRV = \frac{Market\ Price}{Vaulted\ Realized\ Price}$$

Vaulted Realized Price may be considered to be a pricing level that reflects the 'potential energy' stored in the system. Somewhat counter-intuitively, the more long-term coin accumulation that takes place, the larger the uncertainty becomes between the proportion of truly lost vs. HODLed supply. Vaulted Realized Price will trade lower in this instance, as more cointime accumulation takes place, and uncertainty regarding future distributive pressure builds (and vice-versa).

Vaulted Realized Price and Vaulted MVRV can best appreciated by considering the extremes:

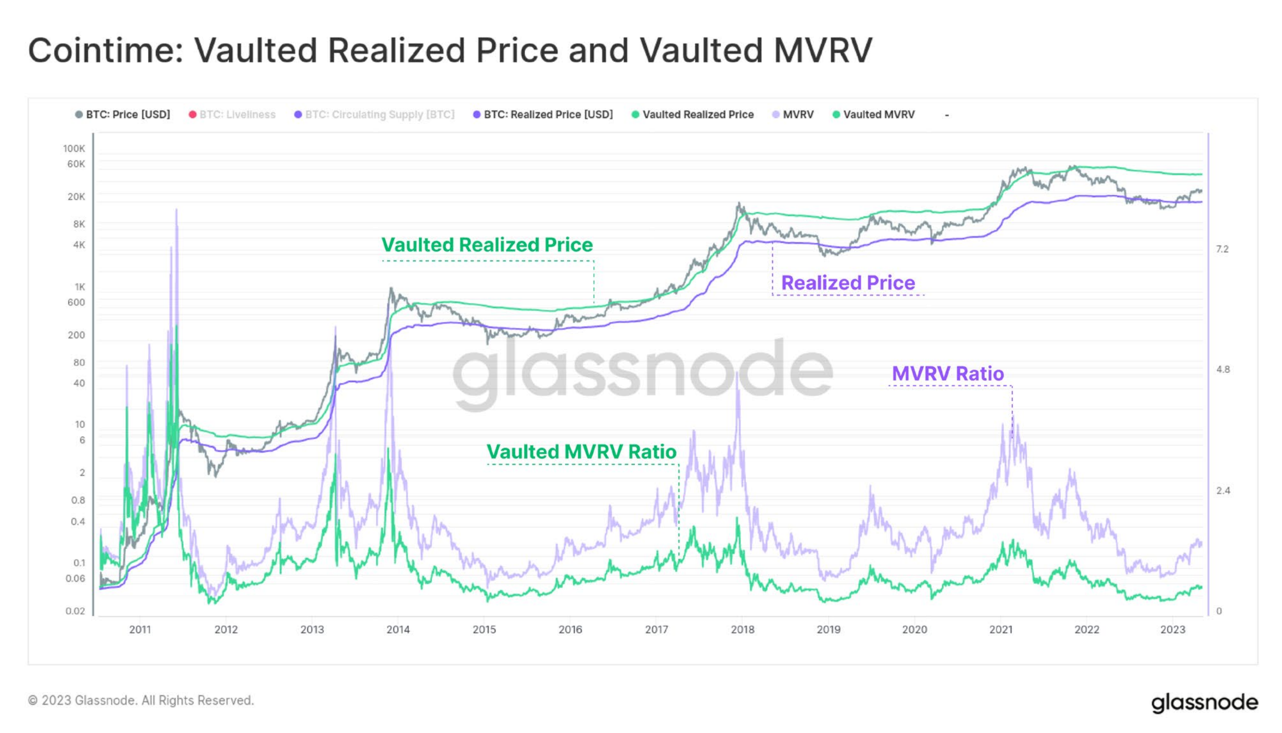
- **In the event where every coin that can be spent (i.e., non-lost) is spent**, Vaultedness will decrease to a minimum, and Vaulted Supply will provide a true reflection of lost supply. In this instance, Vaulted Realized Price would increase to a maximum, reflecting a high degree of certainty regarding the balance of lost and economically active supply.
- **In the event that all coins cease transacting for an extended period of time**, Vaultedness will increase towards a maximum, and uncertainty regarding the balance between lost and HODLed supply within the Vaulted Supply region will build. In this instance, Vaulted Realized Price would decrease over time towards a minimum, reflecting a high degree of uncertainty regarding future distributive pressure.

Vaulted MVRV accounts only for the relatively inactive, HODLed and/or Lost coin supply. By excluding active supply, Vaulted MVRV provides a more consistent and stable minimum value near historical cycle lows. Low values of this model represent periods where coin inactivity peaks, synonymous with a market preference for acquisition and transfer to cold storage. The Vaulted Supply denominator swells as the market saturates with higher conviction owners, whom contribute heavily to establishing bear market floors. Cycle peaks are less reliably identified as the economically active coins contributing to daily trade are discounted.



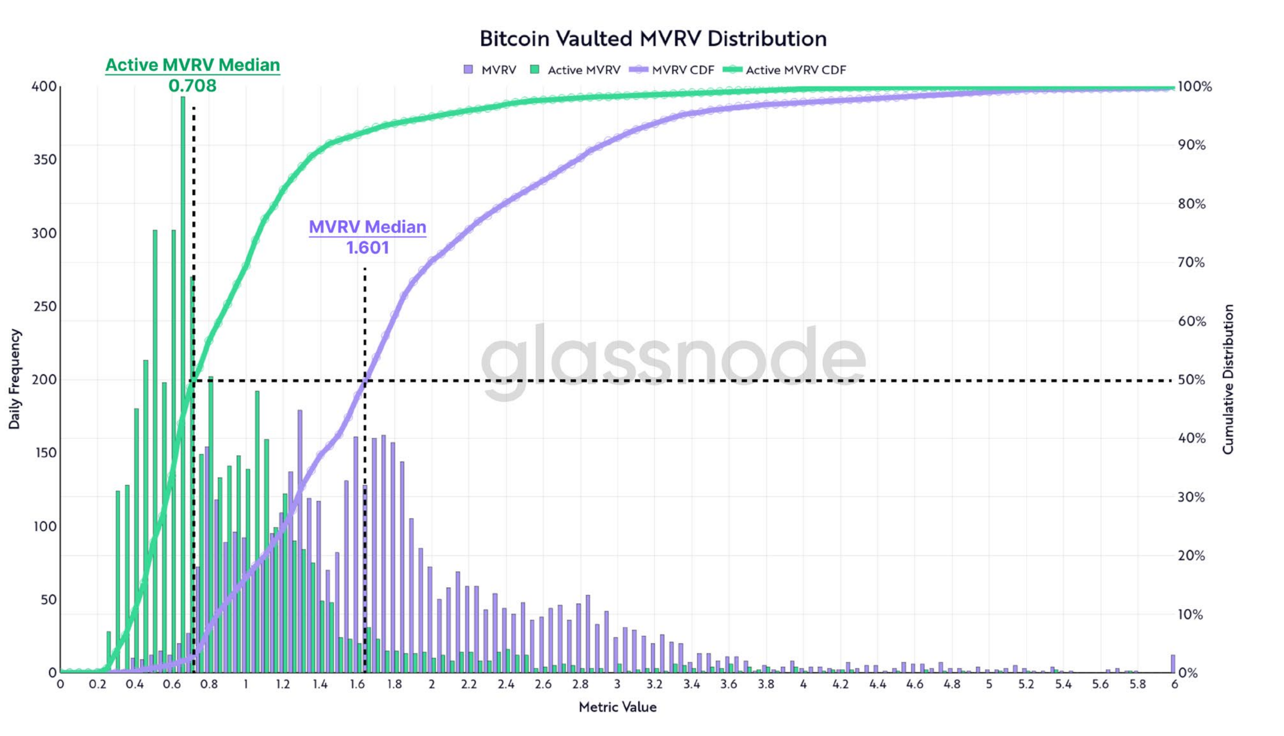
Data as of 8-May-2023. Past performance is not indicative of future results.

The chart below shows that Vaulted Realized Price does indeed tend to trade closer to historical market cycle tops, as previously dormant coins re-enter circulation and Active Supply approaches equilibrium with the coins that are likely to be spent during that cycle. Vaulted MVRV tends to peak above a value of 1.0 during these late stage periods of market euphoria, coincident with a maximum release of stored cointime, and increased probabilities of oversupply.



Data as of 8-May-2023. Past performance is not indicative of future results.

Similar to Active MVRV, the median (0.708) and mean (0.834) values of Vaulted MVRV are below, but much closer to 1 than the traditional MVRV counterpart. Only 29.97% of trading days have seen spot prices close above the Vaulted Realized Price.



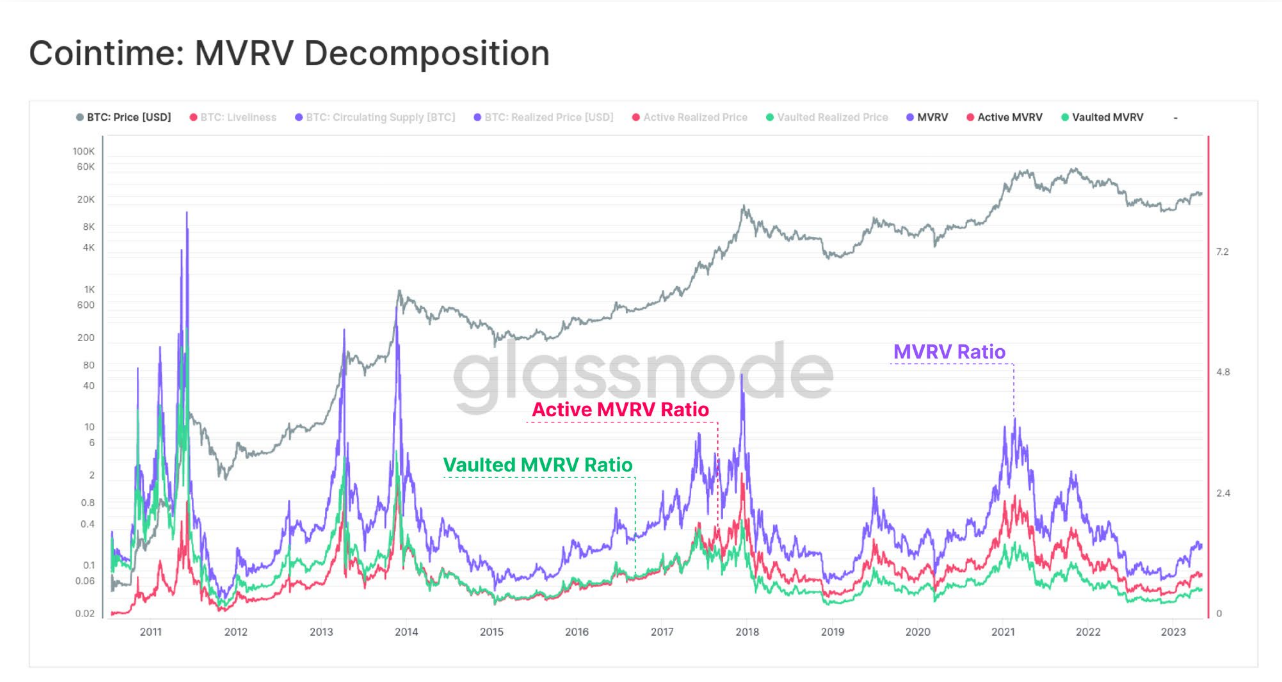
Data as of 8-May-2023. Measured since inception. Past performance is not indicative of future results.

Metric	Median	Mean	Standard	Skew	History Trading > 1
MVRV	1.601	1.638	1.016	0.887	75.88%
Active MVRV	0.776	0.804	0.514	0.543	30.91%
Vaulted MVRV	0.708	0.834	0.632	2.120	29.97%

Decomposition of the MVRV Ratio

The traditional MVRV Ratio accounts for all coins in the supply, irrespective of their realized value. Thus, MVRV reflects the 'circulating supply' component of the three-region symmetry of Cointime Economics. Since Active Supply and Vaulted Supply are subsets of Circulating Supply, it can be demonstrated that MVRV may also be decomposed into an Active and a Vaulted component.

$$
\begin{aligned}
MVRV &= Active\ MVRV + Vaulted\ MVRV \\
&= MVRV * Liveliness + MVRV * Vaultedness \\
1 &= Liveliness + Vaultedness \\
LHS &= RHS
\end{aligned}
$$



Data as of 8-May-2023. Past performance is not indicative of future results.

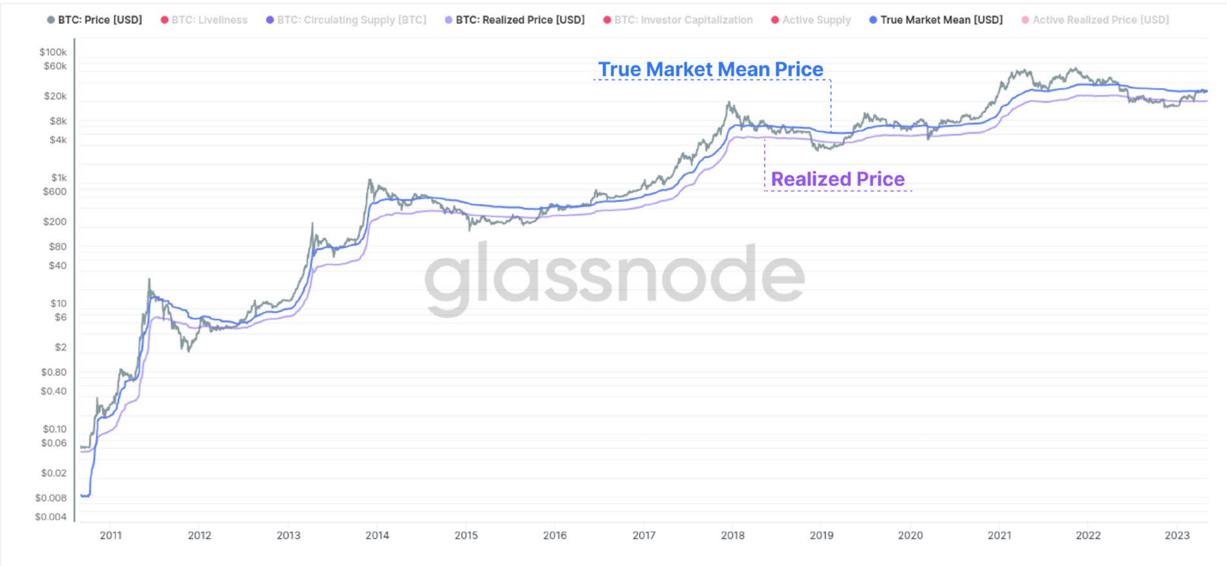
The True Market Mean or Active-Investor Price

We also propose a second and arguably superior iteration for estimating the aggregate on-chain cost basis of the market. Here we remove all coins acquired by mining power expenditure (Thermocap) and isolate only those which have been spent, assumed sold, and thus transferred between investors (Investor Cap)

Thus we define the True Market Mean or the Active-Investor Price representative of the cost basis for all coins acquired on secondary markets. We argue that this on-chain cost basis is the most accurate model available for analysts seeking the aggregate average on-chain acquisition price by investors, and thus a likely reference point for mean reversion models.

$$True\ Market\ Mean\ (of\ Price) = \frac{Investor\ Cap}{Active\ Supply}$$

Cointime: True Market Mean (Price)



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

Separation of the Investor Cap from the Thermocap is important as the Thermocap cannot experience a decline in value, since all newly mined coins can only add to the cumulative total valuation. The Investor Cap on the other hand, captures the net change in coins' realized value as they are spent, capturing both profit- and loss-making transactions.

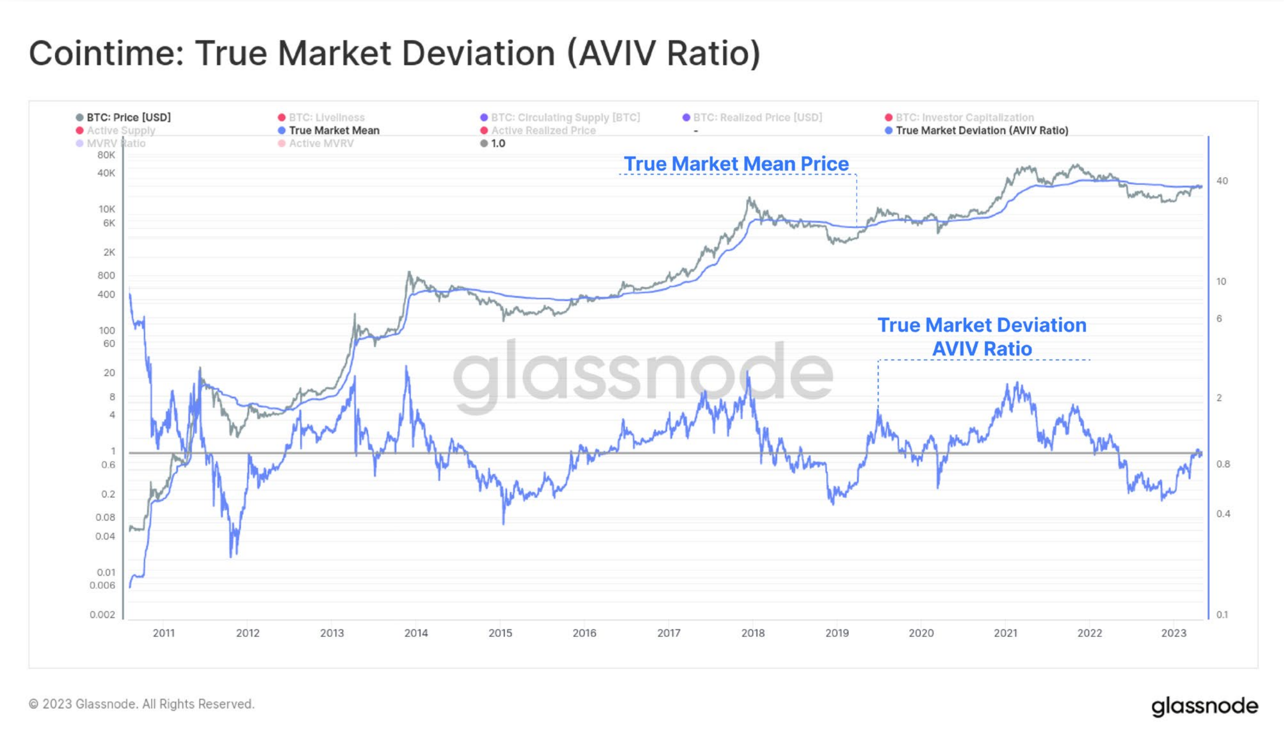
Metric	Median	Mean	Standard	Skew	History Trading > 1
MVRV	1.601	1.638	1.016	0.887	75.88%
Active MVRV	0.776	0.804	0.514	0.543	30.91%
Vaulted MVRV	0.708	0.834	0.632	2.120	29.97%
AVIV Ratio	1.038	1.018	0.582	0.151	53.30%

Given the Active Supply represents the economically active supply region, we can thus deduce a new variant of MVRV, comparing the Active Market Cap to the Investor Cap. We propose this to be the True Market Deviation, or otherwise known as the Active-Value-to-Investor-Value (AVIV) Ratio.

$$Active\ Cap = Active\ Supply * Price$$

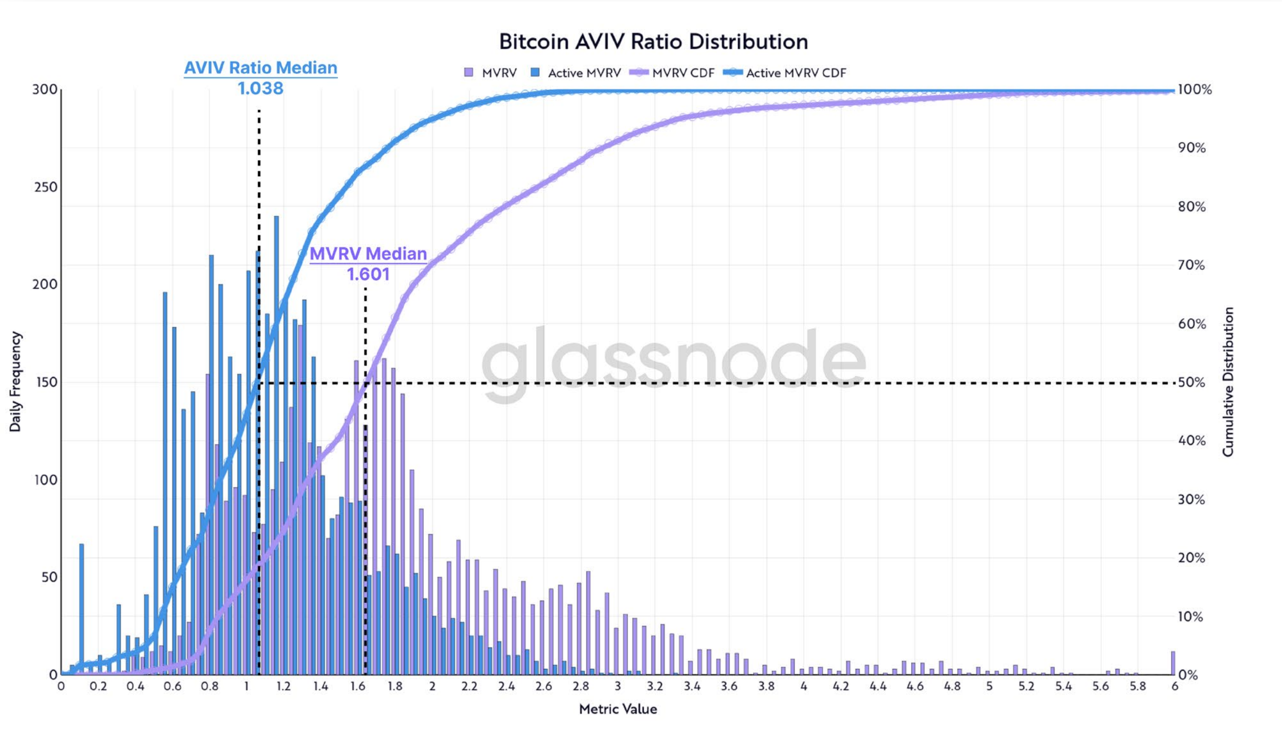
$$True\ Market\ Deviation\ (AVIV\ Ratio) = \frac{Active\ Cap}{Investor\ Cap}$$

The AVIV Ratio can be seen to oscillate around a value of 1.0 throughout historical market cycles, with transitions between cyclical bull and bear markets being more responsive than other MVRV variants. This is due to the heavier emphasis on investor spending behavior in particular declines in the Realized Cap due to the realization of losses during market wide capitulation events, which impacts the Investor Cap but not the Thermocap.



Data as of 8-May-2023. Past performance is not indicative of future results.

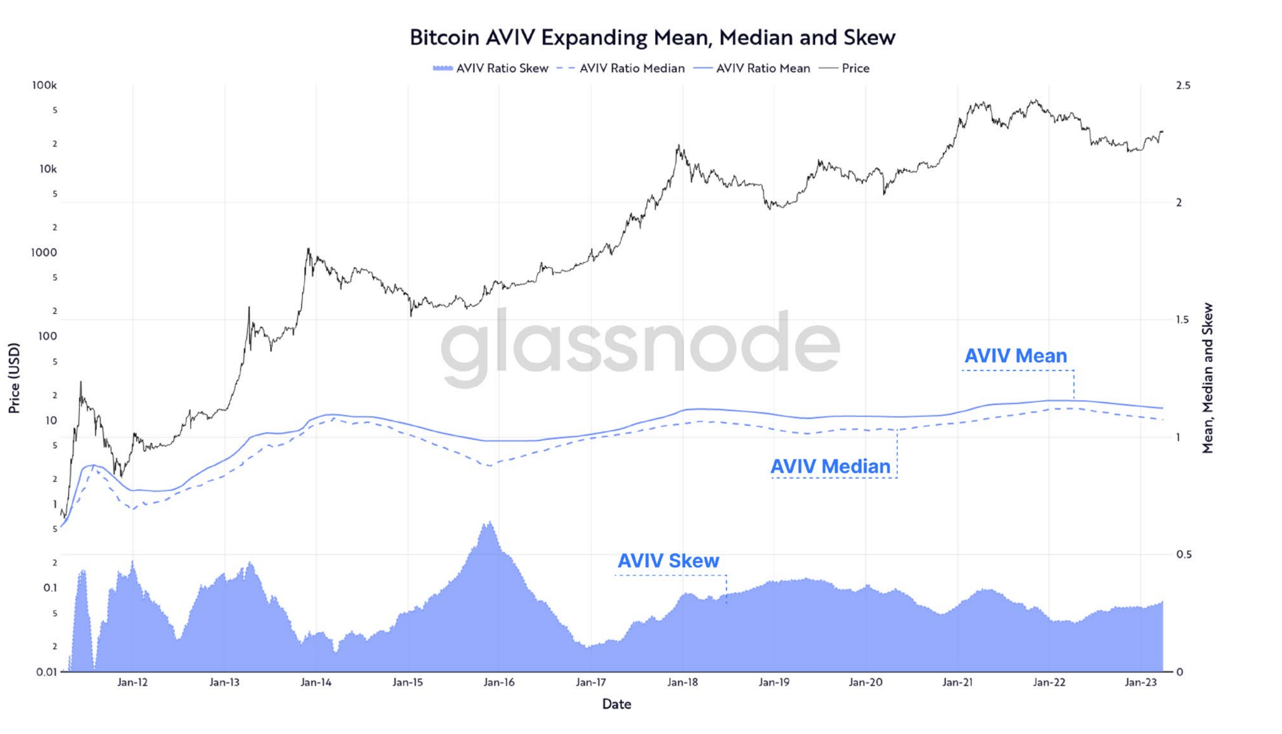
To support the notion of the True Market Mean as a valid market centroid, both the median (1.038) and mean (1.018) of the AVIV Ratio are very close to the 'breakeven' level 1.0, and certainly much closer than the other MVRV variants. Approximately 53.3% of all Bitcoin trading days have closed with an AVIV Ratio above 1.0, again reinforcing this metric as a valid representation of a center of gravity for the Bitcoin market.



Data as of 8-May-2023. Measured since inception. Past performance is not indicative of future results.

Metric	Median	Mean	Standard	Skew	History Trading > 1
MVRV	1.601	1.638	1.016	0.887	75.88%
Active MVRV	0.776	0.804	0.514	0.543	30.91%
Vaulted MVRV	0.708	0.834	0.632	2.120	29.97%
AVIV Ratio	1.038	1.018	0.582	0.151	53.30%

The AVIV Ratio has maintained a remarkably stable mean and median around a value since 2013 and displays a small and slightly positive skew throughout history.



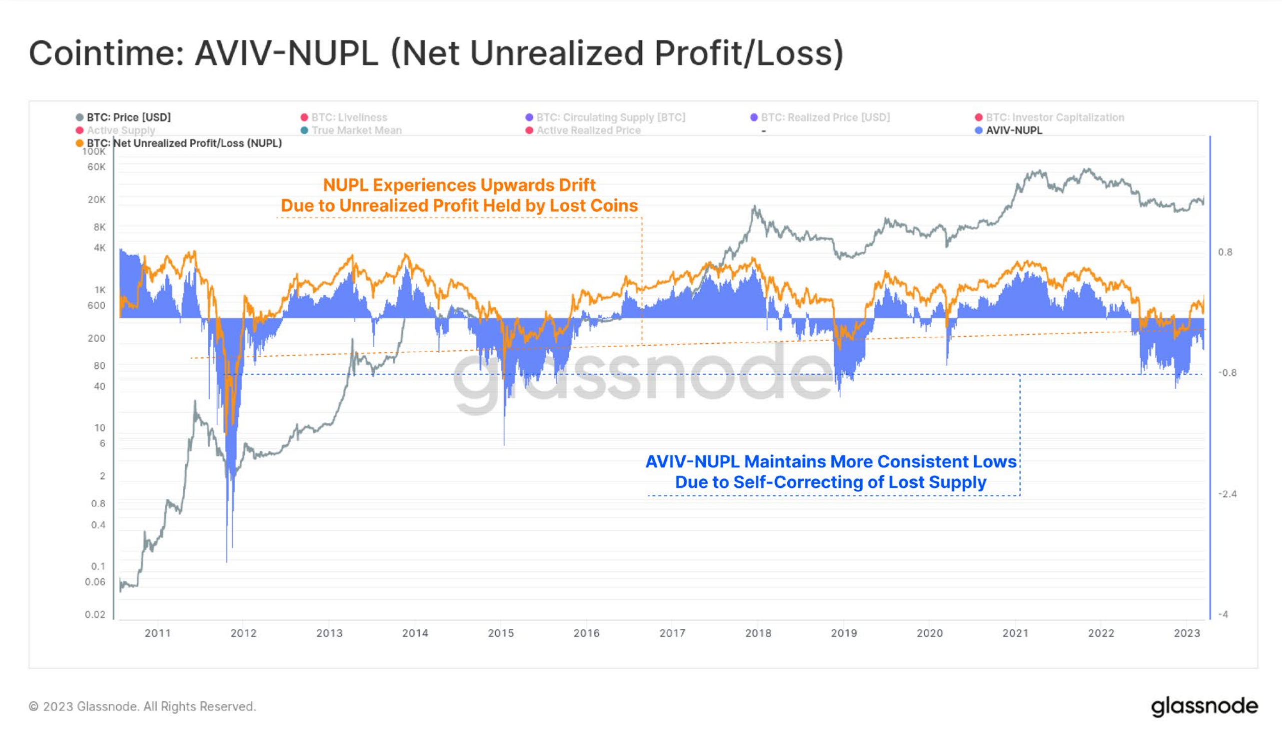
Data as of 8-May-2023. Past performance is not indicative of future results.

AVIV Net Unrealized Profit/Loss (AVIV-NUPL)

From this True Market Mean valuation framework, we can derive variants of popular market indicators such as Net Unrealized Profit/Loss (NUPL). This model takes the difference between the spot valuation of the Active Supply (Active Cap) and the Investor Cost Basis (Investor Cap), and then normalizes by the Active Cap.

$$AVIV\ NUPL = \frac{Active\ Cap - Investor\ Cap}{Active\ Cap}$$

This oscillator provides a gauge as to the relative degree of profit (positive) or loss (negative) value held within the economically active supply. AVIV-NUPL effectively discounts lost and long dormant coins in a responsive and self-correcting way, negating the observable long-term upwards drift observable in cycle lows of the original NUPL metric.



Data as of 8-May-2023. Past performance is not indicative of future results.

The AVIV Relationship, 'Investorness', and 'Producerness'

Now that we have reviewed the apparent effectiveness of relating Active Cap to Investor Cap in order to track the Bitcoin market's 'center of mass', a key insight emerges when comparing these metrics to its primers. As a refresher, let's revisit the following assertions, whilst establishing a few new ones:

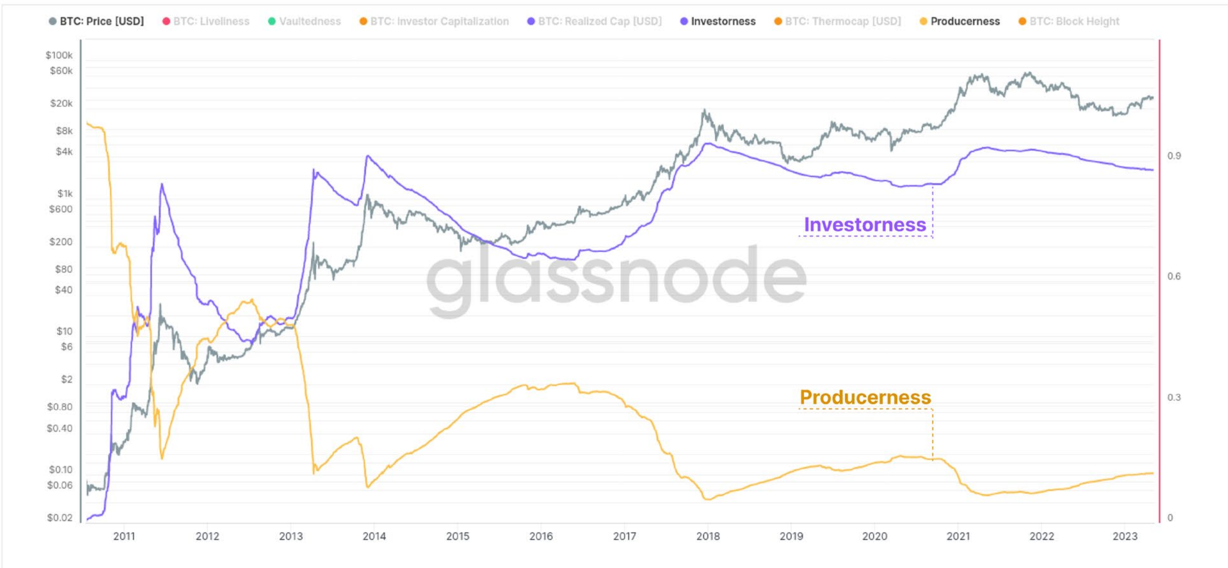
- **Market Cap** is composed of **Active Cap** and **Vaulted Cap**.
    - **Liveliness** denotes how 'economically active', 'mobile', 'spendable', or otherwise 'alive' the Bitcoin's capitalization is in aggregate. Liveliness has tended to increase over the network's lifetime and is equal to the ratio between Active Cap and Market Cap.
    - **Vaultedness** denotes how 'locked', 'inactive', 'dormant', 'unmoved', or otherwise 'lost' the Bitcoin's capitalization is in aggregate. Vaultedness has tended to decrease over the network's lifetime and is equal to the ratio between Vaulted Cap and Market Cap.
- **Realized Cap** is composed of **Investor Cap** and **Thermocap**. Here, we introduce two new metrics to explore this relationship: Producerness and Investorness.
    - **'Investorness'** denotes the relative contribution of transactions and trade by coin holders and investors (as well as investor-dependent entities like exchanges) to the valuation of Bitcoin's Realized Cap. Investorness has tended to increase over Bitcoin's lifetime, denoting a growing influence of this cohort over time.

$$Investornessness = \frac{Investor\ Cap}{Realized\ Cap}$$

- **'Producerness'**, denotes the relative contribution of miner production costs to the valuation of Bitcoin's Realized Cap. Producerness has tended to decrease over the network's lifetime, influenced by both declining issuance via halvings, as well as market boom-and-bust cycles. Producerness is equal to the ratio of Thermocap and Realized Cap.

$$Producerness = \frac{Thermocap}{Realized\ Cap}$$

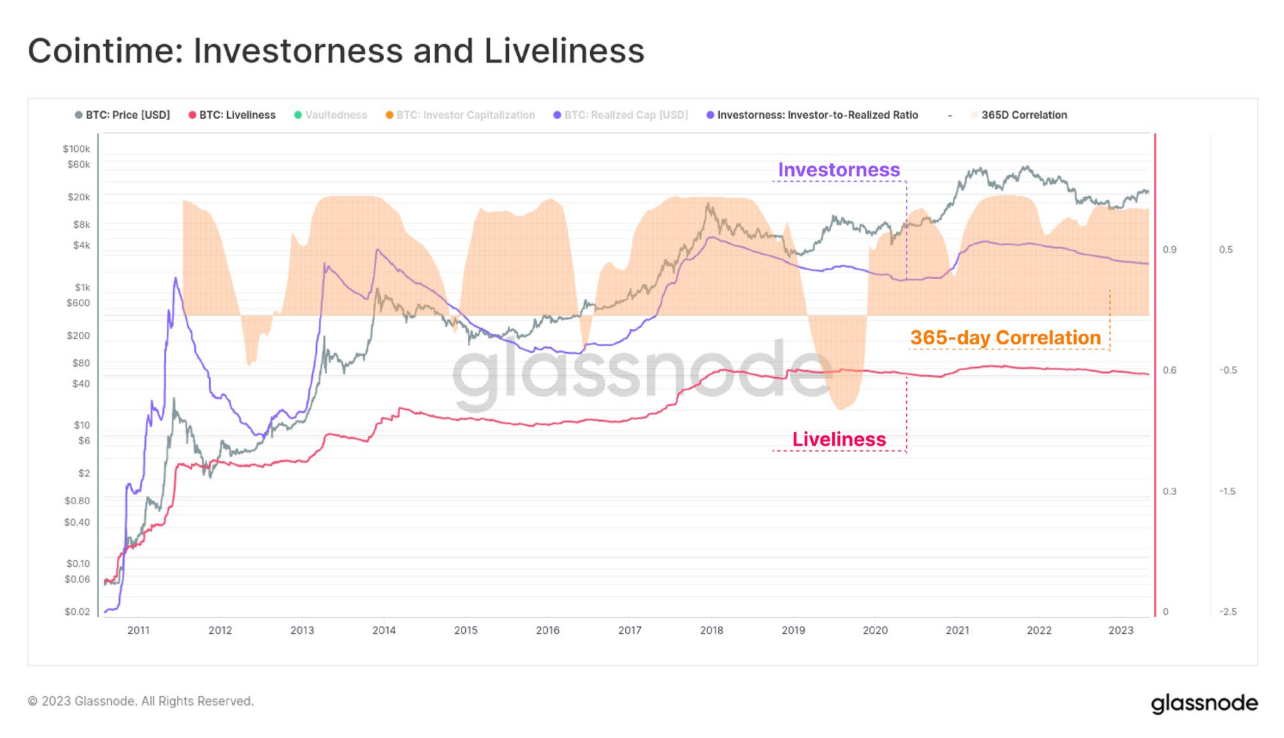
Cointime: Investorness and Producerness



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

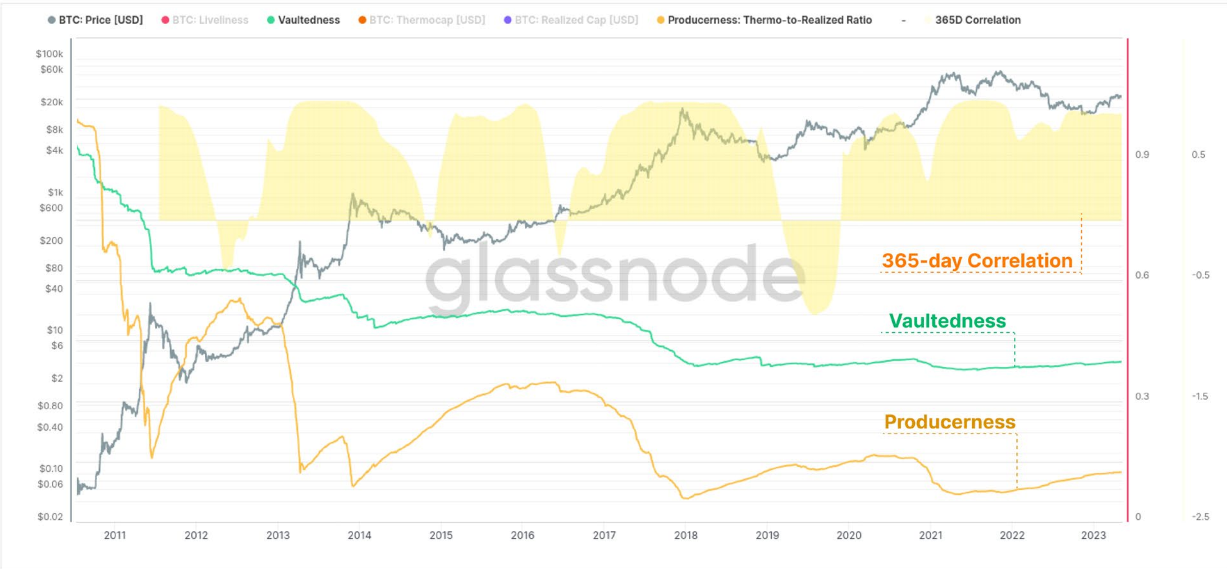
The chart below shows Investorness, Liveliness, alongside the 365-day Pearson correlation between the two, which maintains values in excess of 0.7 for the majority of Bitcoin's trading history.



Data as of 8-May-2023. Past performance is not indicative of future results.

Naturally, we can see that a similar relationship and correlation exists between Producerness and Vaultedness, given they are the inverse to Investorness and Liveliness, respectively.

Cointime: Producerness and Vaultedness



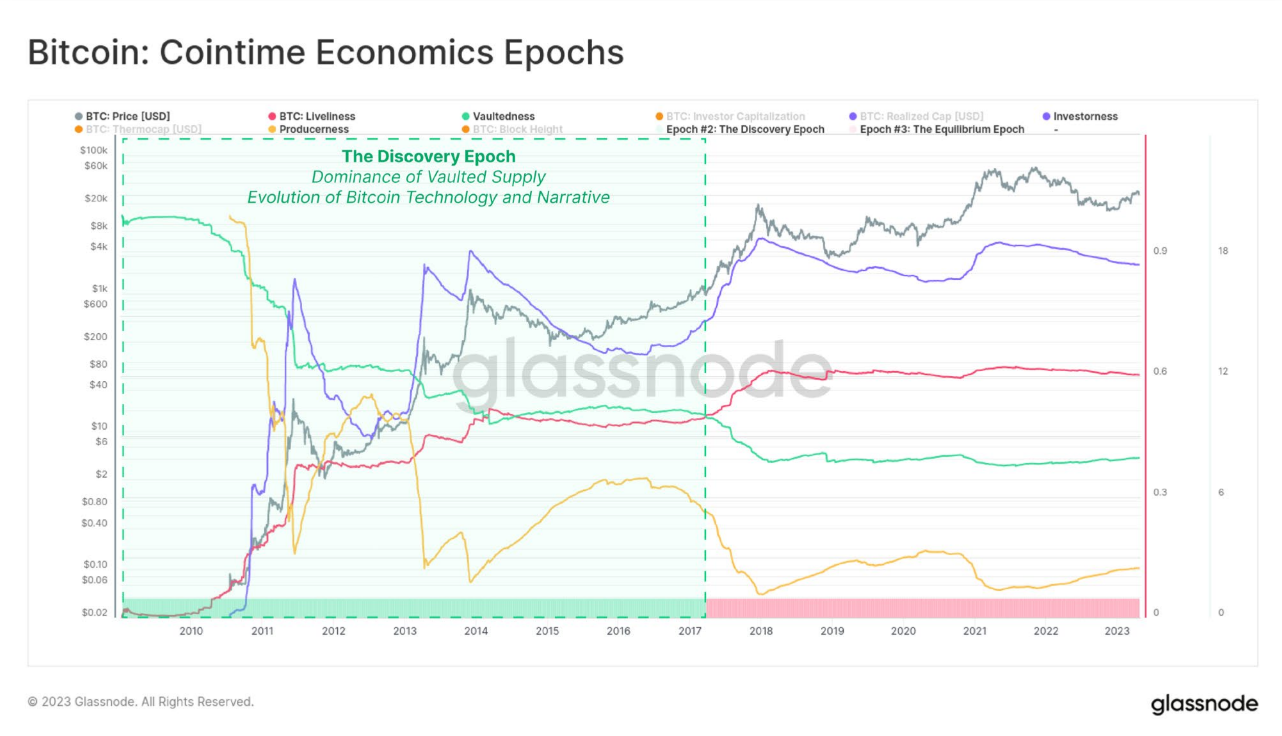
Data as of 8-May-2023. Past performance is not indicative of future results.

It can be seen that both pairs of **Liveliness and Investorness**, and **Vaultedness and Producerness**, appear to be proportional to each other. We call this the **AVIV Relationship**.

We argue that this relationship underlies the accuracy of the Active-Investor Price and AVIV Ratio, since investor activity is mostly inherently related to active coins incurring in economic transactions, just as production activity is inherently related to miners, with many of them in the early days having rarely spent their held supply (thus primarily vaulting).

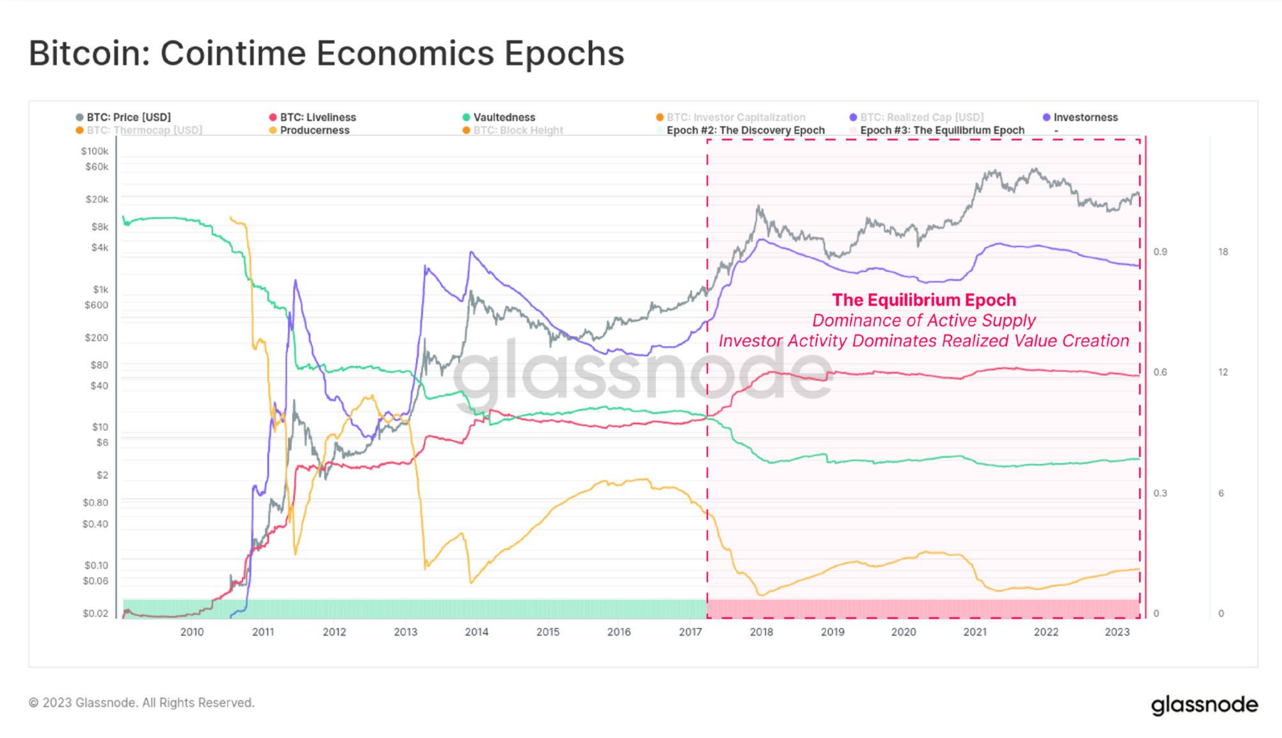
From these phenomena, we can further characterize the major epochs of the economic history of Bitcoin:

The Discovery Epoch (Genesis-2017) is characterized by a relatively high, but declining Vaultedness and declining Producerness. The influence of early miners and lost coins remained significant to both the supply and network realized value. All four components of the AVIV Relationship experienced notable volatility, with relative dominance rising and falling significantly. This period also experienced a fast pace evolution with respect to the relevance, awareness, and narratives surrounding Bitcoin as an asset and a network. Furthermore, the development of superior wallet technology made the loss of coins less frequent towards the end of this epoch.



Data as of 8-May-2023. Past performance is not indicative of future results.

The Equilibrium Epoch (2017 Onwards) is characterized by market conditions having arrived at an apparent equilibrium—with Liveliness, Vaultedness, Investorness, and Producerness becoming structurally range-bound. Of note is that a large volume of coins acquired within the Disovery Epoch were spent both during the 2017 bull run and to take advantage of the Bitcoin Cash hard-fork in August of 2017. Awareness, adoption, and the perceived value of Bitcoin increased during this time, as did market liquidity, trading frequency, and financial services for Bitcoin holders.



Data as of 8-May-2023. Past performance is not indicative of future results.

Despite all the intricacies and events described above, the AVIV Relationship, as well as the accuracy of Active-Investor Price and AVIV Ratio, seems to persist from Bitcoin's inception to this day.

[9] *Source: Coin Metrics. "Introducing Realized Capitalization", Coin Metrics, 2018*
https://coinmetrics.io/realized-capitalization/

[10] *Source: Glassnode. "Bitcoin: Balance in Miner Wallets [BTC]—Patoshi".*
https://studio.glassnode.com/metrics?a=BTC&category=&m=distribution.BalanceMinersSum&miner=Patoshi

[11] *Source: Glassnode. "Bitcoin: Probably Lost Supply [BTC]".*
https://studio.glassnode.com/metrics?a=BTC&category=&m=supply.ProbablyLost

[12] *Source: Schultze-Kraft, Rafael, et al. "Quantifying Short-Term and Long-Term Holder Bitcoin Supply", Glassnode, 2020.*
https://insights.glassnode.com/quantifying-bitcoin-hodler-supply/

Cointime Valuation Models

Cointime Value Created, Destroyed, and Stored

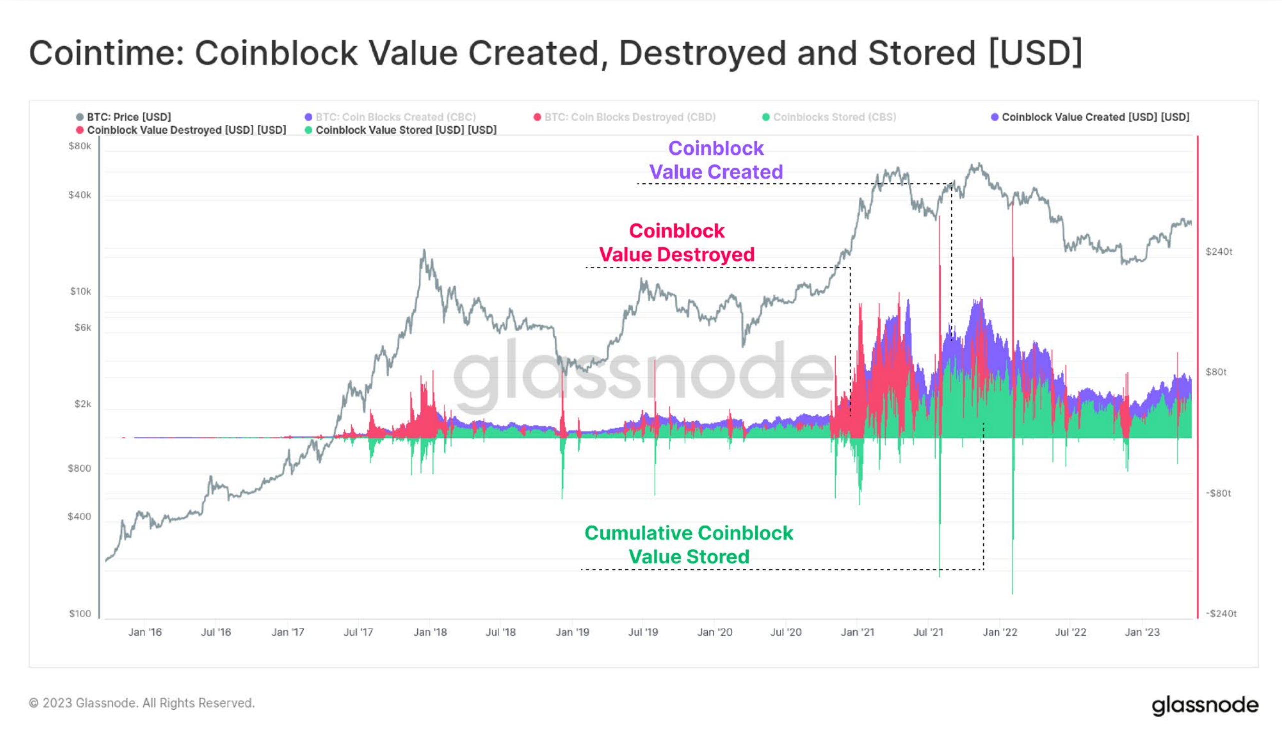
Cointime Economics may also be applied within the price domain by valuing coinblocks at the point of creation, destruction, and storage. Since coinblocks are fungible, we can value all coinblocks directly against the spot price at the time of inclusion in a block. From this we can yield both the incremental and the cumulative total cointime-weighted value in each of the three supply regions.

This yields the concept of **Cointime Value**, with units of 'dollarblocks'.

$$Cointime\ Value\ Created = \sum_{N=1}^{i} (Price * CBC)_N\ [Dollar.blocks]$$

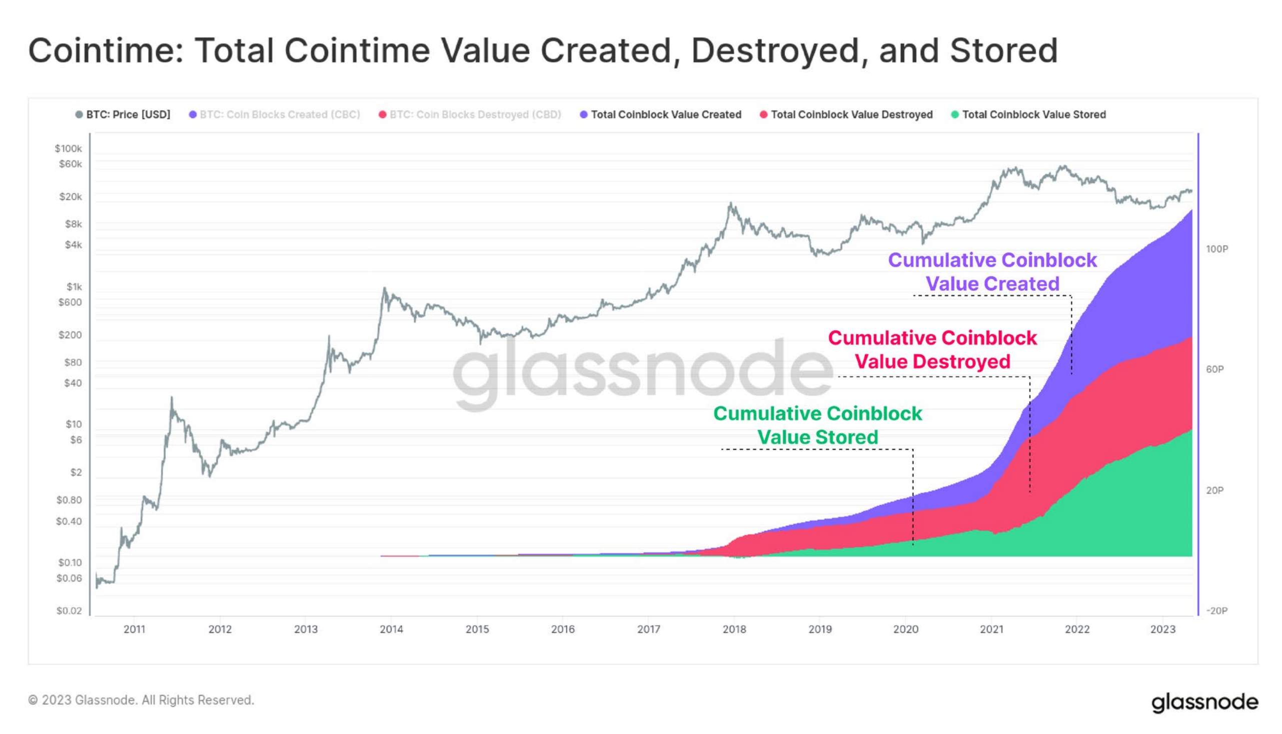
$$Cointime\ Value\ Destroyed = \sum_{N=1}^{i} (Price * CBD)_N\ [Dollar.blocks]$$

$$Cointime\ Value\ Stored = \sum_{N=1}^{i} (Price * CBS)_N\ [Dollar.blocks]$$



Data as of 8-May-2023. Past performance is not indicative of future results.

- 114.2 Quadrillion Dollarblocks Created.
- 72.5 Quadrillion Dollarblocks Destroyed.
- 41.7 Quadrillion Dollarblocks Stored.



Data as of 8-May-2023. Past performance is not indicative of future results.

Cointime Price

A series of pricing models may now be derived directly from the Cointime Economics framework, the most foundational of which is the **Cointime Price**, as well as the **Cointime Cap.** These valuation models are based on the notion that all coinblock destruction reflects an economic decision and indicates that the spent coins are indeed active, non-lost, and thus are participating in the global Bitcoin economy.

First we multiply CBD volume in each transaction (T) by price at the time of confirmation, and then aggregate with respect to blockheight (N). This returns the Cointime-Value Destroyed per block. No regard for the source UTXOs that previously held this cointime is required.

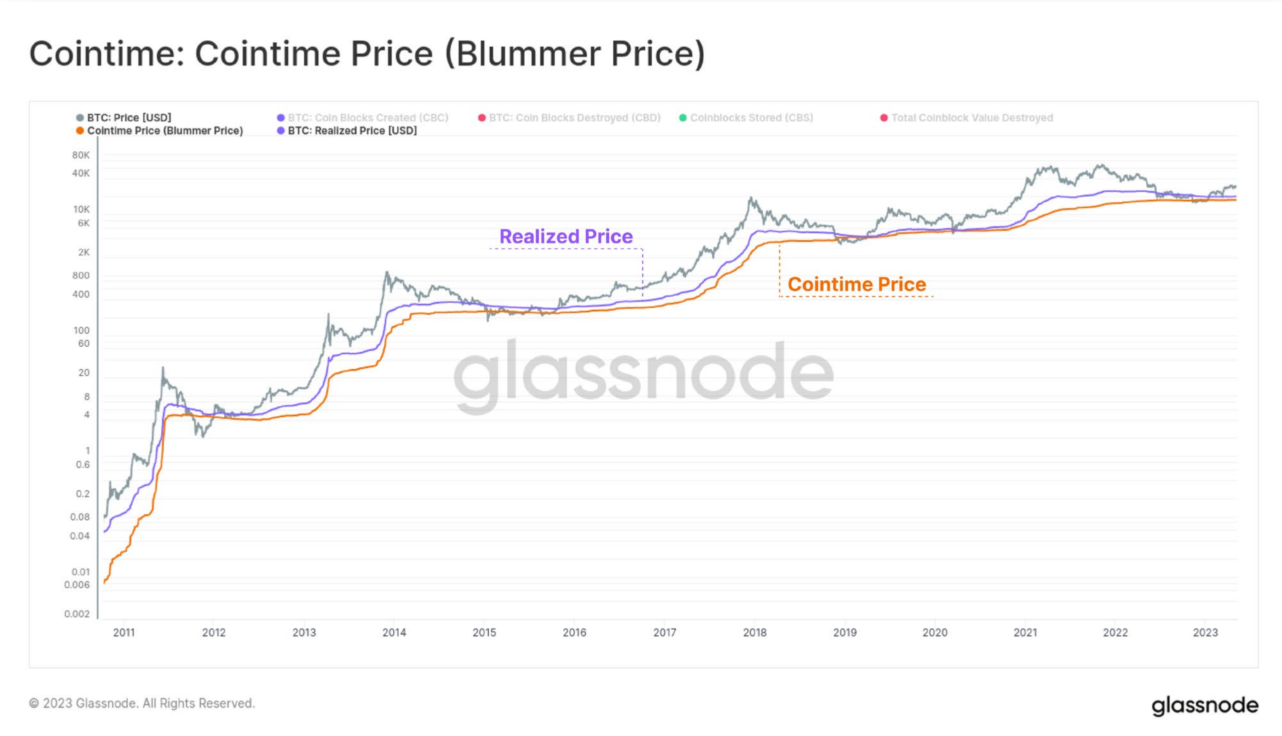
$$Cointime\ Value\ Destroyed_N \quad = \quad \sum_{T=1}^{i}(Price\ * CBD)_T\ [Dollar.blocks]$$

To establish a pricing model, this aggregate value is then distributed across the remaining cointime volume stored in the system. This nets **Cointime Price,** which is the Cointime Economics analogue of the UTXO derived Realized Price.

$$Cointime\ Price = \frac{\sum_{N=1}^{i} Cointime\ Value\ Destroyed_N}{\sum CBS}$$

Cointime Price reflects the aggregate cointime-weighted realized valuation, distributed over the remaining unspent coinblocks stored within the network. It is both a network time-weighted and volume-weighted average realized price. It can be considered as the relative balance between the willingness of the market to spend time and value against the willingness of asset holders to keep owned coins and value inactive.

It can be seen in the chart below that Cointime Price tends to intersect spot prices in late stage bear cycles, with examples in 2015, November 2018, March 2020, and November 2022.



Data as of 8-May-2023. Past performance is not indicative of future results.

🕰️ **In honour of the late Tamás Blummer, who's original work on 'Liveliness' and 'HODLed and Lost Coins' is the bedrock inspiration for this paper, we dedicate the Cointime Price to his memory, offering it the colloquial name of the Blummer Price.**

Note that the numerator of Cointime price can only increase, since coinblock value destroyed is always positive (unless Bitcoin achieves a negative spot price). Thus, Cointime price can only decline during periods where the aggregate rate of coinblock accumulation exceeds that of coinblock value destruction (i.e. when Liveliness trends lower). Historically, periods of lower coinblock destruction and elevated coinblock storage tends to occur during later-stage bear markets. Interestingly, this is also a time when investors have historically realized the largest aggregate losses on spent coins, leading to a coincident decline with the Realized Price.

Cointime Capitalization

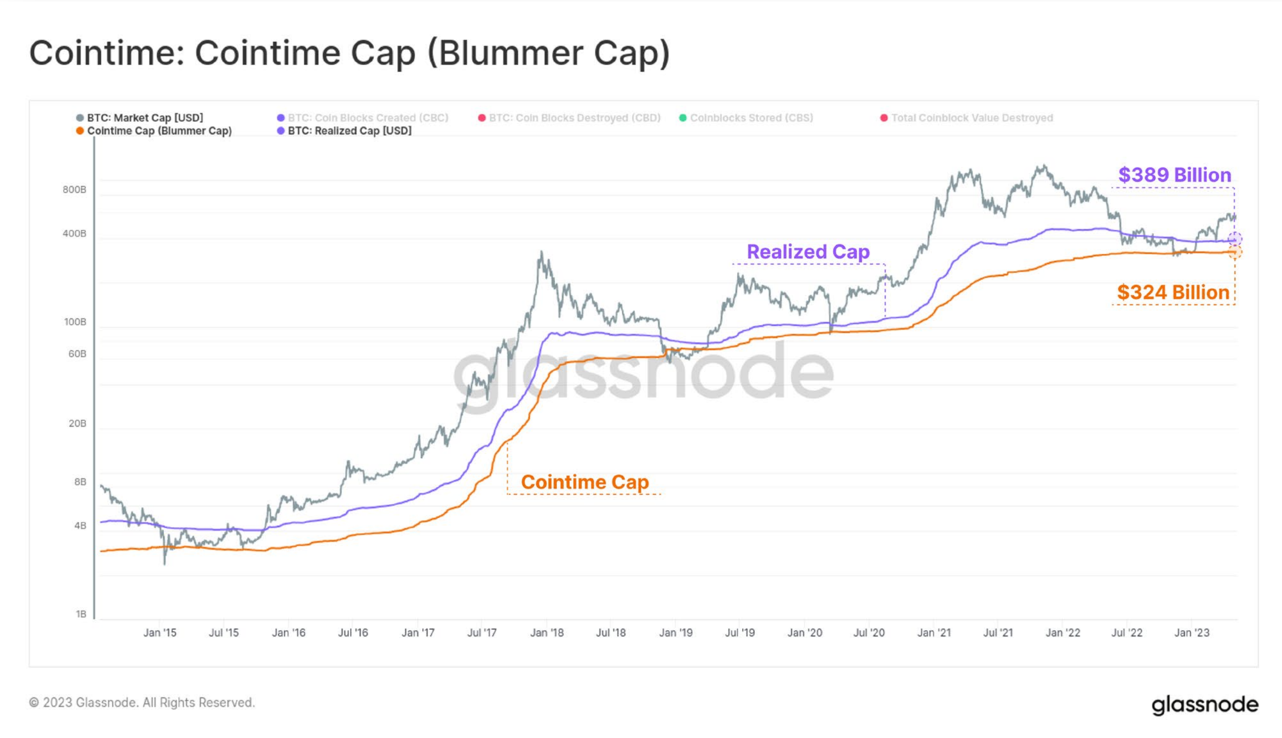
With Cointime Price capturing a network-time-and-volume weighted average price, we can calculate a network valuation metric by multiplying by Circulating Supply. This nets the Cointime Cap, which may be considered the Cointime Economics analogue of the UTXO derived Realized Cap.

$$Cointime\ Cap \quad = \quad Cointime\ Price * Circulating\ Supply$$

In effect, the Cointime Cap represents a lower bound valuation model for Bitcoin which accounts for the following:

- Value held by higher conviction investors that own long-dormant vaulted supply.
- The degree of value realization within the economically active supply

The Cointime Cap is currently $324 Billion, which compares with a Realized Cap of $389 Billion.



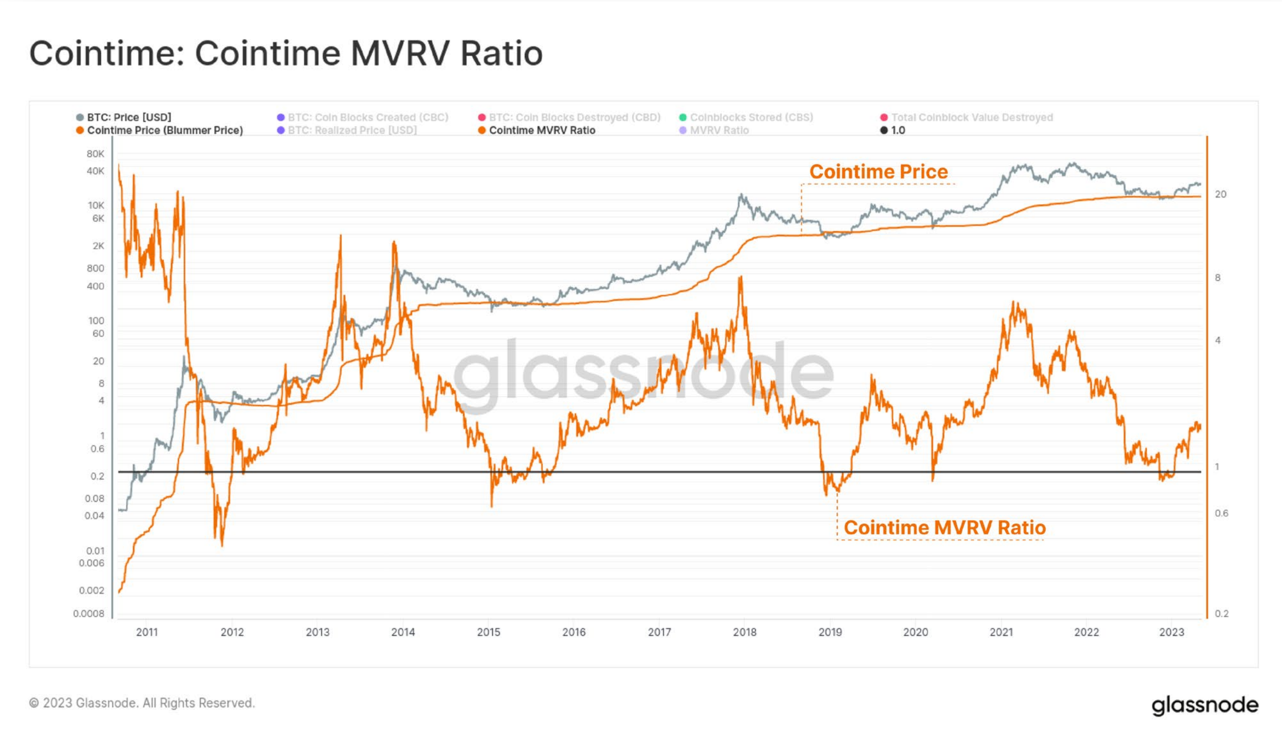
Data as of 8-May-2023. Past performance is not indicative of future results.

Cointime MVRV Ratio

The Cointime MVRV Ratio can then be computed as a reflection of the aggregate unrealized profit/loss multiple held by the market. This MVRV variant has similar properties to the classic MVRV Ratio, although with the added advantage of accounting for both cointime- and volume-weighted market behavior.

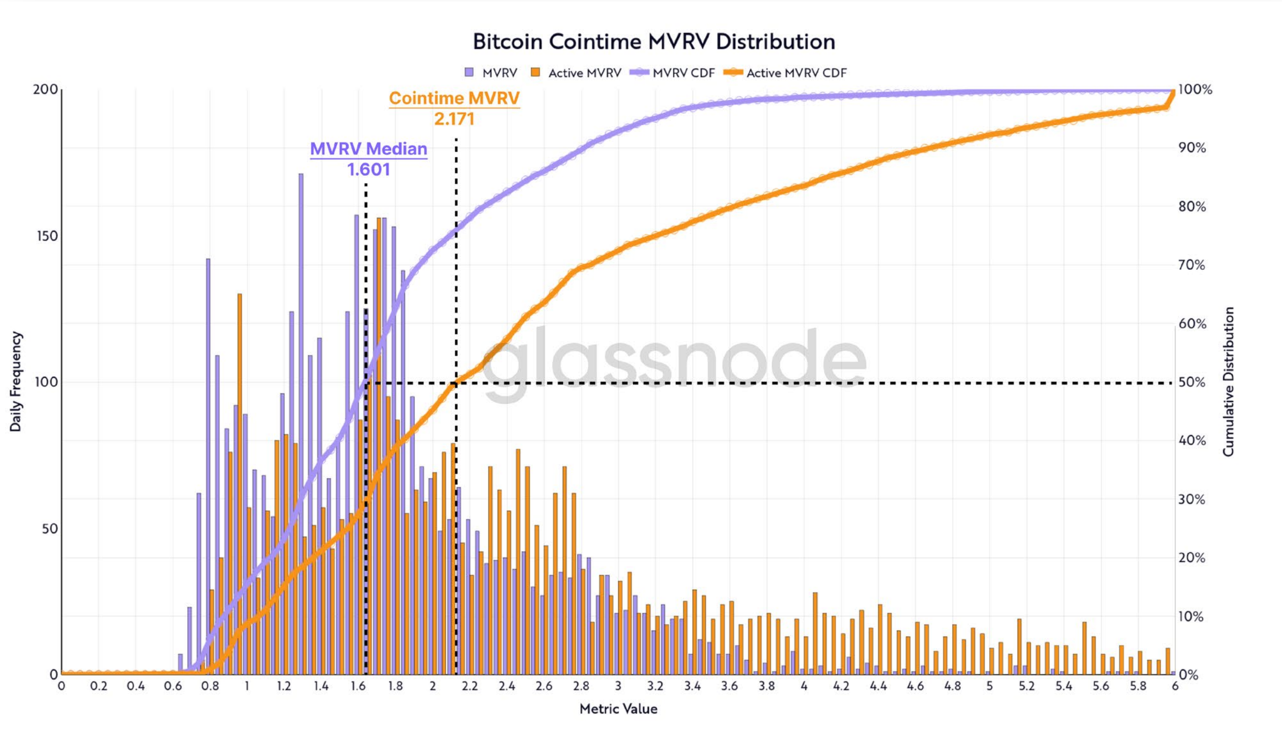
$$Cointime\ MVRV = \frac{Market\ Cap}{Cointime\ Cap} = \frac{Spot\ Price}{Cointime\ Price}$$

Intersections between Market Cap and Cointime Cap tend to occur historically during late stage bear markets and capitulation events. Thus, a Cointime MVRV value of 1.0 signifies an equilibrium has been reached between market price and this time-and-volume weighted lower bound valuation model.



Data as of 8-May-2023. Past performance is not indicative of future results.

From the distribution of Cointime MVRV, we can see that the spot price has spent more than 81% of trading history above this pricing model, and is a more volatile oscillator with larger skew and larger deviations from the mean. This aligns with an interpretation as a lower bound valuation model, which is slow to respond to market events, yet it however provides a more robust lower bound equilibrium and valuation framework for bear market cycles.



Data as of 8-May-2023. Measured since inception. Past performance is not indicative of future results.

Metric	Median	Mean	Standard	Skew	History Trading > 1
MVRV	1.601	1.638	1.016	0.887	75.88%
Active MVRV	0.776	0.804	0.514	0.543	30.91%
Vaulted MVRV	0.708	0.834	0.632	2.120	29.97%
AVIV Ratio	1.038	1.018	0.582	0.151	53.30%
Cointime MVRV	2.171	2.628	1.600	2.033	81.47%

Cointime NVT and RVT Ratios

The measurement of 'transactional volume' in a Cointime Economics framework is best captured by the coinblocks destroyed metric, representing the spent cointime volume at each blockheight. From this we can calculate from cointime-derived network valuation to network throughput ratios. These are analogous to the traditional NVT and RVT ratios, widely popular in the on-chain analysis field.

Here we consider the following framework for establishing Cointime NVT and RVT Ratios:

The Cointime Network-Value-to-Transactions (NVT) Ratio is calculated as the market value of the Active Supply (Active Cap) divided by the 90-day moving average of coinblock value destroyed.

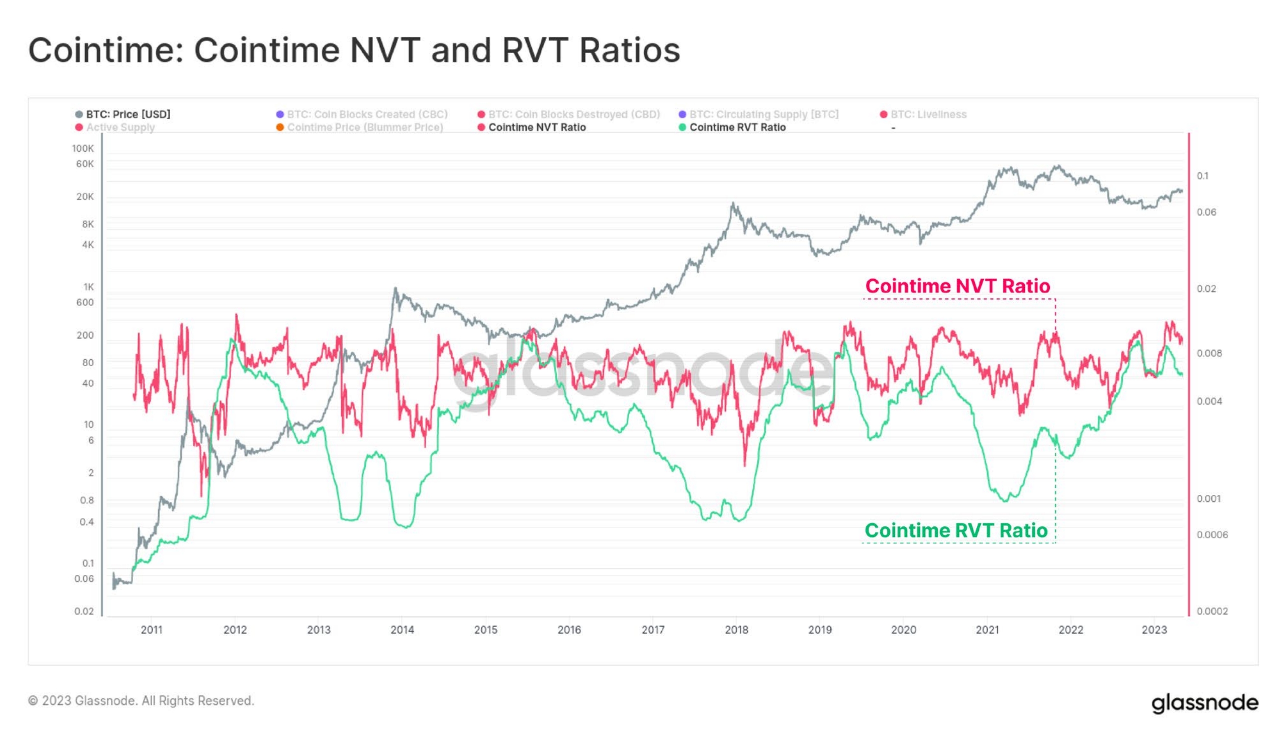
$$Cointime\ NVT = \frac{Price\ *\ Active\ Supply}{(Price\ *\ CBD)_{90DMA}}$$

The Cointime Realized-Value-to-Transactions (RVT) Ratio is calculated as as the cointime realized value of the Active Supply divided by the 90-day moving average of coinblock value destroyed.

$$Cointime\ RVT = \frac{Cointime\ Price\ *\ Active\ Supply}{(Price\ *\ CBD)_{90DMA}}$$

The chart below shows the Cointime NVT (red) and Cointime RVT (green) Ratios, both of which have a remarkable degree of stability over time.

- **High Values** indicate that the valuation of the Bitcoin network is large relative to the degree of coinblock value destruction that is taking place.
- **Low Values** indicate that the valuation of the Bitcoin network is small relative to the degree of coinblock value destruction that is taking place.

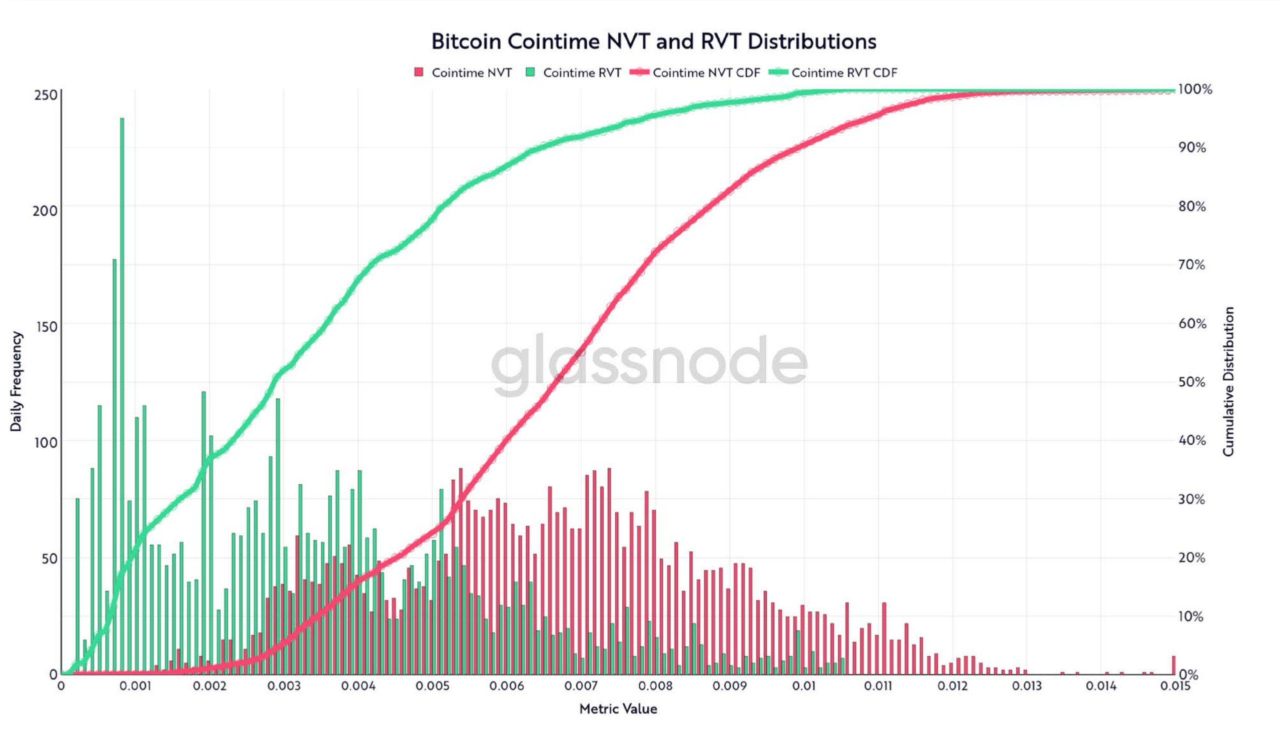


Data as of 8-May-2023. Past performance is not indicative of future results.

It can be seen that both oscillators remain relatively range bound, have historically traded within a long-term sideways pattern, and are normally distributed.

- **Cointime-NVT is a faster and more responsive indicator**, which tends to reach local maxima and minima leading into and following periods of elevated market volatility. This generally describes the classic market phenomena where periods of low volatility (plus quiet cointime expenditure) tend to precede periods of high volatility—and thus high cointime expenditure (and vice-versa).

- **Cointime-RVT Ratio is a slower cyclical indicator**, which operates similarly to the original RVT ratio and displays a longer-term cyclical pattern. Changes in the prevailing Cointime-RVT trend are often more informative than the absolute value, indicating whether there is a prevailing trend of coinblock expenditure or storage relative to the networks cointime valuation.

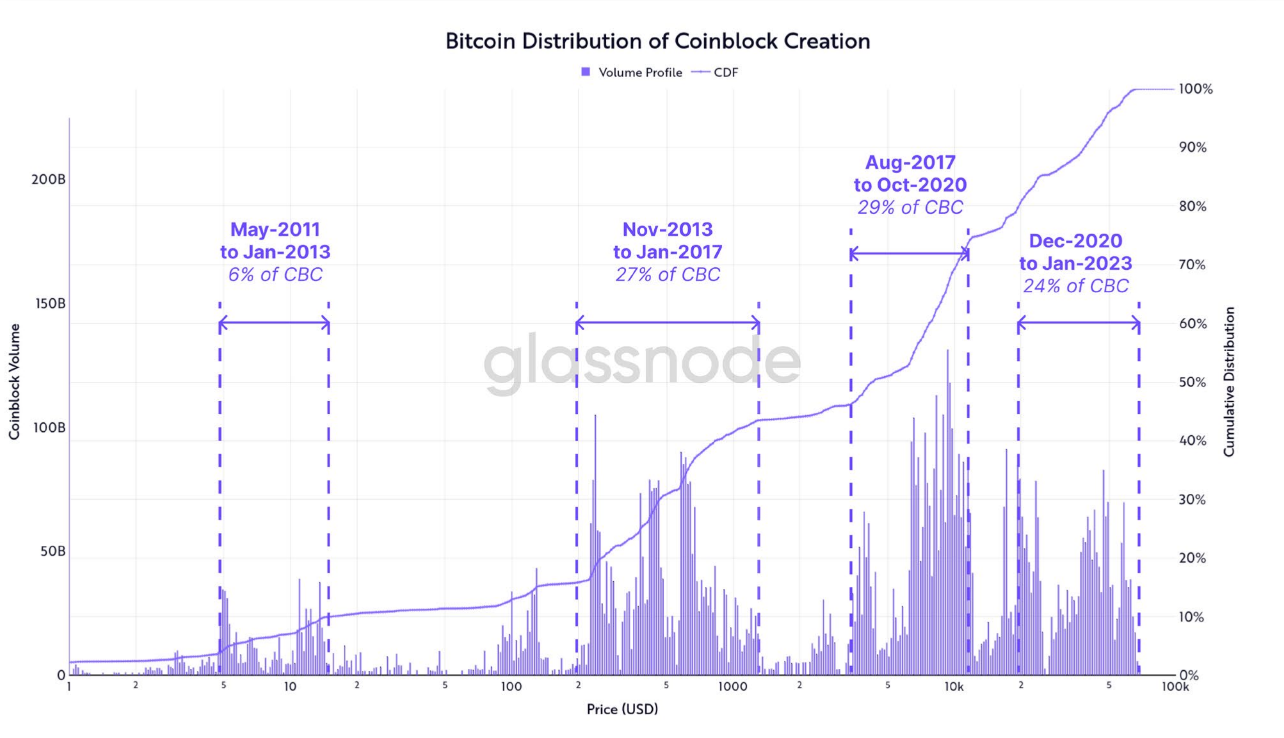


Data as of 8-May-2023. Measured since inception. Past performance is not indicative of future results.

Metric	Range	Median	Mean	Standard	Skew
Cointime NVT	0.11% to 1.50%	0.70%	0.70%	0.24%	0.171
Cointime RVT	0.08% to 1.06%	0.32%	0.36%	0.25%	0.710

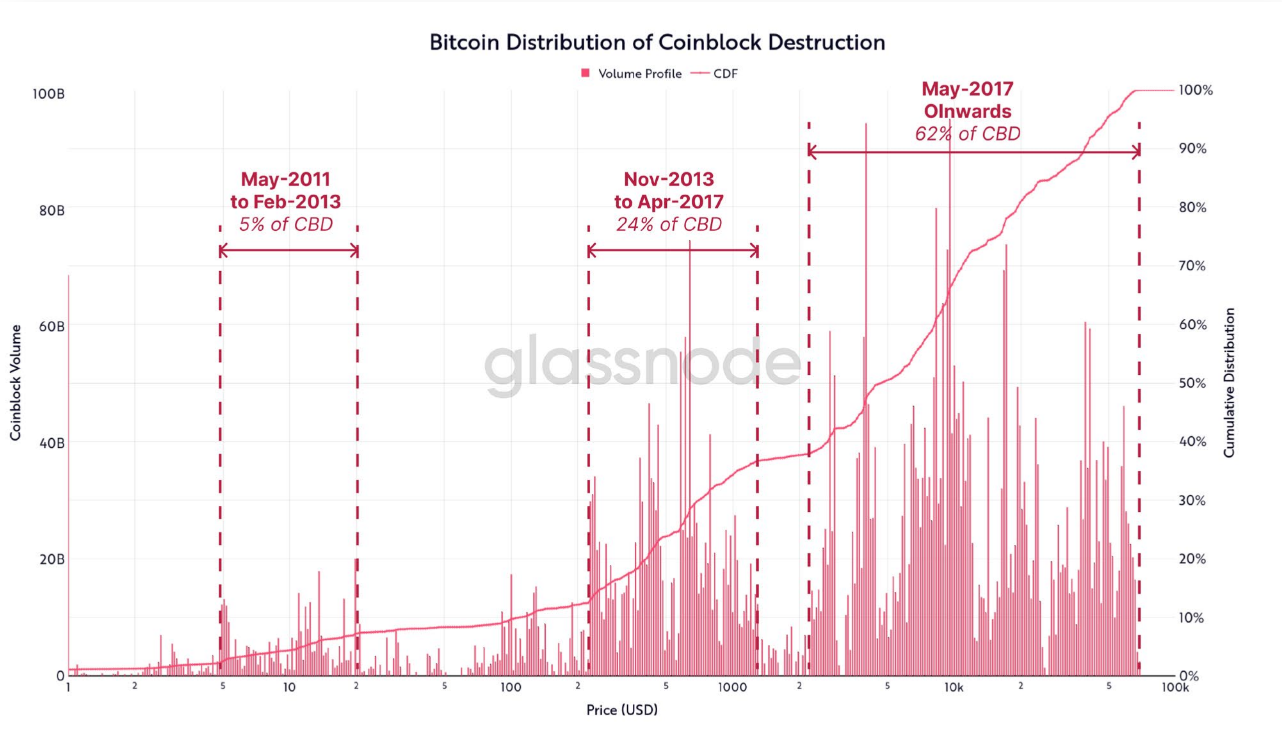
Cointime Distributions

Periods where significant coinblock creation, destruction, and storage take place, naturally correlate with price ranges where a significant market activity occurs. In reviewing the distribution of coinblock activity, we can immediately identify that the majority of coinblock creation takes place between prices corresponding with multi-year bear markets. These periods typically consist of several months to years of price declines, consolidations, and then recoveries within a price range, historically between 75% to 85% below the all-time high.



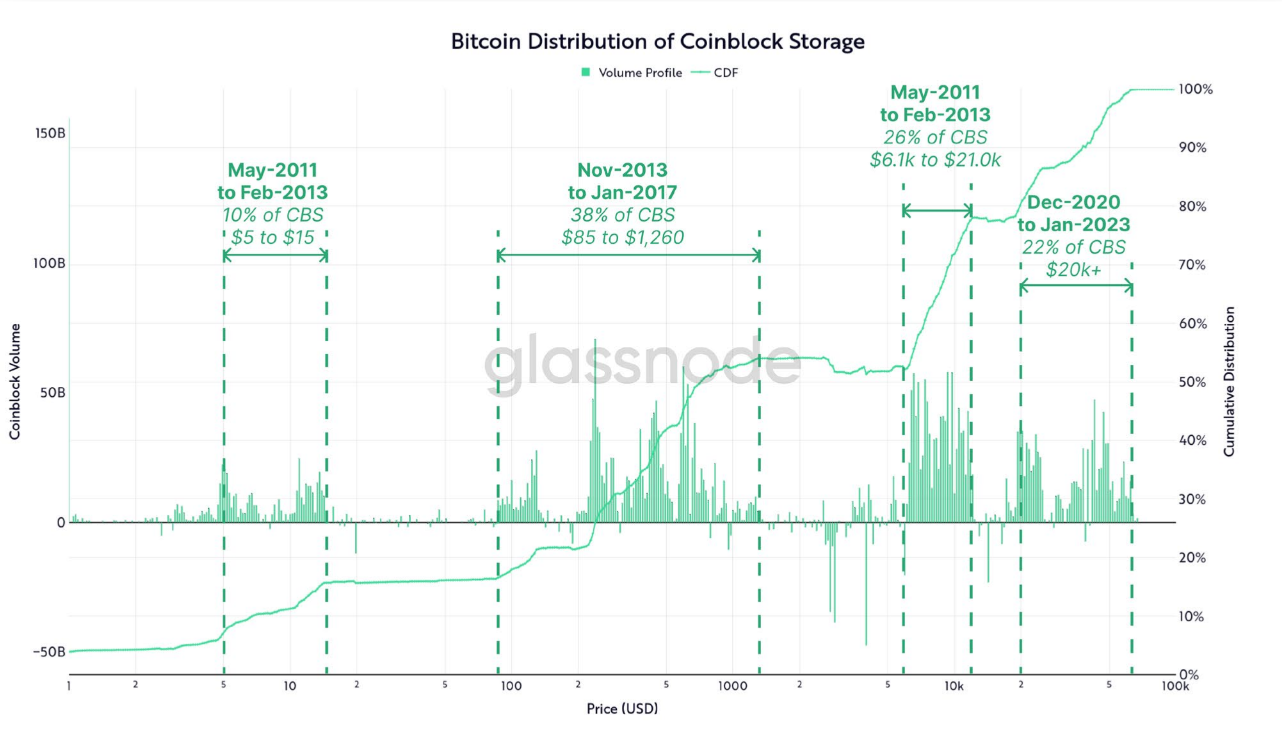
Data as of 8-May-2023. Past performance is not indicative of future results.

For coinblock destruction, we can see similar ranges emerge, however with a larger proportion occurring during the bull market run-up. This is a result of older coins that were often acquired at cheaper prices being spent and sold as longer-term holders take profits.



Data as of 8-May-2023. Past performance is not indicative of future results.

For coinblock storage, the largest proportions tend to correlate with lower bound price ranges reached during later stage bear markets and early stage bull markets. These periods have historically been associated with the lowest degree of network activity and market speculation, as well as a saturation of Bitcoin investors with high conviction and longer-term horizons (both conditions leading to low coinblock destruction).



Data as of 8-May-2023. Past performance is not indicative of future results.

Case Studies & Economic Applications

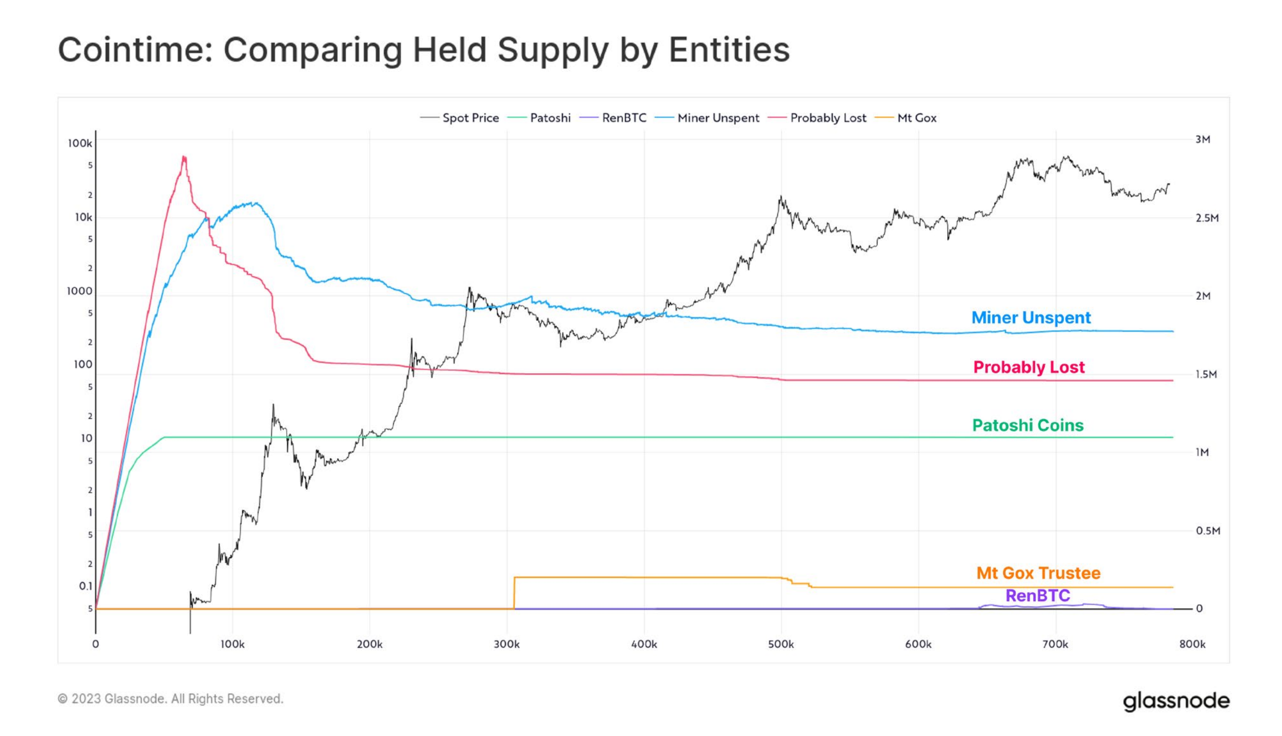
Analysis of On-Chain Entities

When Liveliness was first introduced, it was suggested that it could be used as a tool to monitor and compare the relative activity across various blockchain assets. We agree with this notion and believe Cointime Economics may also be applied on a per-entity basis for cohorts active within the same blockchain. Analysis of such entities can also provide a reference for the relationship between on-chain activity and the behavior of cointime primitives at the extremes.

To demonstrate this, we introduce five Bitcoin entities displaying varying degrees of on-chain activity relative to the total balance held.

Entity Name	Description
Patoshi	Coins commonly associated with the Satoshi entity, which amount to ~1.096M BTC and, to date, have only spent 10 BTC, famously sent to Hal Finney in block 170.
Miner Unspent	Coins which were rewarded to a miner, but have never been spent from the coinbase transaction. This supply will increase with each new block reward and decrease as they are spent (both historically mined and newly mined coins)
Probably Lost	Coins often referred to as 'Zombie Coins', which were mined and/or active prior to the first traded price of Bitcoin in July 2010, but have been inactive ever since.
Mt Gox Trustee	Coins held by the legal trustee on behalf of the Mt. Gox creditors following the failure of the exchange. These coins were moved to a wallet in 2014, have seen one tranche of release in 2017-2018, and are expected to be fully distributed to creditors in 2023.
RenBTC	Coins held by the cross-chain BTC wrapping service Ren. This entity utilized a wallet management system such that each deposit and withdrawal would trigger a spend of the entire balance (which reached over 33.5k BTC at the peak). This acted to consolidate new deposits or peel off withdrawals, creating a full balance spend every few blocks.

The chart below shows the held supply balance history of each entity relative to blockheight.



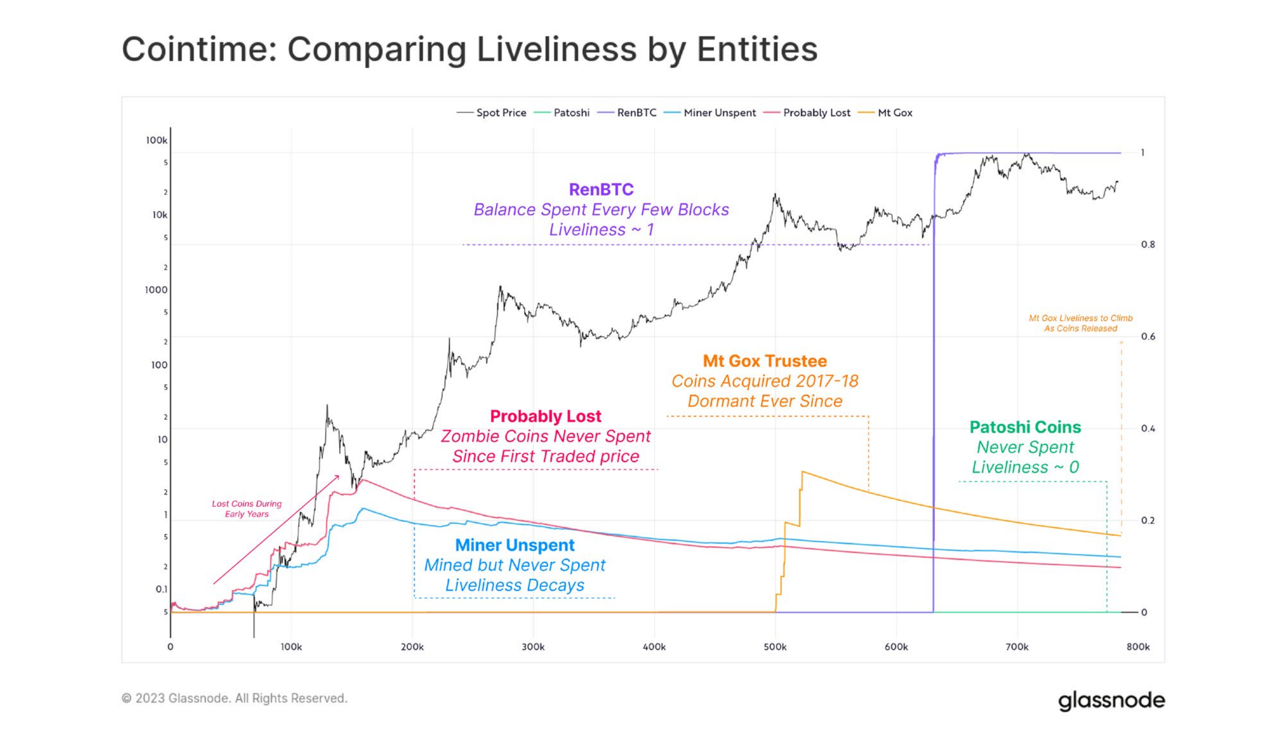
Data as of 8-May-2023. Past performance is not indicative of future results.

Looked at through the lens of Liveliness, we can see the following distinct patterns:

- **Patoshi** coins display a Liveliness of effectively zero, given the balance has remained (and many expect it to remain) inactive indefinitely.
- **Miner Unspent** coins experience an uptick in Liveliness until 2012, at which point ASICs were developed and mining started to industrialize. This led to most mined coins being spent and sold. It can be argued that the remaining 'vaulted' supply within this cohort are very likely lost. Liveliness for this cohort continues to decay as a result.
- **Probably Lost** coins see a similar overall Liveliness pattern to Miner Unspent, with a notable overlap with this cohort. However, this cohort includes coins which have transacted in the past but have been inactive since Bitcoin's first traded price—and thus are likely lost.

- **Mt. Gox Trustee** coins were initially added to holding wallets in early 2014 and remained dormant for several years, resulting in a Liveliness of zero. In 2017-2018, the first tranche of distribution for a total of 64,215 BTC takes place (31.8% of balance), pushing Liveliness up to a peak of 0.306. When the final distributions take place (expected in 2023), Liveliness will trend towards one as the wallets are emptied.

- **RenBTC** coins can be seen to display a Liveliness close to one for the majority of the protocols operation, since just a few blocks separate each balance spend. The RenBTC balance has declined from a peak of over 33.5k BTC in early 2022 to effectively zero today.



Data as of 8-May-2023. Past performance is not indicative of future results.

Estimation of Lost Coins

The accurate estimation of lost coins is a non-trivial task. Estimation requires some combination of explicit labelling of UTXOs (i.e. Satoshi's coins, burned supply) and/or the application of assumptions and heuristics (e.g., minimum inactivity age threshold). To date, the most popular methods and examples of accounting for lost coins are summarized in the following table.

Method	Confidence in Designation as 'Lost'	Lost Coins Case	Description	Estimated Lost Coins (BTC) *(As of 8-May-2023)*
Provably Lost Supply	Certain	Minimum plausible	Coins which are provably lost such as unclaimed miner rewards, coin sent to burn addresses, and those not using OP-RETURN.	3,067 BTC
Probably Lost Supply (Zombie Coins)	Moderate to High	Lower Bound	Coins which have been inactive since the launch of the first BTC exchange in July 2010.	1.457M BTC
Miner Unspent Supply	Moderate to High	Lower Bound	Coins which have remained inactive since being mined (i.e. never spent).	1.773M BTC
Inert Supply (Inactive 7y+)	Low to Moderate	Best Estimate	Coins which have been inactive for at least 7 years.	3.895M BTC
Inactive Supply (Inactive 5y+)	Low to Moderate	Best Estimate	Coins which have been inactive for at least 5 years.	5.530M BTC
HODLed and Lost Supply (Vaulted Supply)	Low	Upper Bound	Cointime Economics consolidated equivalent volume of unspent supply.	7.674M BTC

Whilst it is impossible to perfectly assess the exact volume of lost coins over time, Cointime Economics provides an interesting lens and toolkit through which we can refine our estimates, as well as to quantify the degree by which analysts can discount their influence. The goal of this is to obtain a robust Best Estimate case for the most likely volume of lost coins in the BTC supply

To achieve this, we will utilize and compare a combination of the following frameworks:

- **Cointime Economics** where we consider Liveliness of a specific supply region to be a discount factor, apportioning the degree to which that supply is active or vaulted.
- **Long- and Short-Term Holder Heuristics**, which were introduced by Glassnode as heuristic for the analysis of investor cohorts based on the probability of a coin being spent and the holding time of said coin. This heuristic categorizes coins as Long-Term Holder (155-days or more) and Short-Term Holders (155-days or less), reflecting a low and high probability of being spent, respectively.
- **HODL Wave Age Bands**, where UTXOs are grouped based on their age and the probability of a coin being lost increases with inactive time. It typically has a threshold of at least 5 years, but generally more than 7 years is considered likely to be lost.

Upper Bound Estimates (UB)

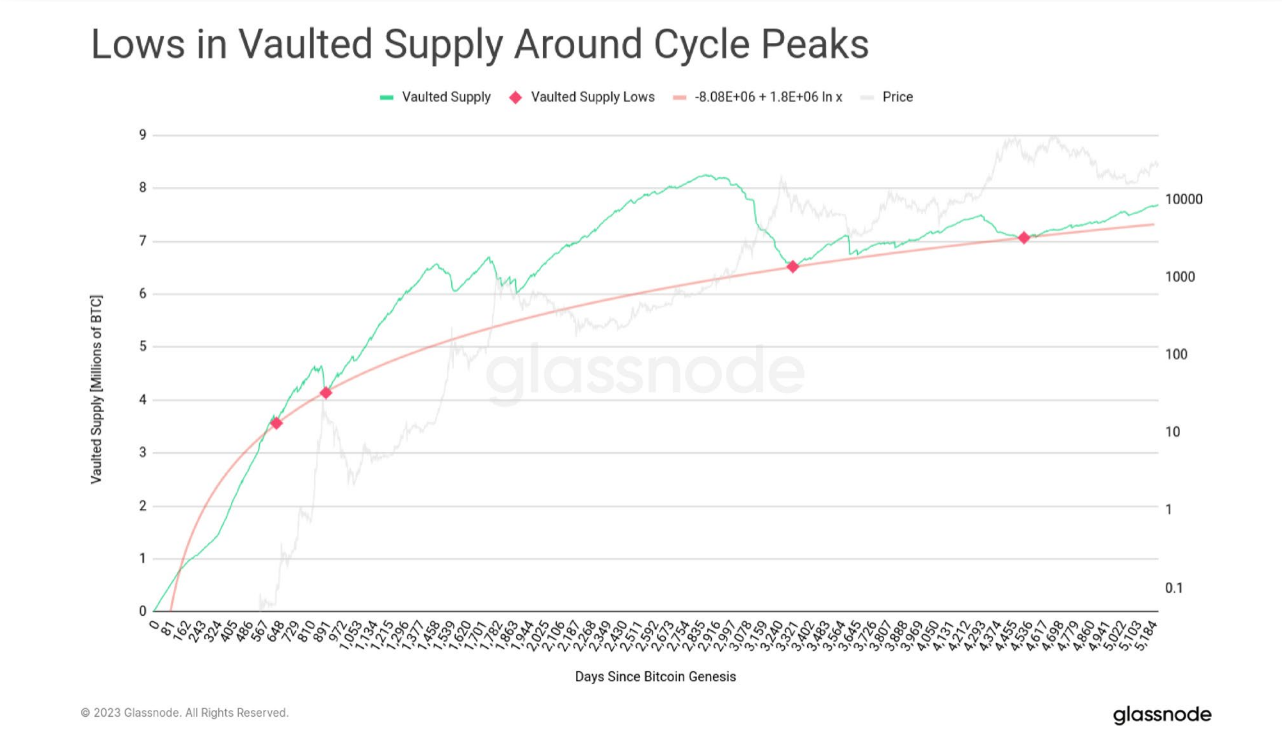
An upper bound estimate for lost coins can be considered from three estimates:

UB1: Vaulted Supply can be considered to be the absolute upper bound estimate on the number of lost coins at any point in time. For a given volume of cointime stored within the network, Vaulted Supply indicates the volume of never-spent supply required to generate it. If every coin that could transact did so in the next block, Vaulted Supply would equal the true volume of lost coins.

UB2: Vaulted Supply at or near Cycle Peaks where we make the assumption that during the blow-off of market cycle peaks, investors have experienced the maximum incentive to spend coins and realize profits. From this, we can approximate a logarithmic curve fit ceiling model, in a simple attempt to separate cyclically HODLed from likely Lost coins.

$$Lost\ Vaulted\ Supply\ Ceiling = -8.08 + 1.8ln(x)\ [Millions\ of\ BTC]$$

$$where\ x = days\ since\ genesis$$



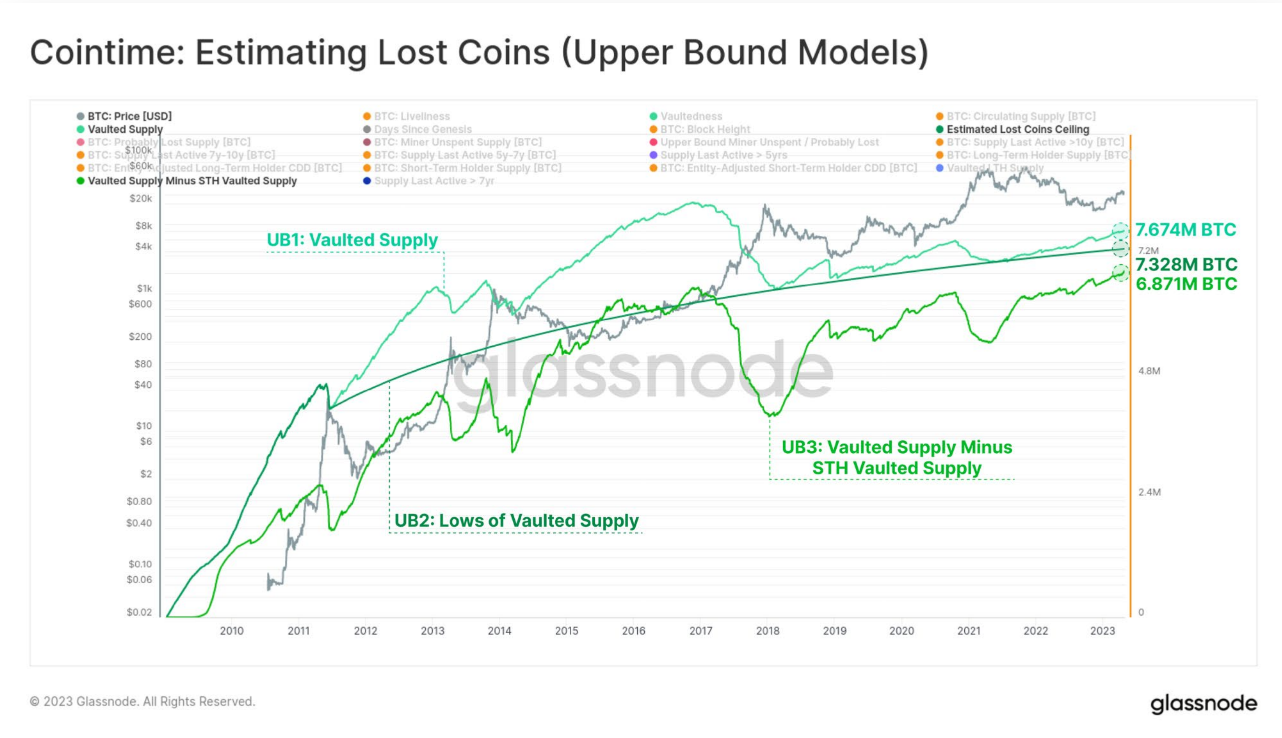
Data as of 8-May-2023. Measured since inception. Past performance is not indicative of future results.

- **UB3: Vaulted Suppl**y minus Vaulted Short-Term Holder (STH) Supply. Based on the observation that STH-Supply is the most likely to be spent, we can also reasonably assume that is the least likely to be lost. This is despite the fact that STH Supply has accumulated and stores a degree of cointime. Thus, we can calculate STH Vaultedness, and STH Vaulted Supply, and subtract this from the total Vaulted Supply.

$$
\begin{aligned}
STH\ Vaulted\ Supply &= Vaultedness_{STH} * STH\ Supply \\
&= \left(1 - \frac{\sum CBD_{STH}}{\sum CBC_{STH}}\right) * STH\ Supply
\end{aligned}
$$

The table and chart below summarise these three upper bound estimates for lost coins.

Upper Bound Models *(As of 8-May-2023)*	**Estimated BTC**	**Percent of 21M Cap**
UB1 Vaulted Supply	7.674M BTC	36.54%
UB2 Vaulted Ceiling	7.328M BTC	34.90%
UB3 Vaulted minus STH Vaulted (Adopted Value)	6.871M BTC	32.72%



Data as of 8-May-2023. Past performance is not indicative of future results.

Lower Bound Estimates (LB)

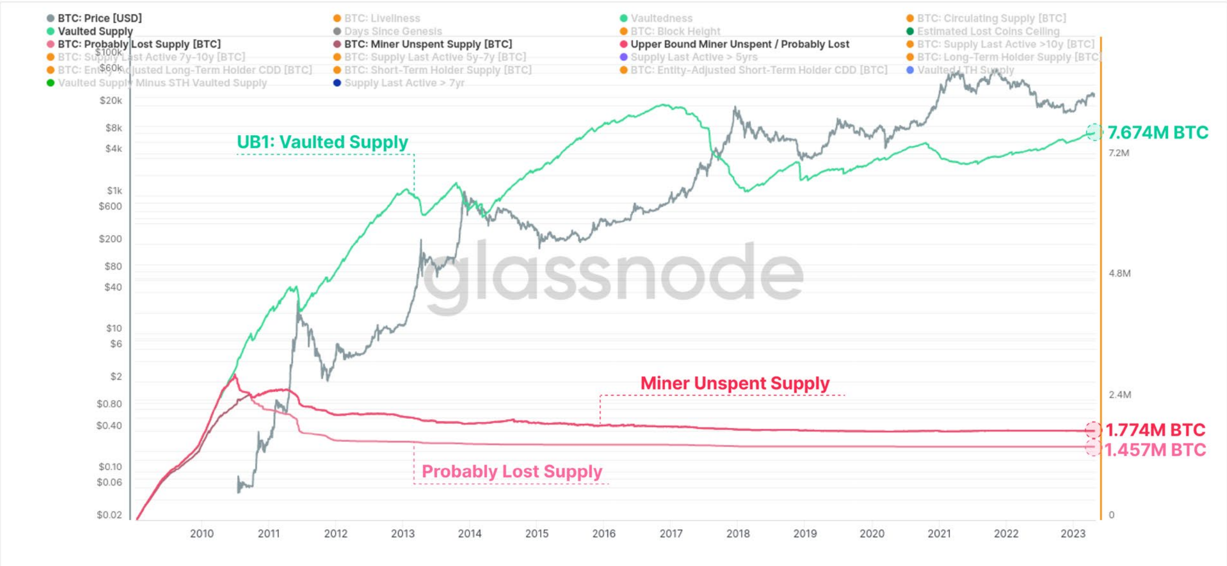
A lower bound estimate for lost coins can be reasonably considered from two model estimates:

LB1: Upper bound of Miner Unspent and Probably Lost Supply. This model accounts for all coins that were mined and never spent, and those which have been inactive since Bitcoin's first traded price in July 2010. Given modern miners have industrialized and now rarely lose mined coins, the majority of this supply region is from the early years and are highly likely to be lost.

The table and chart below summarize these lower bound estimates for lost coins.

Lower Bound Models *(As of 8-May-2023)*	Estimated BTC	Percent of 21M Cap
Miner Unspent Supply	1.774M BTC	8.45%
Probably Lost Supply	1.457M BTC	6.94%
LB1 Max of Miner Unspent, and Probably Lost Supply (Adopted Value)	1.774M BTC	8.45%

Cointime: Estimating Lost Coins (Lower Bound)



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

Best Estimates

It is likely that the true volume of lost coins lies in between these upper, and lower bound estimates. To calibrate this, we consider three supply region models:

BE1 Coins Inactive 5y+, making the assumption that five years is an appreciable period of time for a Bitcoin holder to experience a classic 4-year halving market cycle. Whilst this region is likely to contain a large majority of the lost coins, it is also expected to be an over-estimation given the propensity for Bitcoin investors to hold for long periods of time.

BE2 Coins Inactive 7y+ is similar to BE1, however is likely a better estimate given the extensive period of inactivity and exposure to multiple market up and down cycles.

BE3: Long-Term Holder Vaulted Supply represents the most inactive subset of LTH supply. LTHs are already the least likely cohort of coins to transact, having remained inactive for ~155 days. Whilst this supply region will include a great majority of lost coins, it is incorrect to assume that the entirety are lost. Instead, we can calculate Vaultedness for LTH Supply, and consider the Vaulted component of LTH Supply as the subset which is the most likely to be lost.

$$Vaultedness_{LTH} = \left(\frac{\sum CBD}{\sum CBC}\right)_{LTH}$$

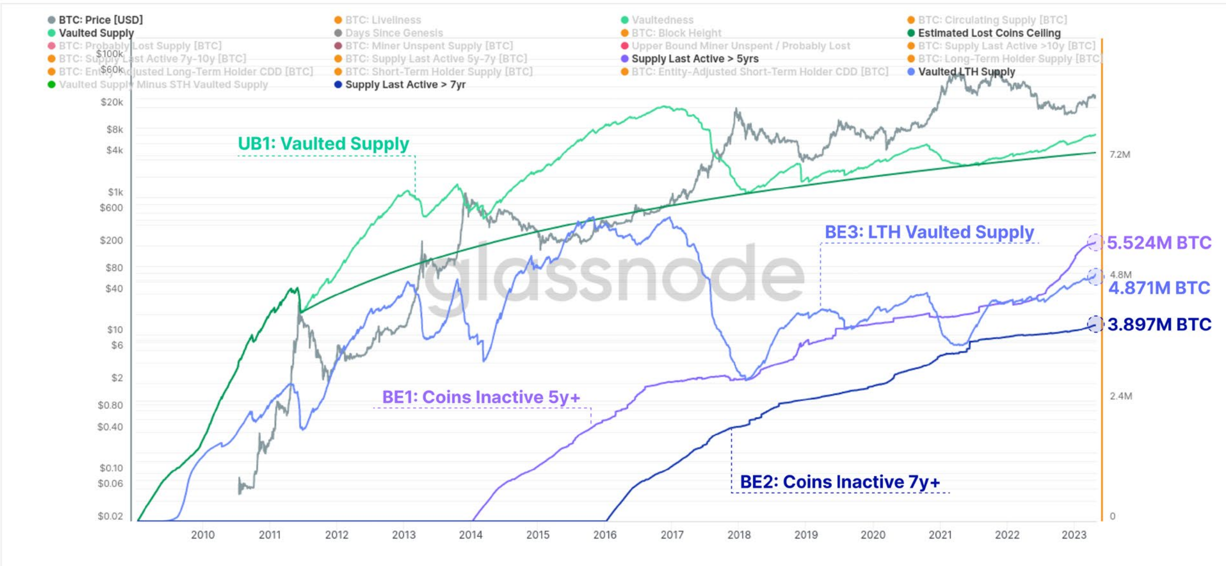
$$Vaulted\ Supply_{LTH} = Vaultedness_{LTH} * Supply_{LTH}$$

We also note in the chart below, that this model experienced a significant decline in 2017, as many long dormant coins were transacted during the market run-up. This moved away from levels similar to upper bound model UB3, suggesting a re-evaluation of the truly lost supply had taken place. After this time, it has persisted between 2.9M and 4.9M BTC, at levels closer to best estimate models BE1 and BE2.

This raises an important note regarding the application of Cointime Economics in that it reflects the relevant discounting factor for coin inactivity at the data point of evaluation. Thus the higher historical data up until mid-2017 reflects a case where, until that time, there was an elevated probability that lost coins were closer in volume to that suggested via the upper bound models.

Best Estimate Models *(As of 8-May-2023)*	**Estimated BTC**	**Percent of 21M Cap**
BE1 Coins Inactive 5y+	5.524M BTC	26.30%
BE2 Coins Inactive 7y+ (Adopted Value)	3.897M BTC	18.56%
BE3 LTH Vaulted Supply (Adopted Value)	4.871M BTC	23.19%

Cointime: Estimating Lost Coins (Best Estimates)



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

Concluding Estimates of Lost Coins

Whilst we reiterate that accurate estimation of lost coins is an extremely difficult task, we believe that simplified methods enabled by Cointime Economics provide analysts with a toolkit by which to improve their estimates. The results share agreement with industry standard heuristics and provide a unique lens through which to update and adjust economic calculations which are influenced by lost coin volumes (e.g., metrics related to unrealized profits).

Our range of estimates are summarised in the table and chart below, with our best estimate of lost Bitcoin supply being between 18.5% (3.897M BTC), and 23.2% (4.871M BTC) of the circulating supply.

Estimate of Lost Coins *(As of 8-May-2023)*	Case	Estimated BTC	Percent of 21M Cap
LB1 Max of Miner Unspent and Probably Lost Supply	Lower Bound	1.774M BTC	8.45%
BE2 Coins Inactive 7y+	Lower Best Estimate	3.897M BTC	18.56%
BE3 LTH Vaulted Supply	Upper Best Estimate	4.871M BTC	23.19%
UB3 Vaulted minus STH Vaulted	Upper Bound	6.871M BTC	32.72%

Cointime and Supply in Profit/Loss

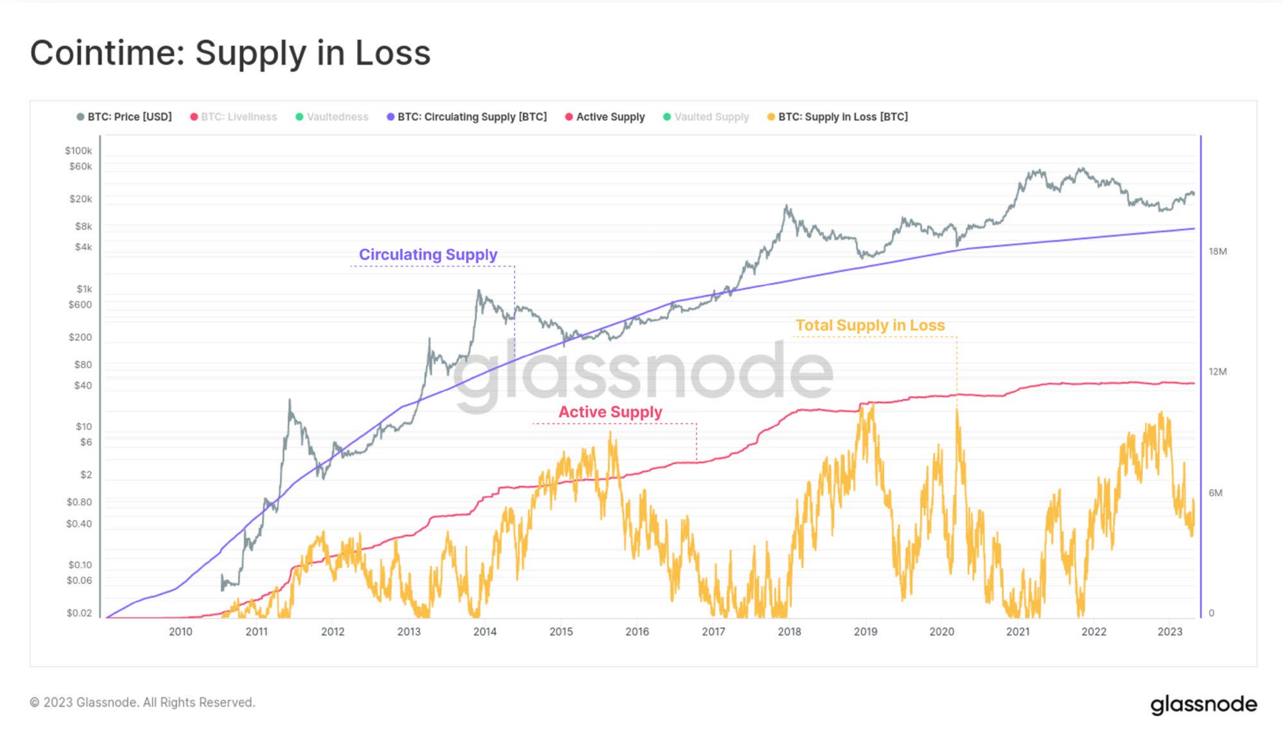
In Chapter 6, we made the claim that the traditional MVRV break-even value of 1.0, may in fact be masking the scale of unrealized loss held within the economically meaningful supply. We believe this assertion is sound and is visible when comparing Cointime supply regions with the total Supply Held in Profit or Loss.

We consider a unit of BTC to be 'in profit' where the spot price is trading above the realized price of the coin (i.e. the pricestamp of the UTXO or the price when coin last transacted on-chain).

The chart below shows the following traces:

- Circulating Supply, being the total BTC coin supply.
- Active Supply, reflecting a volume equivalent to the economically active supply.
- Total Supply in Loss, being the volume with a realized price higher than the spot price.

We can see an interesting phenomena, whereby the Total Supply in Loss has approached and historically intersected with Active Supply, typically during the latest stages of cyclical bear markets. This would suggest that a vast majority, if not all, of the economically active coin supply is in fact held at a loss during these times.

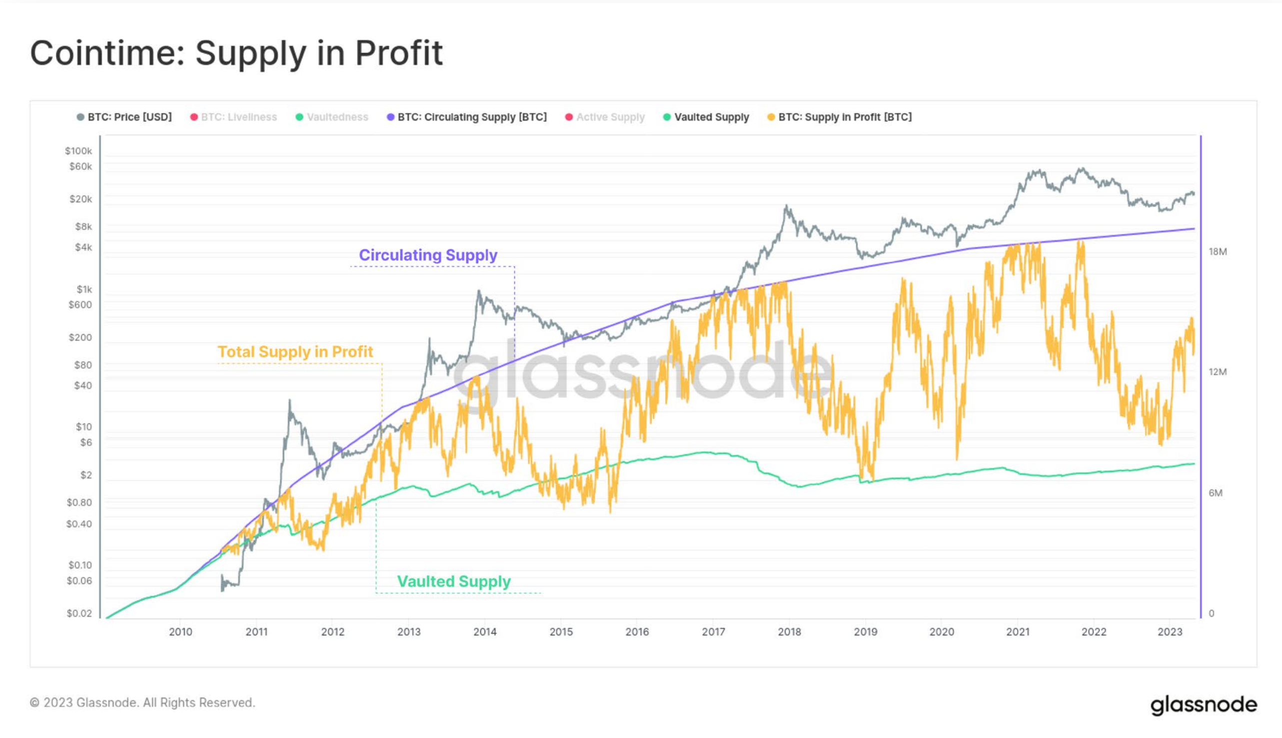


Data as of 8-May-2023. Past performance is not indicative of future results.

By contrast, the chart below shows the relationship between the opposing supply regions:

- Circulating Supply.
- Vaulted Supply, reflecting a volume equivalent to the economically inactive supply.
- Total Supply in Profit, being the volume with a realized price lower than the spot price.

These convergence events between Total Supply in Profit and Vaulted Supply, suggests a degree of saturation by price-insensitive holders who are unwilling to spend their coins despite the market drawdown. It aligns with the widely discussed formation of Bitcoin market floors by the highest conviction holders.

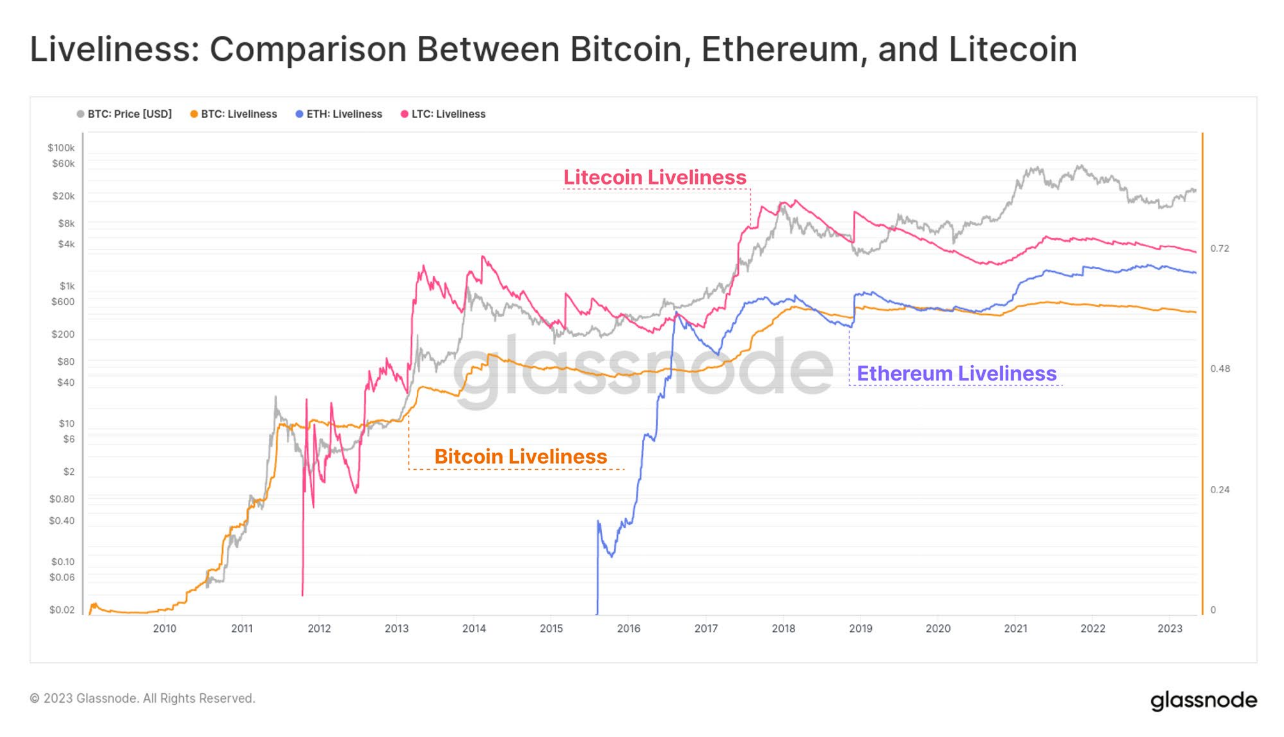


Data as of 8-May-2023. Past performance is not indicative of future results.

Of interest is the gradual divergence between these traces over time, where the volume of Supply in Profit has not fallen beyond the lower bound of Vaulted Supply since the 2015. This may be related to, or perhaps a driver of, the progressively smaller absolute drawdowns observed over each Bitcoin market cycle. It suggests that a portion of the economically active supply remains held in profit, as inflows of demand establish market floors earlier as Bitcoin adoption and awareness increases.

Application to Other Crypto-asset Networks

Cointime Economics can, in theory, be applied to any asset from which a Circulating Supply and a Liveliness value can be computed. The chart below shows Liveliness for Bitcoin, Ethereum, and Litecoin, which are three of the oldest and most widespread crypto-assets. It can be seen that Bitcoin has consistently maintained the lowest Liveliness value of the three, which indicates that a larger proportion of the supply is lost, inactive, and otherwise Vaulted.



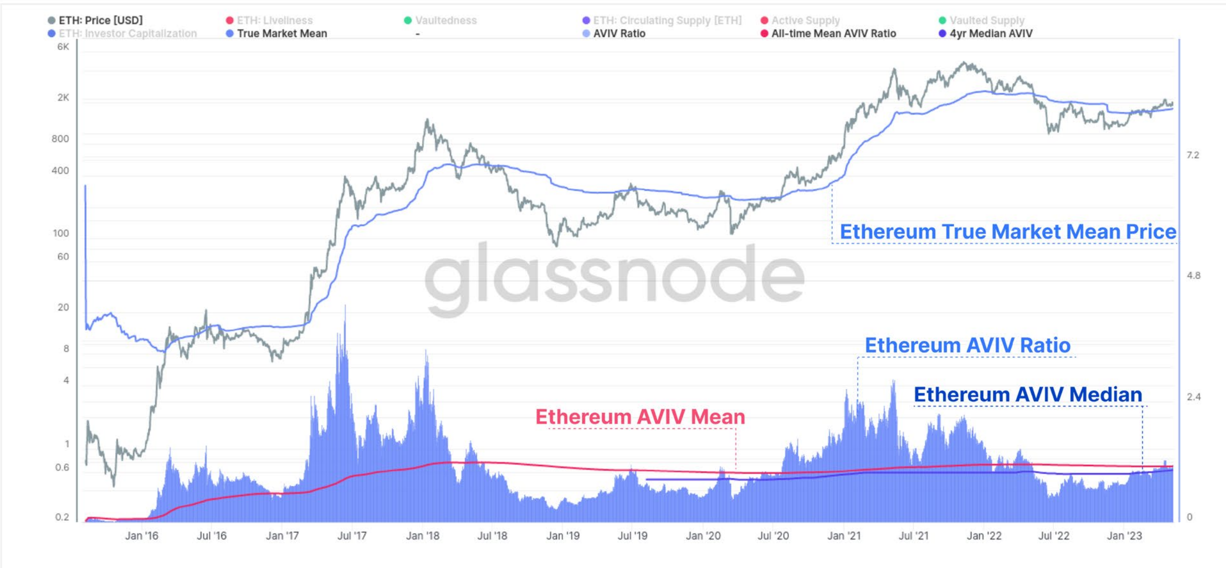
Data as of 8-May-2023. Past performance is not indicative of future results.

It is likely that one of the metrics of greatest interest for analysis of these assets is the True Market Mean Price and the AVIV Ratio, having been shown to be a true middle value for Bitcoin. What we find is quite remarkable in that the mean and median for AVIV continue to oscillate around values very close to 1.0 for all three assets.

Crypto-asset	AVIV Median	AVIV Mean	Percent of History AVIV > 1
Bitcoin	1.038	1.018	53.30%
Ethereum	1.029	1.110	45.91%
Litecoin	0.905	1.253	50.56%

For Ethereum, we can see that the True Market Mean Price acts as a point of mean reversion, being a threshold that is often crossed by spot prices as secular market tides turn. The mean (1.110) and median (1.029) are extremely close to 1.0, and 45.91% of trading days have closed with an AVIV Ratio above 1.0 (nearly half of Ethereum's 7.5-year history).

Ethereum: Cointime True Market Mean and AVIV Ratio

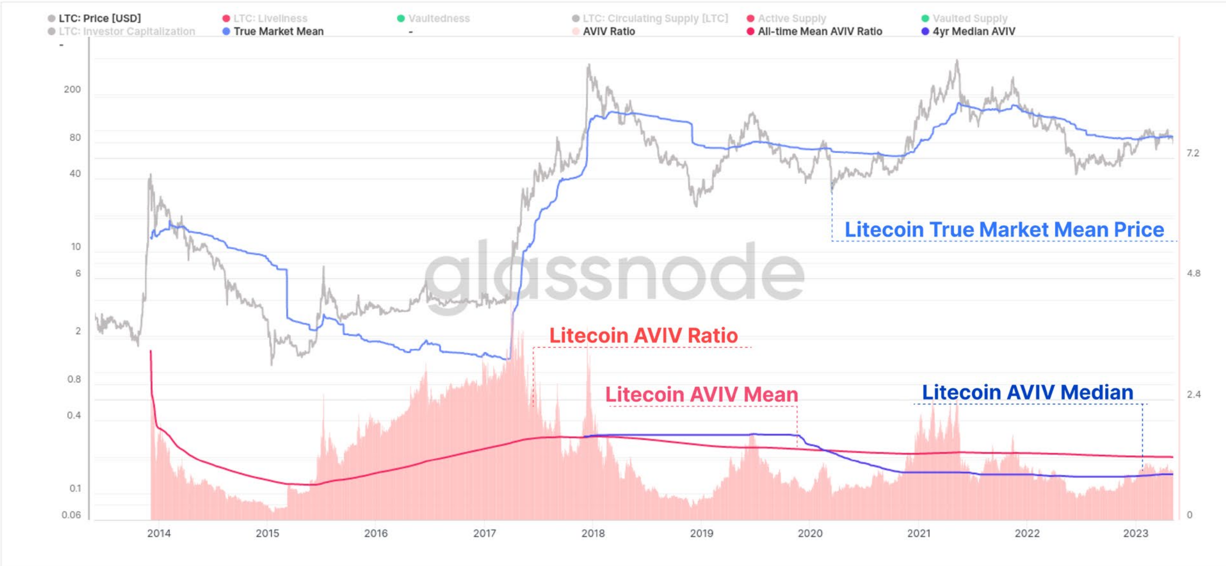


glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

A similar set of observations can be made for Litecoin, which has 11.5 years of trading history and displays an AVIV Ratio with a mean (1.253) and median (0.905) that are much closer to 1.0 than traditional MVRV counterparts.

Litecoin: Cointime True Market Mean and AVIV Ratio



glassnode

Data as of 8-May-2023. Past performance is not indicative of future results.

Crypto-asset networks are unique in the degree of transparency into their economic performance, available through inspection of the blockchain database. The consistency of these Cointime Economics frameworks across several networks and assets leaves the authors wondering if they would perhaps be applicable to other commodities, equities, and similar, if Liveliness data was to ever come to light.

About the Authors

James Check

Lead Analyst at Glassnode

James Check (pseudonym Checkmate) is the lead analyst for Glassnode and specializes in the study of the Bitcoin economy.

He fell down the Bitcoin rabbit hole during 2018 bear market, and began his research into the field of on-chain analytics as the discipline began to emerge later that year. He developed passion for macro economics, markets, and Bitcoin on-chain data, and started down the path of education, seeking to help curious investors understand more about what happens under the hood of Bitcoin.

James joined Glassnode as Lead Analyst in Feb 2021, where he manages a team of analysts responsible for conducting research, developing new metrics, analysing markets, and creating educational content around the discipline of on-chain analytics.

David Puell

Research Associate at ARK Invest

David joined ARK in January 2022. As a Research Associate, he focuses on Bitcoin and cryptoasset on-chain and market research.

Prior to ARK, he was Head of Research at Adaptive Capital in 2019 and 2020. He is best known for pioneering the emergent field of cryptocurrency on-chain analysis and has created a dozen metrics used industry-wide today, including the MVRV Ratio and the Puell Multiple. His metrics are featured in most major cryptoasset data platforms such as Glassnode, Coin Metrics, and CryptoQuant.

David has been quoted in Bitcoin Magazine, Coindesk, among other publications, and has been featured in the Bitcoin Magazine Podcast, Will Clemente's Blockware Intelligence Podcast, and The Pomp Podcast.

-----BEGIN BITCOIN SIGNED MESSAGE-----

Introducing Cointime Economics by James Check and David Puell

(98ffd17758330871f53a10b36b94a3f96739de69ec4db9e60b71b06a691fb6f1i0)

-----BEGIN BITCOIN SIGNATURE-----

12CT4LDZgMWjzPah3dtMJbX4aThXXTroB7

IOARb4ScmnZnuRL2gAj6pSPSJu8hTUmv1GPd5S0mvTJ3VhA4mq1v5Z/MJRTvVgOnBgCdV3UJjaC//P61GOy6ETE=

-----END BITCOIN SIGNATURE-----

Important Information

Please note that the information presented in this paper represents a new concept that has not been widely used or adopted at the time of publication and should not be relied upon as a basis for any investment decision.

The information provided is for informational purposes only and is subject to change without notice. This report does not constitute, either explicitly or implicitly, any provision of services or products by ARK, and investors should determine for themselves whether a particular investment management service is suitable for their investment needs. All statements made regarding cryptocurrencies are strictly beliefs and points of view held by ARK and/or Glassnode and are not recommendations by ARK to buy, sell or hold any cryptocurrency. Historical results are not indications of future results.

Certain of the statements contained in this material may be statements of future expectations and other forward-looking statements that are based on current views and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in such statements. ARK assumes no obligation to update any forward-looking information contained in this material. ARK and its clients as well as its related persons may (but do not necessarily) have financial interests in the cryptocurrencies that are discussed. Certain information was obtained from sources that ARK believes to be reliable; however, ARK does not guarantee the accuracy or completeness of any information obtained from any third party.

CRYPTOCURRENCY RISK—Cryptocurrency (notably, bitcoin), often referred to as "virtual currency" or "digital currency," operates as a decentralized, peer-to-peer financial exchange and value storage that is used like money. Cryptocurrency operates without central authority or banks and is not backed by any government. Even indirectly, cryptocurrencies may experience very high volatility. Cryptocurrency is also not legal tender. Federal, state or foreign governments may restrict the use and exchange of cryptocurrency, and regulation in the U.S. is still developing. Cryptocurrency exchanges may stop operating or permanently shut down due to fraud, technical glitches, hackers or malware.

This paper is the result of a collaboration between David Puell of ARK and James Check of Glassnode. Glassnode is a blockchain data and intelligence provider that generates innovative on-chain metrics and tools for digital asset stakeholders, and is unaffiliated with ARK.

glassnode

×

ARK INVEST