MEKETA

Fitting crypto in a portfolio

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Though Bitcoin was launched in 2009, it took roughly a decade for many institutional investors to show serious interest in it and other cryptocurrencies. As their interest in cryptocurrencies grew, a natural question arose about where these assets should fit within their portfolio, since cryptocurrencies are unlike anything else in which these institutions had typically invested.

This paper seeks to help investors answer that question. It focuses primarily on Bitcoin, as Bitcoin has the longest track record as a successful digital currency, a regulated futures market, and a market cap that makes its integration into the investible universe more complete. The paper reviews historical performance as a potential guide, delves into a qualitative analysis of the return drivers for the asset class, and then examines the question from a quantitative perspective.[1]

Key takeaways

- Bitcoin's early years were defined by extreme volatility and illiquidity. The market has since changed, and it continues to evolve. This makes it challenging to rely on past performance behavior in extrapolating expectations for the future.
- Bitcoin's price movements are not tied to traditional drivers such as GDP growth, interest rates, or corporate earnings. Instead, they are influenced by speculation, sentiment, and liquidity cycles in the short term, with network adoption likely being a key long-term return driver. Bitcoin's empirical record shows it has behaved like a high-beta equity asset and is often correlated with "risk-on" assets.
- Although Bitcoin's finite supply and independence from central banks suggest it could protect against certain types of inflation and currency debasement, this potential remains unproven. Bitcoin's underperformance during the inflation spike from 2021 to 2023 showed that it is not an ideal hedge for supply shock-induced inflation.
- Bitcoin's present correlation with risk assets restricts its effectiveness as a defensive asset, while its volatility diminishes its suitability as a stable store of value. However, increased adoption and institutional participation may eventually mitigate this volatility and enhance its prospects as a reliable store of value.

[1] Not all cryptocurrencies have the same economics and use cases as Bitcoin. Bitcoin benefits from network effects that make it likely to retain its dominant position for the foreseeable future. The total number of Bitcoins to be created is already limited by the blockchain encryption rules. This limit makes its future scarcity a driver of near-term value – much like diamonds or gold or even oil reserves. The very high price for a single Bitcoin makes is largely unsuitable for daily consumer transactions but ideal for preservation of large sums of wealth. Most other cryptocurrencies have no upper limit in the number of crypto coins produced.

- Despite its high volatility, Bitcoin can improve risk-adjusted returns in portfolios, though the extent of this is very dependent on the assumptions used. Bitcoin may benefit portfolios via its low correlation with most assets and a non-intuitive boost to potential return from its high level of volatility. However, it poses systemic and regulatory tail risks that are not easily accounted for in traditional risk frameworks.
- Even small allocations to Bitcoin can heavily influence total portfolio risk. A 5% Bitcoin allocation may contribute roughly 10-20% of total portfolio volatility, depending on the assumptions used. Likewise, Bitcoin could add an outsized amount of tracking error versus peer benchmarks or policy portfolios.

Learning from history?

Typically, when we want to understand the nature of an asset class, we start by examining its history. Bitcoin presents many challenges in this regard, as it has a fairly short history compared to most other asset classes, and its history over the past fifteen years may be less representative of its future than is the case for other asset classes. Hence, learning from Bitcoin's history is not straightforward. Investors should be cautious about assigning too much emphasis to Bitcoin's history and extrapolating the wrong lessons from it.

Using the longest available history to analyze performance metrics is usually considered a best practice. The longer the history, the broader the range of market environments the analysis captures, including rare but impactful events like financial crises and recessions. It also provides a more robust dataset, reducing the influence of short-term anomalies or other forms of endpoint bias that can distort metrics.

However, Bitcoin presents a conundrum. The first five years of Bitcoin's history were characterized by shockingly large price swings (see Figure 1). Eight of Bitcoin's ten largest month-over-month percentage changes occurred prior to 2014. The largest of these took place in November 2013 with a jump in price of 451%. These large upswings were accompanied by dramatic losses, such as the 93% peak-to-trough price decline in 2011.

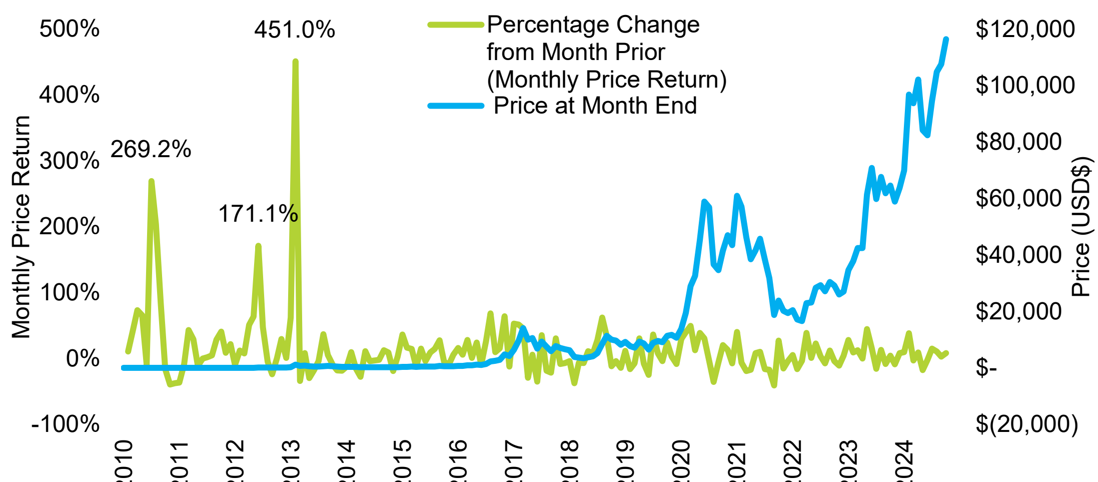

FIGURE 1

Bitcoin Monthly Price and Return

Source: Bloomberg as of July 31, 2025. Indices Used: Bitcoin-USD Cross. While Bitcoin was created in 2008 and launched in 2009, the earliest for which we have access to price data began in October 2010. This should not meaningfully impact the analysis since, as described in the first section of the paper, we start the analysis post-2013.

Of note, the depth and liquidity of the Bitcoin market was relatively low in Bitcoin's earlier years. Trading venues were primitive at the time, and daily volumes were tiny - sometimes only a few thousand dollars.[2] Substantial price swings tend to be more common in less liquid markets as large trades can move prices significantly. Because the Bitcoin market has since become more liquid, such large price swings are less likely in the future.

In addition, history shows that newly investable assets often exhibit a high-return, high-volatility "frontier" period, followed by a moderation as they mature. Economists sometimes call this the "initial adoption premium" or "novelty effect."[3] Thus far, Bitcoin fits neatly into this historical pattern. When Bitcoin was introduced, the idea of a decentralized digital currency was not widely known or understood, and untested in real-world financial markets.[4] After Bitcoin began to gain traction, other cryptocurrencies were created, and investment climbed sharply. Since then, cryptocurrencies have become household names, with an increasing number of offerings and ways to access the market. The market is likely to continue to become more efficient as new products (e.g., ETFs) make the asset class more accessible and professional investors arbitrage away mispricings and inefficiencies.

Therefore, it makes sense to assume that the future returns of Bitcoin will not closely resemble those seen in the very earliest years of Bitcoin's life. However, this leaves open the question of exactly what time period to use.

Figure 2 depicts how the rolling one-year standard deviation for Bitcoin from years 2011 through 2014 was more than three times as high as its post-2014 standard deviation. Bitcoin's annualized standard deviation over the full period was 171%, but it dropped to less than half of that post-2013 at 75%. In recent years, it has been closer to 50%.

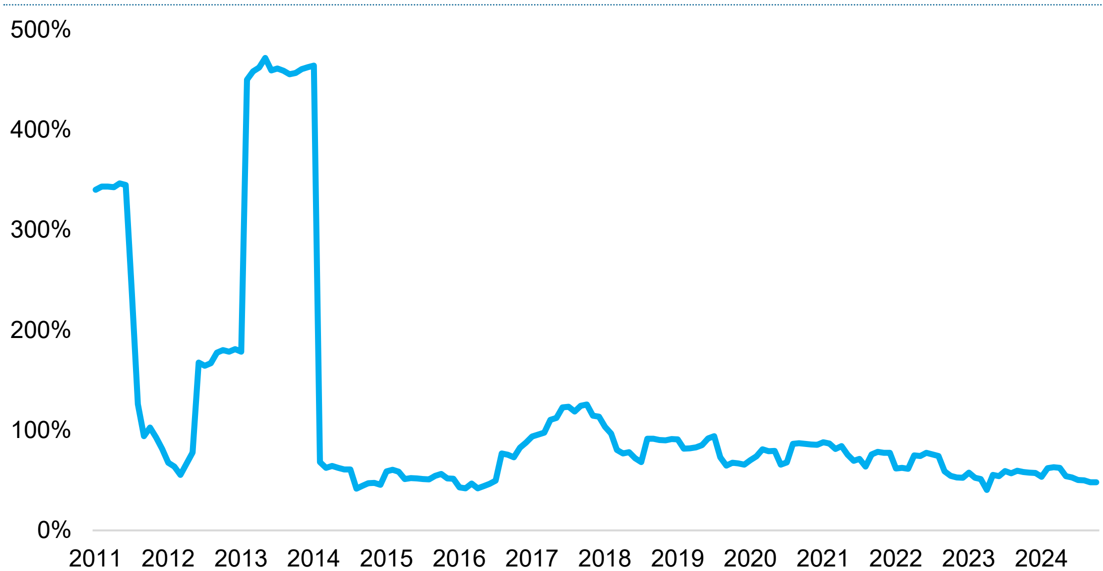

FIGURE 2

Rolling 1-Year Annualized Standard Deviation

Source: Bloomberg as of July 31, 2025. Indices Used: Bitcoin-USD Cross.

2 Source: Bitcoinity.org.

3 See "Time-Varying World Market Integration" by Bekaert and Harvey (1995), "Does Arbitrage Flatten Demand Curves for Stocks?" by Wrugler and Zhuravskaya (2002), and "Trading and Arbitrage in Cryptocurrency Markets" by Makarov and Schoar (2019).

4 Additionally, during its early life Bitcoin was largely owned (and therefore controlled) by a small group of people, making it a less accurate representation of the current market position which is dispersed among a large number of parties.

The first major cryptocurrency exchanges were starting to gain traction in the period from 2013 to 2016, which makes this a potentially solid jumping off point.[5] Another possible starting point is 2017, when the CME and CBOE launched regulated Bitcoin futures, which provided a turning point for institutional access. Global cryptocurrency exchanges (e.g., Coinbase, Binance, Kraken) were established around this time and experienced billions in daily volume. More recently, the creation of Bitcoin ETFs in 2024 further institutionalized the market. Therefore, to balance using the longest available history while also excluding this early period of distorted performance, throughout this paper we use January 2014 as the earliest data point considered.

Return drivers

The question remains, what is driving Bitcoin's monumental climbs and falls, and should we continue to expect them in the future? Bitcoin's performance is not generally attributable to traditional asset class return drivers. Unlike financial assets, Bitcoin does not derive its value from claims on current and future cash flows. And, unlike real assets, Bitcoin does not represent ownership of a physical asset. Therefore, Bitcoin's performance is not driven by traditional return drivers like dividend yield, GDP growth, and valuations for equities, yield to worst and credit spreads for fixed income, or common drivers for private markets such as leverage and valuations.

Given that Bitcoin was designed to be an alternative to fiat currencies, it may be more relevant to examine the return drivers of traditional currencies. Indeed, Fidelity argues that "Bitcoin is best understood as a monetary good,"[6] which is to say, a currency. However, comparing Bitcoin to traditional fiat (i.e., government-issued) currencies would not show a complete picture since one of Bitcoin's core principles is to be decentralized and therefore not tied to any government or nation. Gold shares some core attributes with Bitcoin that may make it relevant to examine in this context. Both gold and Bitcoin have a limited supply, are not tied to a central bank, are globally accessible, and neither is ideal for exchanging most goods and services. Conversely, Bitcoin is not universally considered a "safe" store of value like gold (yet), has exhibited significantly more price volatility, and does not have a proven history of serving as a diversifier or inflation hedge. For better or worse, Bitcoin presents a new and unique case where its return drivers cannot easily be attributed to those of an already-established asset class.

Academic and institutional research has generally found Bitcoin's short-term returns to be dominated by speculation, sentiment, and liquidity conditions. Studies found that attention and momentum have fueled a self-reinforcing feedback loop of demand where rising prices attract more buyers, driven by media coverage and the lure of extraordinary gains, which in turn pushes prices even higher.[7] In other words, it suggests that Bitcoin's valuation is largely dependent on the collective belief that its price will continue to rise. Similarly, research has found that global liquidity has a strong influence over Bitcoin's performance as it tends to move in

5 Note, however, that the collapse of Mt Gox in 2014 served to accelerate the already declining price in Bitcoin.

6 Source: "Bitcoin (BTC): An overview of Bitcoin and its potential use cases", by Fidelity Digital Assets, August 2025. Fidelity notes that "a monetary good is defined as a good that is valued for its tradability rather than its consumption or use."

7 Sources: Raphael Auer, Giulio Cornelli, and Jon Frost, Crypto Trading and Bitcoin Prices: Evidence from a New Database of Retail Adoption, BIS Working Paper No. 1049, Basel: Bank for International Settlements, November 13, 2022. Paola Di Casola, Maurizio Michael Habib, and David Tercero-Lucas, Global and Local Drivers of Bitcoin Trading vis-à-vis Fiat Currencies, ECB Working Paper No. 2868, Frankfurt: European Central Bank, 2023. Tito Nícias Teixeira da Silva Filho, Curb Your Enthusiasm: The Fintech Hype Meets Reality in the Remittances Market, IMF Working Paper WP/22/233, Washington, DC: International Monetary Fund, December 2022.

tandem with equities and other risk assets during high liquidity periods and expansionary monetary policy.[8] This is consistent with Bitcoin serving as more of a high-beta, sentiment-driven asset (like risky equity assets), rather than as a stable store of value like gold or a means of exchange like fiat currencies.

Structural elements play a role in driving long-term trends rather than short-term price swings. Bitcoin's fixed supply schedule and halving events support narratives of digital scarcity, while network adoption and institutional integration (such as ETF approvals and improved custody solutions) help broaden access and credibility. These factors may represent genuine fundamental value and will likely be increasingly important as a determinant of Bitcoin's long-term performance.

The Case(s) for Bitcoin

Some of the largest Bitcoin investors routinely make the case for Bitcoin as an inflation hedge and/or a store of value.[9] Bitcoin is potentially attractive as an inflation hedge, particularly for investors who fear the active depreciation in value of their currency. This is most evident in countries where inflation may run high and monetary policy supports money printing (e.g., Venezuela, Argentina, and Turkey). This is because Bitcoin is decentralized and independent from any government (i.e., nobody can inflate away its value). This is theoretically also the case, though to a lesser degree, for US-based investors. If inflation is permitted by the Fed (or uncontrollably amplified via fiscal policy) to run at higher rates in the US than it has on average over the past 40 years, Bitcoin's value would remain independent of this inflation.[10]

Importantly, however, this does not necessarily mean that Bitcoin would serve as an attractive hedge against all types of inflation, especially relative to other assets that are available to US-based investors. For example, commodities, short-term TIPS, and natural resources have shown themselves to be better hedges against short-term inflation, particularly if they are caused by something other than monetary and fiscal policy (e.g., supply shocks). Moreover, most long-term investors likely care less about short-term inflation than about long-term inflation eroding the value (or purchasing power) of their assets. In this regard, real assets (e.g., real estate and infrastructure) have proven to be reliable long-term inflation hedges. Furthermore, most long-term investors' portfolios are dominated by equities (via a mix of public and private companies) that have historically shown the ability to pass along costs to customers and grow their earnings in excess of inflation. Therefore, these investors will have to ask themselves if they feel they need even more long-term inflation protection in their portfolio than they currently have, and if so, do they want to use Bitcoin, which does not (yet) have the same track record of reliability as an inflation hedge. Perhaps they will, if they believe they need a hedge against the specific case of monetary-induced inflation (i.e., they are particularly concerned about the level of US debts and deficits).

[8] Sources: Paola Di Casola, Maurizio Michael Habib, and David Tercero-Lucas, Global and Local Drivers of Bitcoin Trading vis-à-vis Fiat Currencies, ECB Working Paper No. 2868, Frankfurt: European Central Bank, 2023. Tobias Adrian, Tara Iyer, and Mahvash S. Qureshi, Crypto Prices Move More in Sync With Stocks, Posing New Risks, IMF Blog, January 11, 2022.

[9] This includes Blackrock, Fidelity and Grayscale. See: "Bitcoin (BTC): An overview of Bitcoin and its potential use cases", by Fidelity Digital Assets, August 2025; "Why Bitcoin? A model portfolio builder's view" by Brett Wager and Michael Gates, BlackRock, February 2025; "The Macro Case for Crypto" by Zach Pandl, Grayscale, September 2025.

[10] Recently, this has become known as the "debasement trade" in the US. See "A New Wall Street Trade Is Powering Gold and Hitting Currencies", Wall Street Journal, October 7, 2025, by David Uberti and Jack Pitcher.

For investors whose portfolios are dominated by fixed income, they have generally adopted this structure because either 1) they are hedging long-term liabilities, or 2) they are risk adverse. Alas, Bitcoin is not a natural fit for either of these portfolio objectives. There is no direct link between Bitcoin and the present value of liabilities that are calculated based on interest rates. And the level of volatility experienced by Bitcoin investors is inconsistent with a risk-adverse portfolio, at least for now. With greater institutionalization, it is quite possible that someday the volatility of Bitcoin will decline to a level where such investors can tolerate having small amounts of it in their portfolio.

This leads us to the store of value and greater adoption theories. The current level of volatility for Bitcoin makes it intolerable as a store of value, at least for US-based investors who have many other assets available to them to serve in that role that exhibit far less volatility (e.g., cash, fixed income, gold).[11] But over time, greater adoption of Bitcoin, both for transactional and investment purposes, is likely to lead to lower volatility. There are historical precedents for emerging assets stabilizing over time as trust and adoption grow. Two case studies on this are the US dollar (post-gold standard) and gold (post-Bretton Woods).[12] They show that after an initial "shake out" period during which markets and consumers gradually develop greater confidence in the long-term viability of these assets, they become more widely accepted and their price volatility declines.

[11] The regulatory uncertainty of Bitcoin may also give investors pause, though the tide in recent years (e.g., the approval of Bitcoin ETFs) bodes well.

[12] See the appendix for more information on these.

Related to this is the extent to which the large historical gains experienced by Bitcoin investors will decline as it becomes more "institutionalized." As an asset matures and becomes more widely adopted, its potential for outsized returns tends to decrease. This is because as more capital flows in and the market becomes more efficient, the asset's price tends to stabilize, and the high growth potential that comes from early adoption phases diminishes. One way to try to evaluate this for Bitcoin is to look at supply and demand. Part of this equation is well established, given the limited supply of Bitcoin. The question then becomes at what rate will demand increase. Will it continue to increase so quickly as to drive up Bitcoin at double-digit annual rates for the foreseeable future? If so, it could exceed earnings growth for the equity market, which would make Bitcoin potentially a very attractive asset for return-seeking investors. If instead it grows at low-to-mid-single digit rates, it could still be attractive to investors, but in a different capacity. An asset that provides mid-single digit returns while exhibiting no more than equity-like volatility and that is uncorrelated with equities (and the economic cycle) would indeed be attractive. But if mid-single digit returns are accompanied by high volatility and returns that are highly correlated with risk-on environments, long-term investors may reasonably ponder what benefit adding such an asset to their portfolio would have.

If Bitcoin volatility eventually falls to bond-like levels, then its role as a store of value becomes much more compelling, as it could serve as an alternative "safe haven" asset. In such a role, Bitcoin could complement or even replace bonds, as Bitcoin does not have the same direct link to interest rate risk and would not be as susceptible to various negative outcomes that may arise from an unsustainable level of US government debt and deficits, notably, higher rates and higher inflation (or default, which seems rather unlikely).[13] That said, Bitcoin remains susceptible to several tail risks, such as exchange hacks, regulatory changes, and protocol vulnerabilities, that could cause severe losses.[14] The presence of these risks (and their perceived probability) will influence the pace of institutional adoption and the attractiveness of Bitcoin as a store of value.

Estimating the long-term price/returns for Bitcoin is beyond the scope of this paper. There are a multitude of models available for doing so, some of which resemble models for valuing gold (e.g., cost of production), and some of which are unique to Bitcoin (e.g., "on-chain" metrics such as stock-to-flow, network value to transactions ratio, realized cap, hodler supply, hash rate). Some of these are more focused on short-term price changes or identifying current relative value rather than projecting long-term returns. Still, investors who want to base their case for investing in Bitcoin primarily on long-term expected returns should probably dig deeper into these models.

Any investor who is a student of market history may notice similarities between the greater adoption theory for Bitcoin and the greater fool theory. The greater adoption theory suggests that the value of an asset, like Bitcoin, is driven by its increasing adoption and utility. In other words, as more people, institutions, and even governments adopt it, the asset's value grows due to its real-world use cases and network effects.[15] The greater fool theory posits that the asset's value is driven mainly by the expectation of selling it to someone else at a higher price. This theory often implies a bubble, where the asset's price is disconnected from its fundamental value. And this is the key difference – the greater adoption theory sees long-term value driven by real use, while the greater fool theory sees value driven by speculative trading. Any investor who is curious or concerned that Bitcoin could be in a bubble might consider using some of the models noted above, as well as analyzing trading volume and sentiment analysis. Just as it may have been rational for the Dutch to invest in tulip bulbs in 1634, only to see speculation drive prices to unsustainable heights over the subsequent two years,[16] it is prudent for investors who believe that Bitcoin is fairly (or under-) valued to be mindful of speculation driving prices to untenable levels.

Note that there are other investment cases for Bitcoin. For example, BlackRock argues that Bitcoin can serve as a "hedge to US dollar hegemony and political instability, and proxy play on the broader 'offline' to 'online' digital transition of goods and services – supercharged by 'boomer-to-millennial' demographic tailwinds."[17] Bitcoin's perceived role as a geopolitical hedge, particularly amid rising fiscal deficits, the trend toward gradual dedollarization, and declining trust in fiat

[13] Note that assets that are denominated in foreign currencies could serve as a partial hedge in such an environment if the US dollar depreciates meaningfully, as such a decline would boost the returns of foreign holdings for USD investors.

[14] Bitcoin carries structural risks unique to decentralized digital assets. These include potential vulnerabilities in consensus mechanisms, mining centralization, governance coordination, and cryptographic dependencies. In addition, investors face exchange and custody-related risks, which stem from the infrastructure used to access and store Bitcoin rather than the Bitcoin network itself. Bitcoin's long-term investment profile may also be shaped by evolving regulatory and policy risks, such as more stringent anti–money-laundering requirements, taxation rules, restrictions on self-custody, or the emergence of central bank digital currencies. While the probability of any of these events may be low, such events could severely impair value.

[15] See Metcalfe's Law, which is a principle that describes how the value of a network grows as more participants join it (specifically, the value of a network is proportional to the square of the number of its users).

[16] There is a great deal of useful and entertaining research on Tulip mania, including: "The Tulipomania. Memoirs of Extraordinary Popular Delusions and the Madness of Crowds" by Charles Mackay, (1856); "The Tulipmania: Fact or Artifact?" by Earl A. Thompson, (2007); "Famous First Bubbles" by Peter M. Garber, (1990).

[17] Source: "Why Bitcoin? A model portfolio builder's view" by Brett Wager and Michael Gates, BlackRock, February 2025. BlackRock also opined that investors might want to treat Bitcoin as an insurance policy on the legacy financial system.

systems, is a core rationale for portfolio inclusion by some investors. Others might see Bitcoin as a play on a digital future or a key application of blockchain technology. The extent to which an institutional investor may decide to hedge themselves against such scenarios and/or restructure their portfolio to profit from this potentially unique benefit will vary, likely based on the importance and probability the investor assigns to these possible outcomes.

The challenge of creating assumptions

While Meketa emphasizes taking a "mosaic" approach to asset allocation and understanding the risks in a portfolio, for decades, mean-variance optimization (MVO) has been the traditional starting point for determining asset allocation for many investors.[18] MVO requires just three sets of inputs for each asset class that is included in the model: expected return, expected volatility, and correlation.[19] Thus, an investor will want to create these assumptions for Bitcoin if they are considering its inclusion in their portfolio. And herein lies the challenge – while the dispersion of expectations for some asset classes (e.g., investment grade bonds) is tight, the expectations for other asset classes can be quite varied and potentially controversial. Anecdotal evidence (e.g., conversations with our clients) implies that the expectations around Bitcoin are as wide-ranging as the American golden plover.[20]

Historical performance

Since January 2014, Bitcoin's average annualized return and standard deviation have been 54.6% and 75.0%, respectively.[21] Volatility declined considerably after 2014 (the price of Bitcoin fell 80% between December 2013 and January 2015), and volatility descended further since 2020. Returns have exhibited considerably large peaks and valleys, though the amplitude of both has declined over the last decade.

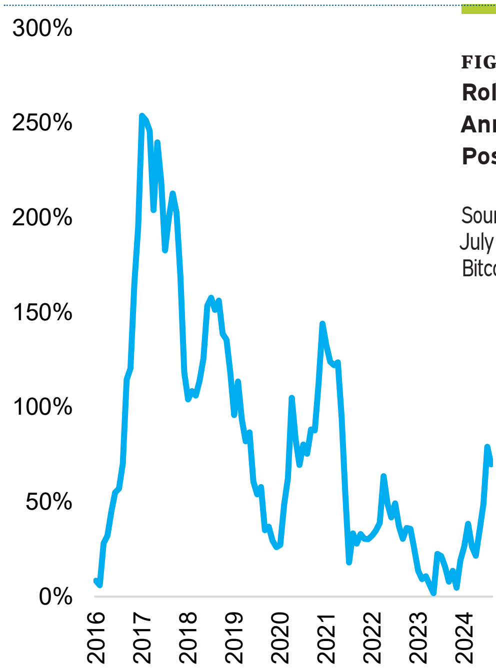

FIGURE 3
Rolling 3-Year Annualized Return Post-2013

Source: Bloomberg as of July 31, 2025. Indices Used: Bitcoin-USD Cross.

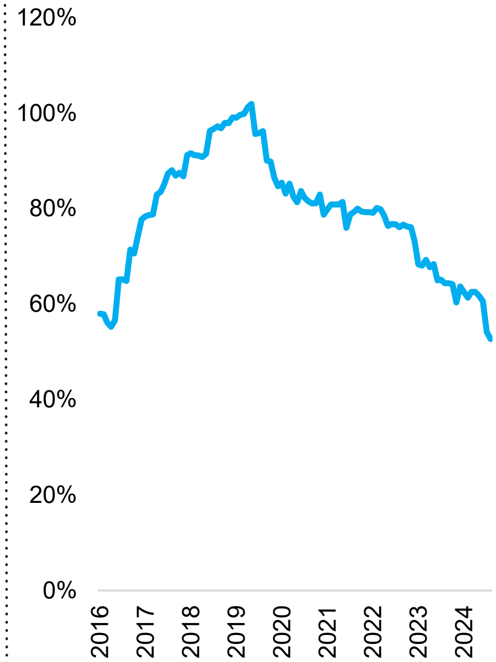

FIGURE 4
Rolling 3-Year Annualized Standard Deviation Post-2013

Source: Bloomberg as of July 31, 2025. Indices Used: Bitcoin-USD Cross.

18 See "A Timeless Approach to Asset Allocation" by Meketa Investment Group.

19 Mean-Variance Optimization is the process of weighting risk (expressed as variance or standard deviation) against return to find the most efficient allocation of assets. It allows users to identify a portfolio that provides the theoretical best return at a given level of risk, or lowest risk for a given level of return. Traditional optimization has several key shortcomings, not least of which is the assumption of normal distributions and stable correlations, neither of which has thus far held true for Bitcoin. Another shortcoming is the fact that the output of the model is only as good as the inputs, an issue we address later by analyzing the impact of using different assumptions.

20 The plover's annual migration distance has been estimated at over 25,000 miles round-trip. For a humorous aside on the plover and other birds, see the movie "The Big Year".

21 Source: Bloomberg as of July 31, 2025. Indices Used: Bitcoin-USD Cross. For the period January 1, 2014, to July 31, 2025.

An important distinction to make about Bitcoin is that while it does not directly tie to economic growth or the level of interest rates, this does not necessarily mean that in practice it is uncorrelated to traditional markets. Since January 2014, Bitcoin has exhibited an average correlation of 0.14 to investment grade bonds and 0.33 to US equities. As seen in Figure 5, Bitcoin's correlation with investment grade bonds has remained fairly steady and low; however, the correlation with US equities has increased to a substantially positive relationship. In fact, since 2020, Bitcoin's correlation with US equities has averaged 0.58. This higher correlation implies that Bitcoin was acting more like a high-volatility equity proxy during this period.

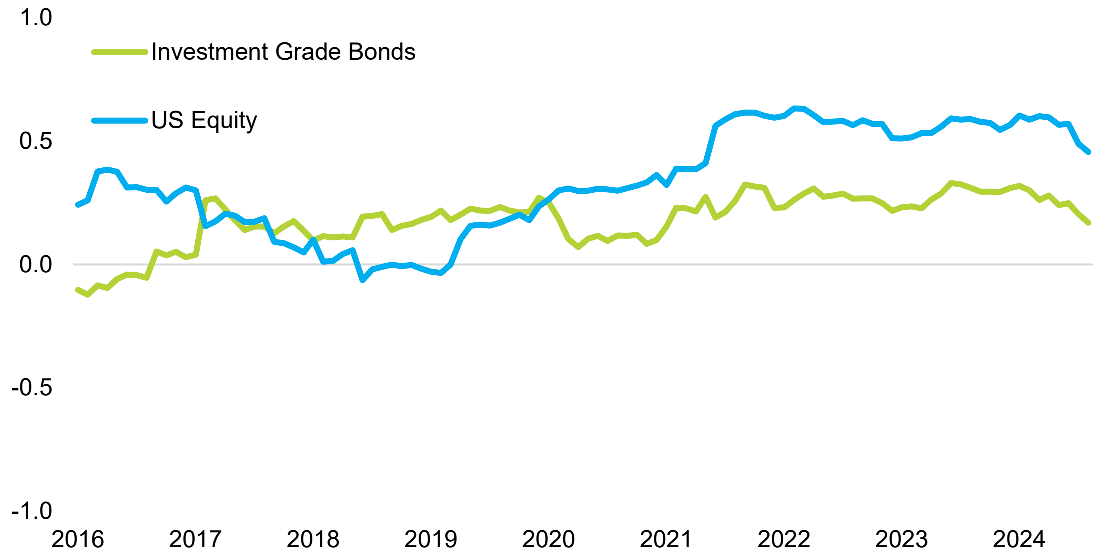

FIGURE 5

Rolling 3-Year Correlation to Bitcoin for US Stocks and Bonds

Source: Bloomberg and InvMetrics, as of July 31, 2025. Indices: Russell 3000, Bitcoin-USD Cross, Bloomberg Aggregate.

Bitcoin was designed to be decentralized and not directly tied to any single government or nation. In this sense, it offers similar characteristics as gold, and hence its performance behavior is worth comparing to gold. Despite offering similar traits, Bitcoin has been uncorrelated with gold (see Figure 6). Likewise, Bitcoin has mostly been uncorrelated to modestly negatively correlated with the US dollar. Since January 2014, Bitcoin has exhibited an average correlation of -0.18 to the trade-weighted dollar.

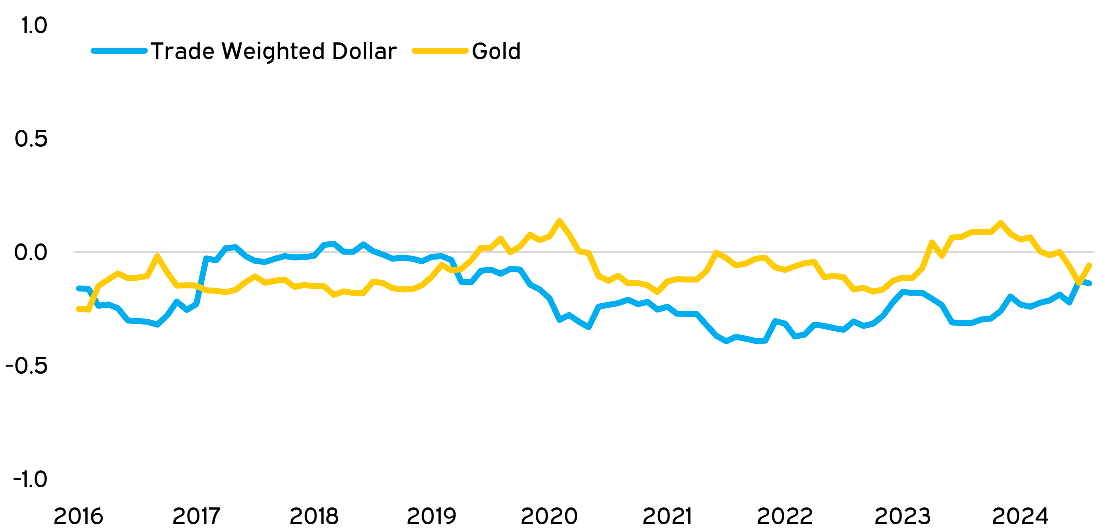

FIGURE 6

Rolling 3-Year Correlation to Bitcoin for Gold and the Dollar

Source: Bloomberg, FRED, and InvMetrics, as of July 31, 2025. Indices: Bitcoin-USD Cross, LBMA Precious Metal Prices: Gold USD, Nominal Broad US Dollar Index.

Meketa's Assumptions

For purposes of our analysis, we start with our 2025 10-year capital markets assumptions. We walk through our methodology in creating our Bitcoin assumptions below. However, our analysis spends considerable time evaluating the sensitivity of outcomes to our (or any) assumptions related to Bitcoin.

Our model for Bitcoin is quite different than for any other asset class, as Bitcoin does not derive value from income, some future stream of cash flows, or a risk premium. The model assumes that Bitcoin's returns are driven by price appreciation, primarily speculative asset pricing. Using the price and trading volume of Bitcoin, we estimate the probability of an investor entering and exiting the market during each of three historical Bitcoin cycles. We calculate the expected price for each period by weighting prices according to trading volume. Using these probabilities, we estimate the expected return for each period. These expected gains and losses are then averaged, and this cumulative return is spread evenly across ten years to create the 10-year expected return assumption.[22]

[22] Note that, partly as a result of the analysis we have done in researching this topic, we are likely to change our model and assumptions for Bitcoin in our future capital markets expectations.

Adding bitcoin to a portfolio

From an MVO standpoint, while the assumptions used for Bitcoin are important, they may not matter in the way that is intuitive to most investors.

To evaluate Bitcoin's potential impact on a portfolio, we first compared three theoretical diversified portfolios with varying allocations to Bitcoin: no Bitcoin, 3% Bitcoin, and 5% Bitcoin (see Figure 7). The output shows that allocating a small percentage of Bitcoin improves risk-adjusted returns for the overall portfolio, as measured by the expected Sharpe ratio. The Sharpe ratio increases from 0.321 for the no Bitcoin portfolio, to 0.339 for the 3% Bitcoin portfolio, and to 0.344 for the 5% Bitcoin portfolio.

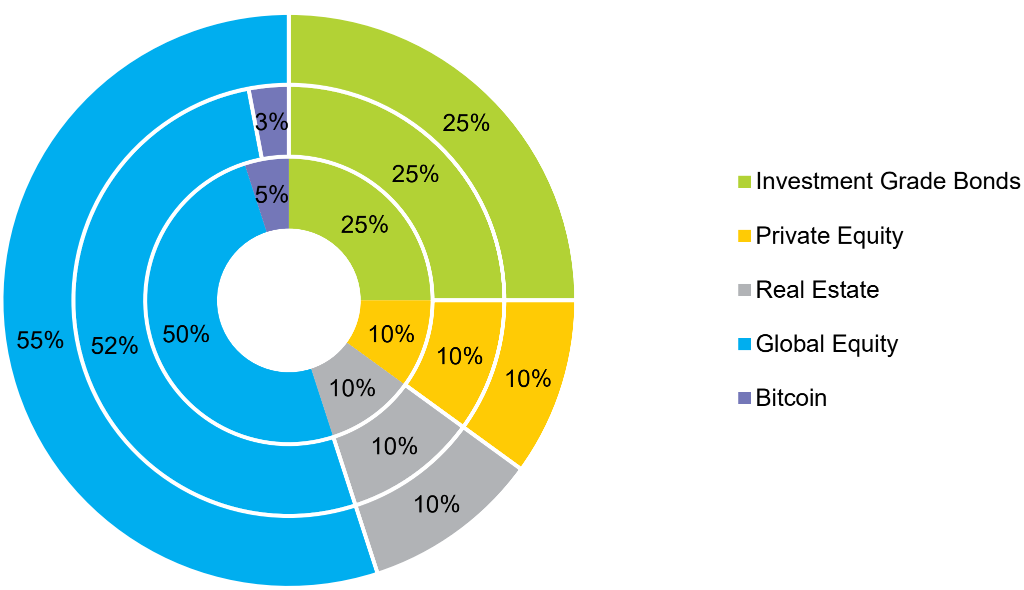

FIGURE 7
Asset Allocation Breakdown of Three Theoretical Portfolios: No Bitcoin (Outer), 3% Bitcoin (Middle), & 5% Bitcoin (Inner)

Source: Meketa's Asset Allocation Tool. Meketa uses our expected return for cash as the risk-free rate when calculating expected Sharpe ratio.

Despite Bitcoin's lower expected return and significantly higher standard deviation than global equity (the allocation it reduces in this example),[23] the overall portfolio's risk-adjusted return profile improved when Bitcoin was added.[24] The reason for this is a combination of traditional diversification benefits and the counter-intuitive impact of high volatility.

From a diversification standpoint, investors can build portfolios with better expected risk-return tradeoffs by adding assets (even riskier ones) that are not highly correlated with the primary assets in a portfolio. Most investors who are familiar with MVO will already understand this. But the impact of volatility warrants further explanation.

Mean-variance optimization uses arithmetic expected returns. The conversion from our geometric assumptions to arithmetic returns incorporates the expected standard deviation. A higher expected volatility will contribute to a higher arithmetic return. Since Bitcoin possesses an expected standard deviation of 75% in our 2025 capital markets expectations (CMEs), for the purposes of MVO, a 2.9% 10-year geometric return now becomes 19.5% expected arithmetic return. Despite Bitcoin's expected standard deviation being by far the largest in our CMEs, the optimization algorithm will tend to favor Bitcoin's high expected arithmetic return and allocate a larger weight to Bitcoin. Hence, so long as Bitcoin remains a relatively volatile asset, it will likely find a home along the efficient frontier.

Investors who are familiar with MVO are also likely aware that it is highly sensitive to the assumptions it is provided. To understand the level of this sensitivity as it relates to Bitcoin, we created eight different efficient frontiers that use varying assumptions. The baseline case uses our 2025 10-year CMEs for each asset class included. Each additional frontier then varies one or more of the assumptions for Bitcoin: 1) increase the geometric expected return from 2.9% to 9.2% (applying a beta of 1.64 for Bitcoin – its average from 2014 to 2025 – to our 10-year expected returns for equities and cash), 2) decrease the standard deviation from 75% to 50% (the approximate trailing one-year standard deviation as of mid-2025), and 3) increase the correlation with equities from 0.33 to 0.58 (the average correlation with US equities since 2020).[25]

Figure 8 shows the results of this analysis with the MVO-generated efficient frontiers plotted based on their respective expected return and standard deviation. The analysis shows a higher return assumption for Bitcoin unsurprisingly moved the efficient frontier up and to the left. Conversely, a higher correlation assumption or lower volatility assumption moved the frontier down and to the right. This makes sense given the explanation above about the benefits of diversification (via lower correlations) and the boost to arithmetic returns provided by higher volatility.

[23] Based on Meketa's 2025 Asset Allocation Tool, Bitcoin's expected 10-year return is 2.9 % and standard deviation is 75%. Global equity's expected 10-year return is 6.7% and standard deviation is 17%.

[24] This is similar to, when holding all else the same, changing a 30% investment grade bond allocation within a diversified portfolio to 20% investment grade bonds and 10% long-term government bonds improves the overall portfolio's risk-adjusted returns despite long-term government bonds having a meaningfully higher standard deviation. See Meketa's "The Art of Patient Investing" whitepaper for more information.

[25] We minimized the number of asset classes and included constraints so as to focus the analysis on Bitcoin. See the appendix for more information around this analysis, including assumptions and constraints, as well as a more detailed explanation of the impact of standard deviation on return expectations.

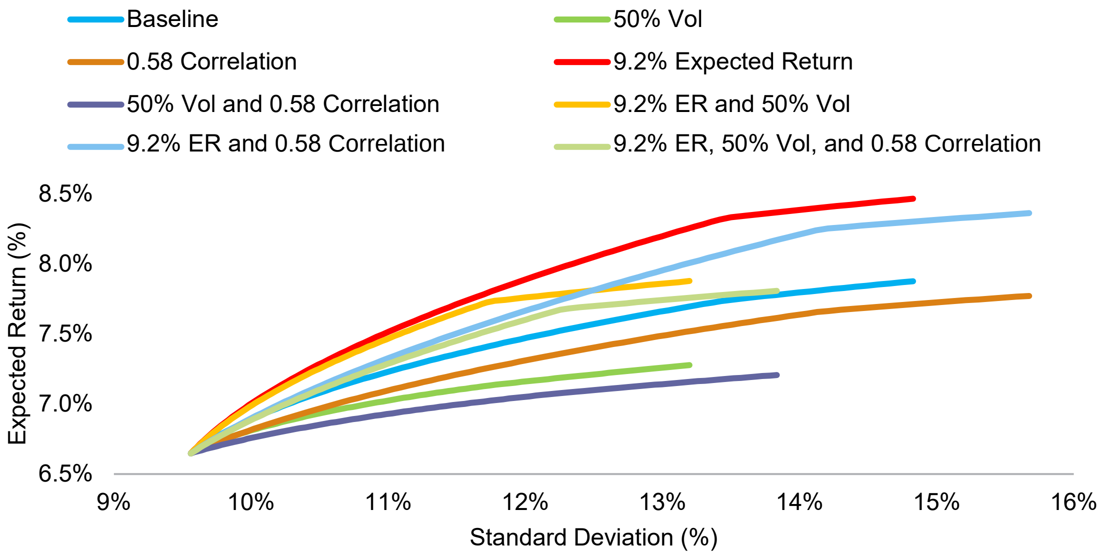

FIGURE 8

MVO Generated Portfolios with Various Bitcoin Assumptions

Source: Based on Meketa's 10-Year 2025 capital markets assumptions.

What is interesting but not obvious from the chart is the role that Bitcoin plays – in each frontier, Bitcoin has a 0% allocation at the bottom left and maxes out at the 10% constraint we imposed, though the spot on the frontier where it reaches that maximum varies.[26] The curve tends to flatten after the max Bitcoin allocation is reached, implying diminishing returns for the additional amount of risk taken thereafter.

Figure 9 plots the Sharpe ratio and the allocation to Bitcoin of each of these MVO-generated portfolios at the point where it hits a 7.0% expected return. Unsurprisingly, the portfolios with the higher return assumption for Bitcoin exhibit the highest expected Sharpe ratio. These portfolios also tend to call for a lower allocation to Bitcoin, as less of the asset is needed to hit the 7% target. A lower volatility assumption leads to a higher allocation to Bitcoin at the 7% target, but for the counter-intuitive reason noted above that the lower volatility decreases the arithmetic expected return for the asset.

[26] It is hard to overstate the importance of the high level of the volatility assumption for Bitcoin. If volatility is reduced to 20%, the expected geometric return needs to increase to ~4.2% or correlation with equities need to be cut to ~-0.25 for Bitcoin to have more than a 2% allocation somewhere along the efficient frontier.

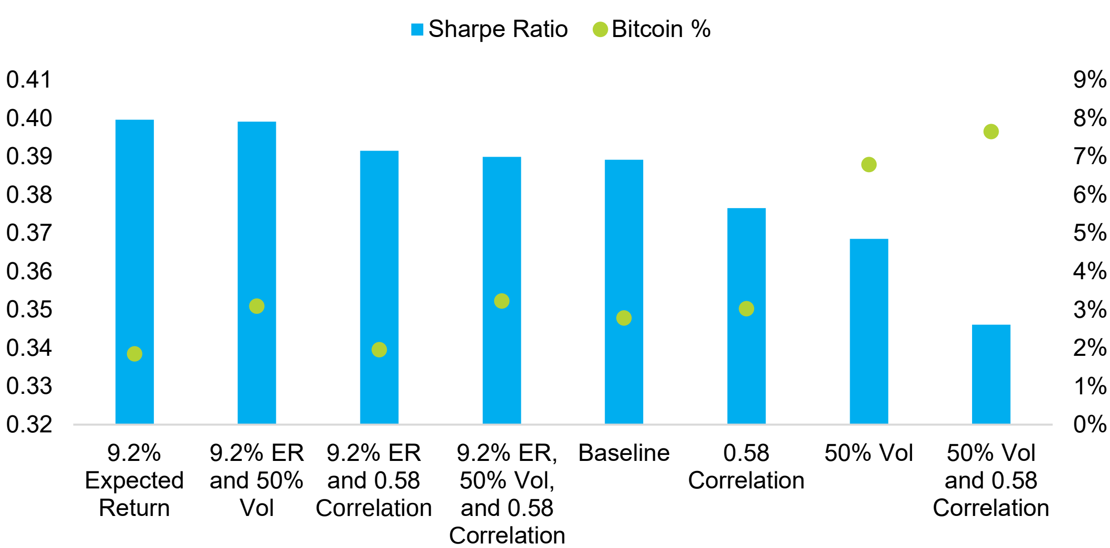

FIGURE 9

Sharpe Ratio and Bitcoin Allocation at 7.0% Expected Return

Source: Based on Meketa's 10-Year 2025 capital markets assumptions.

Scenario Analysis: Inflationary Periods & Market Downturns

When we do asset allocation, we look beyond MVO to form a better understanding of the risks in a portfolio. For example, we often conduct scenario analysis and stress testing to get a sense for behavior in different regimes, such as inflation and downturns. This may be particularly important for evaluating the role of Bitcoin, given its unique return drivers and risks. But here, too, Bitcoin's limited history leaves us wanting, as we have very few historical scenarios to evaluate. Moreover, the results are inconsistent with some of the theories surrounding the drivers of Bitcoin's return behavior.

Since Bitcoin's inception, there has only been one notable period of high inflation, which lasted from roughly January 2021 to June 2023 (shown as the grey shaded area in Figure 10). During this period, both gold and Bitcoin lagged US equities despite surging inflation. In fact, Bitcoin appeared to mirror broader risk assets, falling as tighter monetary policy drained liquidity.

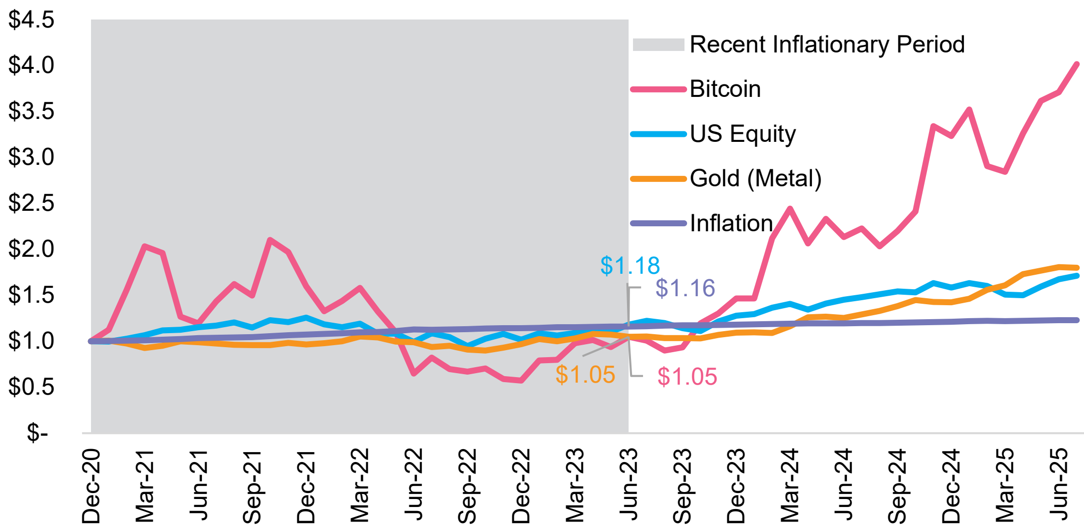

FIGURE 10

Growth of $1 Since the Recent Inflationary Period

Source: Bloomberg, FRED, and InvMetrics, as of July 31, 2025. Indices: Russell 3000, Bitcoin-USD Cross, LBMA Precious Metal Prices: Gold USD, CPI-U.

Gold and Bitcoin's underperformance during this high inflation period warrants further discussion. It is important to remember that gold does not always outperform traditional asset classes during high-inflation periods, particularly when interest rates are climbing (i.e., monetary tightening). Gold's performance typically depends on the balance between inflation and real interest rates. If inflation outpaces rate hikes, real yields stay low or negative, reducing the opportunity cost of holding gold. At the same time, worries about monetary stability, currency weakness, and financial stress drive safe-haven demand. In such periods, investors value gold less for income and more as a trusted store of value, which can push its price higher despite higher bond yields. These factors were not present during this most recent inflationary period, which contributed to gold's underperformance.

Similarly, there may have been idiosyncratic factors that impacted Bitcoin's performance, such as the several high-profile cryptocurrency failures that undermined market confidence during this time.[27] Further, our past work has shown that not all traditional "inflation hedges" work in all inflationary environments.

[27] Some of the largest failures include the Terra / LUNA and UST stablecoin collapse, Voyager Digital's bankruptcy, FTX and Alameda Research's bankruptcy, and BlockFi's bankruptcy, among others

Rather, their usefulness as a hedge often depends on the type of inflationary environment, as well as other factors such as economic growth and interest rates.[28] The same may be true for Bitcoin. Assets like gold and Bitcoin will likely serve as a better hedge against monetary debasement than supply shock-induced inflation like that experienced from 2021 to 2023.

[28] Source: Meketa, "The Inflation Variable: Evaluating Potential Outcomes", 2021.

Therefore, judging Bitcoin's ability to serve as an inflation hedge solely on this inflationary period may lead to a flawed assessment. It remains to be seen if Bitcoin provides its theorized inflation-hedging abilities during periods of monetary inflation.

Like the previous section, there is a limited history for which to evaluate Bitcoin's performance during market downturns. Compared to US equity and gold, Bitcoin performed worse during the two major downturns that occurred during its history (the COVID-19 Market Shock and Post-COVID Rate Hikes), but it generated significantly higher returns during an observable market upturn (the COVID Recovery). In other words, Bitcoin has essentially magnified the broader US equity market's performance (see Figure 11), leading to a high market beta. Bitcoin's beta to US equities (proxied by the Russell 3000) has been 1.64 since 2014 and has increased to 2.19 over the past five years.[29] Again, this leads to the observation that Bitcoin has been acting more like a risky (or leveraged) equity asset.

[29] Source: Bloomberg and InvMetrics, as of July 31, 2025. Indices: Russell 3000, Bitcoin-USD Cross.

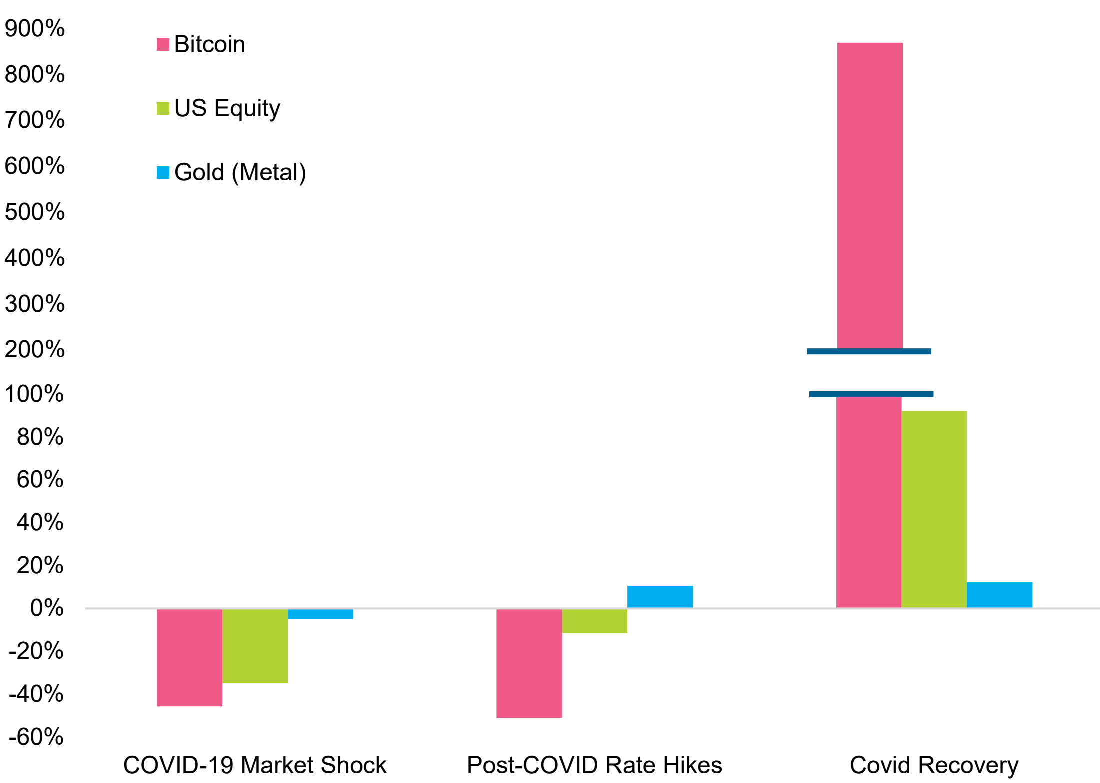

FIGURE 11
Historical Market Downturns & Upturns Since Bitcoin's Inception

Source: Meketa's Asset Allocation Tool. Indices used: Russell 3000 TR, Bitcoin/USD, LBMA Gold Price PM USD. Dates for the events in order are Feb 2020-Mar 2020, Jan 2022-Oct 2023, and Apr 2020-Dec 2021.

Finally, investors who are particularly concerned about the unique systemic and regulatory risks posed by Bitcoin may wish to conduct customized scenario analysis. For example, they could model a severe Bitcoin drawdown during a regulatory ban or exchange crisis to show portfolio-level tail sensitivity.

Risk Contribution and Tracking Error

As we noted earlier, looking solely at MVO is not the ideal way for evaluating an asset's role in a portfolio, and that is especially true for Bitcoin. Among other perspectives, investors may want to consider their Bitcoin allocation from a risk budgeting standpoint. Given Bitcoin's high volatility, it is likely to contribute an outsized portion to portfolio volatility. For example, a 5% allocation results in it contributing 17.3% of portfolio volatility when using a 75% volatility assumption; at 50% volatility, a 5% allocation drops to 10.4% contribution to portfolio volatility (see Figure 12). It is reasonable that long-term investors may want to cap their allocation to Bitcoin at a level where they are comfortable with its contribution to overall portfolio volatility.

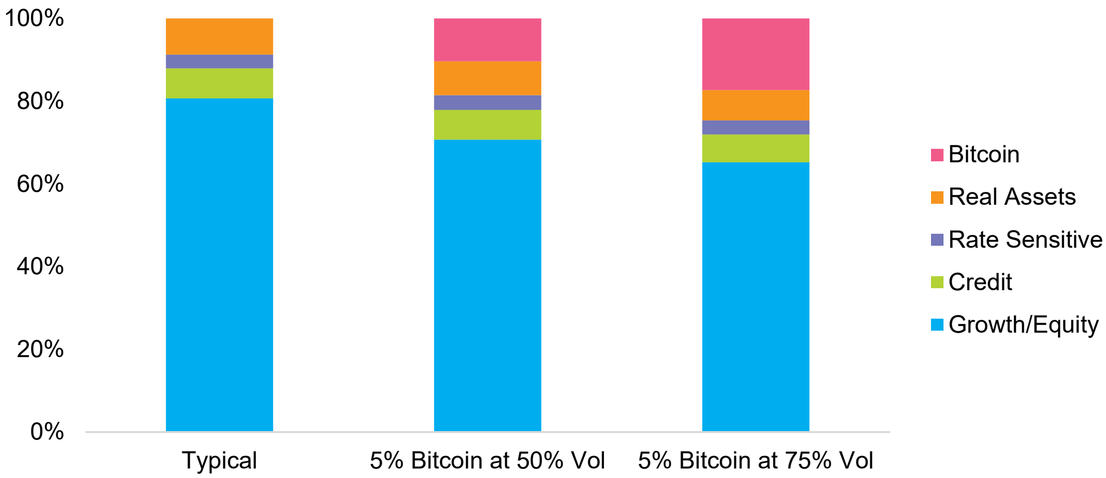

FIGURE 12

Estimated Contribution to Risk from Adding Bitcoin

The allocation for the "typical plan" is 30% investment grade bonds, 10% credit, 40% global equity, 10% private equity, and 10% real estate. Meketa's 2025 10-year capital markets assumptions are used, unless otherwise stated. Note that decreasing the volatility assumption for Bitcoin will decrease its estimated contribution to risk. Likewise, decreasing the correlation with equities will decrease the estimated contribution to risk.

Similarly, investors who care about their performance relative to a peer group may want to consider the amount of tracking error that Bitcoin would introduce to their portfolio. For example, we estimate that a 5% allocation to Bitcoin (taken from global equity) would add between 130 bp and 265 bp of tracking error relative to a peer average of large public pension funds, depending upon their assumptions related to volatility and correlations (see Figure 13). Likewise, Bitcoin could add meaningful tracking error for investors relative to their policy index if Bitcoin is not part of their policy benchmark.

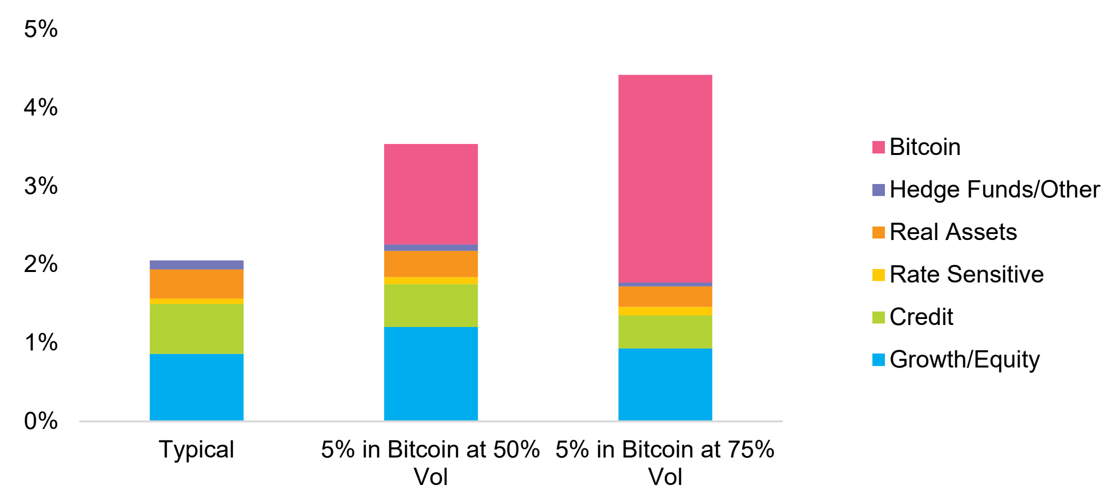

FIGURE 13

Estimated Tracking Error when Adding Bitcoin

We chose the public pension peer average to illustrate the tracking error comparison because asset allocation data is available via annual reports for many large public pension plans and Meketa tracks and calculates this on an annual basis. The allocation for the "typical plan" is 30% investment grade bonds, 10% credit, 40% global equity, 10% private equity, and 10% real estate. Meketa's 2025 10-year capital markets assumptions are used, unless otherwise stated. Note that decreasing the volatility assumption for Bitcoin will decrease the tracking error estimate. Likewise, increasing the correlation with equities will decrease the tracking error estimate (assuming the allocation to Bitcoin comes primarily from equities).

Summary

Although Bitcoin has evolved from a fringe innovation to a more mature and accessible market, its behavior remains unlike most other assets. Bitcoin's unique characteristics and relatively brief history make it challenging for investors to determine its proper place in a portfolio. Early years of extreme volatility have given way to greater liquidity and stability, but Bitcoin still differs fundamentally from traditional financial or real assets, as it generates no cash flows and is not tied to economic growth or interest rates. Its short-term price movements have largely been driven by speculation, sentiment, and liquidity conditions rather than intrinsic fundamentals.

From an investment standpoint, Bitcoin has been compared to both gold and currencies, but it does not (yet) fulfill the characteristics of a reliable inflation hedge or stable store of value. During the 2021–2023 inflationary period, Bitcoin fell alongside gold and equities, and it failed to protect against inflation, reflecting its sensitivity to risk sentiment and monetary conditions. Yet relying solely on this period to draw conclusions about its inflation-hedging nature could be misleading. Its decentralized nature and limited supply make it conceptually appealing as protection against fiat currency debasement. However, its volatility and correlation with risk assets currently limit its defensive use. Over time, greater adoption and institutionalization may reduce its volatility and strengthen its role as a potential store of value.

Quantitative analysis through mean-variance optimization suggests that small allocations of Bitcoin can modestly improve a diversified portfolio's risk-adjusted returns. However, the results are highly sensitive to assumptions about expected returns, correlations, and volatility levels. Moreover, even small allocations can contribute disproportionately to overall portfolio risk, with a 5% allocation potentially accounting for as much as 17% of portfolio volatility. Likewise, small allocations to Bitcoin may contribute meaningfully to tracking error versus peers and policy benchmarks. Finally, Bitcoin poses unique tail risks that may not be sufficiently appreciated by traditional risk models.

Institutional investors should generally view Bitcoin more as a speculative diversifier than as a core asset. Bitcoin's inclusion in a portfolio may be best justified by diversification potential and the ability to enhance portfolio efficiency on the margins, and it should be accompanied by a willingness to accept substantial volatility. Bitcoin should not be relied on as a dependable inflation hedge or risk mitigator, though it may yet prove to be a hedge against US dollar debasement. Investors may want to treat Bitcoin as a leveraged equity asset in the near term, though without all the actual messiness and complexity that typically accompanies leverage. If beta, correlations, and volatility eventually drop, then investors may want to consider thinking about Bitcoin more as a potential store of value.

In the meantime, investors should approach Bitcoin prudently, capping exposure at levels consistent with their risk tolerance and acknowledging its uncertain long-term behavior. As Bitcoin continues to mature and institutional adoption deepens, its utility in portfolios may grow. For many investors, we suspect the allocation they choose will largely depend on what they believe about Bitcoin.

Appendix

Case Studies: the Shake Out Periods for the Dollar and Gold

When a monetary asset's regime changes (due to legal/convertibility rules, market access, policy framework, etc.), the early phase is marked by uncertainty and high volatility. As rules, plumbing, and expectations solidify, volatility typically declines. Two historical examples of this are the US dollar and gold.

Case study 1: The US dollar after the end of Bretton Woods

In August 1971, President Nixon suspended gold convertibility, beginning the end of Bretton Woods. This transition unleashed large currency swings as markets repriced a fiat US dollar and a new policy regime. A combination of policy credibility and coordination gradually stabilized the system. Actions by the Volcker Fed subdued inflation (and inflation expectations), while the Plaza (1985) and Louvre (1987) Accords signaled a new playbook for managing large dollar moves. The Bank for International Settlements and academic research find exchange-rate volatility has trended down for core currencies in the 21st century (after the high-variance 1970s–80s), consistent with stronger monetary frameworks and deeper markets.[30]

[30] Sources: "Will the Secular Decline in Exchange Rate and Inflation Volatility Survive Covid-19?", NBER Working Paper Series, by Ethan Ilzetzki, Carmen M. Reinhart, Kenneth S. Rogoff, November 2020.

Case study 2: Gold after US liberalization & post–Bretton Woods

Private US ownership of gold was legalized effective December 31, 1974. Gold trading/futures took off mid-1970s. The late 1970s saw extreme day-to-day moves culminating in the 1980 spike and crash.[31] As OTC/LBMA benchmarks and futures markets matured, market participation broadened and price discovery improved.

[31] IMF contemporaneous analysis documented huge intraday swings in 1979–80 (e.g., a $113 one-day drop in Jan 1980). Source: "The changing gold market, 1978-80: A view of the volatile, mostly upward movements in the real price of gold", M. Martin, December 1980.

Both the dollar and gold market examples show a similar pattern: a high-volatility shake-out as rules and participation reset, followed by lower, steadier volatility as policy credibility, trading infrastructure, and investor understanding deepen.

Assumptions for Efficient Frontier Analysis

Baseline - Our standard 10-year CMEs (for 2025):[32]

Correlations	Investment Grade Bonds	Multi-Sector Credit	Global Equity	Private Equity	Real Estate	Bitcoin
Investment Grade Bonds	1	0.2222	0.2341	0	0.2608	0.1986
Multi-Sector Credit	0.2222	1	0.7442	0.6737	0.5594	0.3006
Global Equity	0.2341	0.7442	1	0.9069	0.5306	0.3274
Private Equity	0	0.6737	0.9069	1	0.4849	0.0625
Real Estate	0.2608	0.5594	0.5306	0.4849	1	0.0265
Bitcoin	0.1986	0.3006	0.3274	0.0625	0.0265	1

Asset Class	Expected Return	Standard Deviation	Range
Investment Grade Bonds	4.9	4.0	20-40%
Multi-Sector Credit	6.3	10.0	10%
Global Equity	6.7	17	30-50%
Private Equity	9.8	25	10%
Real Estate	6.9	15	10%
Bitcoin	2.9	75	0-10%

Crypto ranges from 0% for the lowest risk portfolio to the 10% max near the high risk-return portfolio.

Scenario 1 – 50% std dev.

Asset Class	Investment Grade Bonds	Multi-Sector Credit	Global Equity	Private Equity	Real Estate	Bitcoin
Bitcoin	0.1986	0.3006	0.3274	0.0625	0.0265	1

Asset Class	Expected Return	Standard Deviation
Bitcoin	2.9	50

0% crypto in the lowest risk portfolio. Maxes at 10%, but much earlier than in the baseline.

[32] Note that Meketa's 2025 cryptocurrency assumption is based on Bitcoin. See our 2025 Capital Markets Assumptions for further information.

Scenario 2 – 0.58 correlation with equities.

Asset Class	Investment Grade Bonds	Multi-Sector Credit	Global Equity	Private Equity	Real Estate	Bitcoin
Bitcoin	0.1986	0.3006	0.58	0.0625	0.0265	1

Asset Class	Expected Return	Standard Deviation
Bitcoin	2.9	75

0% crypto in the lowest risk portfolio. Maxes at 10%, at 7.66% ER.

Scenario 3 – 1.62 beta, leading to higher expected return.

Asset Class	Investment Grade Bonds	Multi-Sector Credit	Global Equity	Private Equity	Real Estate	Bitcoin
Bitcoin	0.1986	0.3006	0.3274	0.0625	0.0265	1

Asset Class	Expected Return	Standard Deviation
Bitcoin	9.2	75

0% crypto in the lowest risk portfolio. Maxes at 10%, at 8.33% ER.

Scenario 4 – 1 and 2.

Asset Class	Investment Grade Bonds	Multi-Sector Credit	Global Equity	Private Equity	Real Estate	Bitcoin
Bitcoin	0.1986	0.3006	0.58	0.0625	0.0265	1

Asset Class	Expected Return	Standard Deviation
Bitcoin	2.9	50

0% crypto in the lowest risk portfolio. Maxes at 10%, at 7.08% ER.

Scenario 5 – 1 and 3.

Asset Class	Investment Grade Bonds	Multi-Sector Credit	Global Equity	Private Equity	Real Estate	Bitcoin
Bitcoin	0.1986	0.3006	0.3274	0.0625	0.0265	1

Asset Class	Expected Return	Standard Deviation
Bitcoin	9.2	50

0% crypto in the lowest risk portfolio. Maxes at 10%, at 7.73% ER.

Scenario 6 – 2 and 3.

Asset Class	Investment Grade Bonds	Multi-Sector Credit	Global Equity	Private Equity	Real Estate	Bitcoin
Bitcoin	0.1986	0.3006	0.58	0.0625	0.0265	1

Asset Class	Expected Return	Standard Deviation
Bitcoin	9.2	75

0% crypto in the lowest risk portfolio. Maxes at 10%, at 8.25% ER.

Scenario 7 – 1, 2 and 3.

Asset Class	Investment Grade Bonds	Multi-Sector Credit	Global Equity	Private Equity	Real Estate	Bitcoin
Bitcoin	0.1986	0.3006	0.58	0.0625	0.0265	1

Asset Class	Expected Return	Standard Deviation
Bitcoin	9.2	50

0% crypto in the lowest risk portfolio. Maxes at 10%, at 7.68% ER.

The impact of volatility on return assumptions

The calculation of arithmetic to geometric returns are as follows:

Arithmetic to geometric return:

$$Geometric\ Return = e^{\left(\mu + \frac{\sigma^2}{2n}\right)} - 1$$

Such that

$$\mu = \log(1 + \ Expected\ Return) - \frac{\sigma^2}{2}$$

$$\sigma = \sqrt{\log\left(\frac{Standard\ Deviation^2}{(1 + Expected\ Return)^2}\right) + 1}$$

In practice, the difference between arithmetic and geometric returns have a larger difference if the expected standard deviation is larger. The following table illustrates this using Meketa's 10-year expected returns and standard deviation assumptions for selected asset classes.

Asset Class	Geometric Return	Standard Deviation	Arithmetic Return
Bitcoin	2.9%	75%	19.5%
US Equity	6.4%	17%	7.6%
Investment Grade Bonds	4.9%	7%	5.1%

FIGURE 14
Conversion from Geometric to Arithmetic Returns for Different Asset Classes

As this table describes, despite US equity having a geometric expected return more than 3% larger than Bitcoin, the latter has a 9% higher expected arithmetic return due to its much larger volatility. Since mean-variance optimization uses arithmetic returns, this will cause the optimizing algorithm to prefer Bitcoin over assets with lower expected arithmetic returns, especially in efficient portfolios that are prioritizing a higher expected return.

To further illustrate this point, the following table shows the arithmetic return of Bitcoin at various volatility assumptions given a geometric expected return of 2.9%.

Bitcoin Volatility	Arithmetic Return
75%	21.4%
50%	13.3%
25%	6.7%

FIGURE 15
Impact of Volatility on Conversion from Geometric to Arithmetic Returns for Bitcoin

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