8% and No More: Empirical Determination of the Optimal Bitcoin Allocation in Global Equity Funds via Rolling Portfolio Optimisation

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Abstract

This study investigates the optimal Bitcoin allocation within globally diversified equity funds through a systematic rolling portfolio optimisation covering the period May 2016 to May 2026. Using daily price data for Bitcoin in euros (BTC/EUR) and the iShares Core MSCI World UCITS ETF (EUNL.DE, Xetra Frankfurt) as a proxy for the global equity universe, 61 rolling five-year optimisation windows are constructed on a monthly basis, each evaluating 101 portfolio combinations from 0% to 100% Bitcoin allocation in one-percentage-point increments. The optimal portfolio is defined as that which maximises the Sharpe ratio subject to a risk-free rate of zero.

The empirical findings reveal that, across the most recent and forward-relevant five-year windows (January–May 2021 start dates, covering 2021–2026 and fully encompassing the 2022 Bitcoin bear market of −77%), the empirically optimal Bitcoin allocation averages 8% (median: 8%; range: 6–15%). A 10% Bitcoin allocation improves the Sharpe ratio relative to a pure equity portfolio in all 61 rolling windows (100% hit rate; average Sharpe improvement: +0.318). The regression of monthly Bitcoin returns on MSCI World EUR returns yields a beta

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of $\beta = 1.68$ and a coefficient of determination of $R^2 = 0.098$, confirming weak unconditional correlation alongside pronounced downside amplification during crisis episodes.

Two structural impediments to higher Bitcoin allocations are identified and empirically substantiated: (1) a crisis autocorrelation effect, whereby Bitcoin's correlation with equities rises materially during market stress episodes — precisely when diversification is most needed; and (2) the complete absence of intrinsic value, as Bitcoin generates no cash flows, dividends, or earnings. These findings empirically validate the recommendation of a maximum Bitcoin allocation of 10% in globally diversified equity funds, with 8% identified as the optimal allocation across the most recent observable market cycle.

Keywords: Bitcoin · Portfolio Optimisation · Sharpe Ratio · Efficient Frontier · MSCI World · Crisis Correlation · Intrinsic Value · Rolling Window Analysis

JEL codes: E42, G11, G12, G17, O33.

Non-Technical Summary

Bitcoin was introduced in October 2008 by an anonymous author or group operating under the pseudonym Satoshi Nakamoto. It is the world's first decentralised digital currency, operating without a central bank or issuing authority. Transactions are validated by a distributed network of participants (miners) and permanently recorded on a public ledger — the blockchain. The total supply of Bitcoin is algorithmically capped at 21 million units, of which approximately 19.8 million had been mined by mid-2026. This fixed-supply architecture underpins the store-of-value narrative that has driven institutional interest in recent years.

The core question addressed by this study: **Should globally diversified equity funds incorporate Bitcoin, and if so, to what extent? The empirical answer, derived from a comprehensive rolling portfolio optimisation across 61 five-year windows spanning May 2016 to May 2026, is precise: 8% and no more.**

The portfolio optimisation: Using real daily price data for BTC/EUR and the iShares Core MSCI World UCITS ETF (EUNL.DE) as a global equity proxy, 101 portfolio combinations (0%–100% Bitcoin in 1% steps) are evaluated for each of 61 rolling five-year windows. The optimal portfolio — defined as the maximum-Sharpe-ratio portfolio — averages only 8% Bitcoin in the most recent and forward-relevant windows (2021–2026, which encompass the full 2022 bear market). A 10% Bitcoin allocation improves risk-adjusted returns relative to a pure equity strategy in 100% of all windows analysed.

Two structural constraints: Bitcoin lacks intrinsic value. Unlike equities — which represent ownership stakes in enterprises generating revenues, profits, and dividends — Bitcoin produces no cash flows. Its price is determined exclusively by the behaviour of future buyers. Furthermore, Bitcoin's correlation with equity markets rises sharply during crisis periods: from approximately 0.3 in normal markets to 0.7–0.9 during acute stress episodes, undermining its diversification benefit exactly when it is most needed.

Practical conclusion: The study recommends a maximum Bitcoin allocation of 10% for globally diversified equity funds characterised by typical portfolio volatility of 10–20% p.a. (model midpoint: 15% p.a.) and a US equity share of approximately 70%, consistent with the average country composition of the MSCI World Index as proxied by EUNL.DE over the 2016–2026 observation period. This threshold is both empirically validated by the rolling optimisation (the most recent optimal allocation averages 8%) and supported by the structural risk arguments. Allocations below 10% — ideally in the range of 3–10% — can serve as a strictly limited, speculative diversification component, subject to regular review.

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1 Introduction

The integration of digital assets into conventional investment portfolios presents one of the most contested questions in contemporary asset management. Bitcoin — the dominant digital asset by market capitalisation, representing approximately 55% of total crypto market value in mid-2026 — has attracted growing institutional attention since the approval of US spot Bitcoin ETFs in January 2024, which attracted inflows exceeding 115 billion US dollars within twelve months. For globally diversified equity funds characterised by volatility of 10–20% p.a. and US equity shares of approximately 70%, the question is no longer whether Bitcoin can be included, but rather at what allocation level the risk-return tradeoff remains favourable.

Prior academic literature has addressed Bitcoin's portfolio properties from multiple angles. Briere, Oosterlinck, and Szafarz (2015) were among the first to apply Markowitz (1952) mean-variance optimisation to Bitcoin, documenting diversification benefits at small allocations of 3–5% using 2010–2013 data. Kajtazi and Moro (2019) extend this analysis to multiple geographies, confirming positive diversification effects but noting their concentration in shorter-term horizons. Platanakis and Urquhart (2019) incorporate transaction costs and find that optimal Bitcoin allocations contract significantly under realistic execution costs. Liu and Tsyvinski (2021) estimate optimal Bitcoin allocations of 1–6% under standard risk aversion parameters using a factor-model approach. Baur, Hong, and Lee (2018) document Bitcoin's hedging properties against traditional financial assets, whilst simultaneously noting its pronounced volatility and distributional non-normality. Corbet, Meegan, Larkin, Lucey, and Yarovaya (2018) find that Bitcoin exhibits low correlation with conventional assets in normal market conditions but heightened co-movement during systemic crises. The present study advances this literature through a comprehensive, data-driven rolling portfolio optimisation that covers the complete market cycle 2016–2026, including the 2022 bear market — a time span deliberately chosen to supersede analyses based exclusively on the 2016–2021 bull market.

Two structural arguments delimit the recommended allocation range. First, Bitcoin exhibits no intrinsic value in the sense of Modigliani and Miller (1958): it generates no cash flows, dividends, or earnings, and cannot be valued using conventional discounted cash flow analysis. Second, a crisis autocorrelation effect — Bitcoin's tendency to correlate positively with equity markets precisely during drawdown episodes — undermines its diversification role when diversification is most needed (cf. Brunnermeier and Pedersen, 2009, on liquidity and market correlations during stress).

The paper is structured as follows. Section 1 (the present section) serves as the introduction, frames the research question, and surveys the prior literature. Section 2 provides an overview of Bitcoin's origins, technology, and economic function. Section 3 analyses the risk profile, including volatility, drawdown history, and correlation structure. Section 4 examines the fundamental valuation problem. Section 5 presents the portfolio

analysis, including the empirical rolling efficient frontier optimisation. Sections 6 and 7 cover investment products and custody solutions respectively. Section 8 discusses the institutional and regulatory environment. Section 9 offers a balanced pro/contra assessment, and Section 10 presents the recommendation and concluding remarks.

2 Bitcoin: Origins, Technology, and Economic Function

2.1 Historical Background

Bitcoin emerged in the aftermath of the 2008 global financial crisis. On 31 October 2008, a white paper entitled 'Bitcoin: A Peer-to-Peer Electronic Cash System' was published under the pseudonym Satoshi Nakamoto (2008). The paper proposed a decentralised payment system in which trust is established not by a central authority but by cryptographic proof and distributed consensus. The genesis block was mined on 3 January 2009; the coinbase transaction contains the message 'The Times 03/Jan/2009 Chancellor on brink of second bailout for banks' — an explicit allusion to the systemic fragility of centralised banking. Table 1 documents the key milestones in this evolution from cryptographic concept to globally traded asset class.

The subsequent evolution of Bitcoin can be characterised by four major price cycles, each followed by a drawdown averaging approximately -85% from peak to trough. The first commercially documented exchange rate was established in May 2010, when 10,000 BTC were exchanged for two pizzas — implying a price of approximately \$0.003 per coin. Bitcoin has subsequently appreciated from \$0.003 to a peak of approximately \$108,000 in late 2024, representing a compound annual growth rate (CAGR) of approximately 140% over fifteen years, with extreme volatility throughout.

Table 1: Key milestones in Bitcoin's history and their market significance

Year	Event	Significance
Oct. 2008	Publication of Nakamoto White Paper	Conceptual foundation of Bitcoin
Jan. 2009	Genesis Block mined	Bitcoin network goes live; embedded headline: 'Chancellor on brink of second bailout'
May 2010	First commercial transaction: 10,000 BTC for two pizzas	First documented real-world exchange rate (˜$0.003/BTC)
2011	Mt. Gox becomes dominant exchange; BTC reaches $31	Early price discovery; first bubble and subsequent 93% drawdown
2013	BTC surpasses $1,000 for the first time; China ban	First media cycle; Silk Road closure by FBI
Aug. 2017	SegWit activation; Bitcoin Cash hard fork	Scalability debate institutionalised; ecosystem fragmentation
Dec. 2017	CME Bitcoin Futures launch; BTC at ˜$19,700	First regulated derivative; subsequent 84% drawdown to $3,200
Mar. 2020	COVID-19 crash: BTC −57% in 48 hours	Correlation with equities spikes to 0.7–0.9 during acute stress
Nov. 2021	All-time high: ˜$69,000 per Bitcoin	Peak of fourth major bull cycle; institutional inflows
Nov. 2022	FTX collapse: $8bn shortfall, >1m clients affected	Systemic counterparty risk; regulatory momentum accelerates globally
Jan. 2024	SEC approves first US spot Bitcoin ETFs (IBIT, FBTC)	Institutional gateway; >$115bn inflows within twelve months
2025–2026	MiCA framework operative across EU; Bitcoin >$100,000	Regulatory maturation; sovereign reserve discussions emerging

Source: own presentation based on data from Nakamoto (2008); Antonopoulos (2017); CoinMarketCap; Cambridge Centre for Alternative Finance (2024); SEC (2024).

2.2 Blockchain Technology and Cryptographic Architecture

Bitcoin operates on a distributed ledger — the blockchain — maintained by a global network of nodes. The Bitcoin blockchain stores ownership of unspent transaction outputs (UTXOs), not account balances: every transaction consumes existing UTXOs as inputs and produces new UTXOs as outputs. Ownership is established by possession of the corresponding 256-bit private key, from which a public key and a Bitcoin address are cryptographically derived via elliptic curve digital signature algorithm (ECDSA).

Each block in the chain contains: (1) a reference to the previous block's cryptographic hash (establishing the chain's immutability); (2) a Merkle tree root of all transactions in the block, enabling efficient verification; (3) a timestamp; (4) the network difficulty target (nBits); and (5) a nonce — a 32-bit value that miners vary to find a hash below the target, constituting the proof-of-work (PoW) mechanism. The computational effort required to

alter a historical block thus increases linearly with the number of subsequent blocks — the fundamental security property of Bitcoin's blockchain.

Bitcoin's hash rate stood at approximately 600 exahashes per second (EH/s) in mid-2026, representing the cumulative computational capacity of the mining network. The energy consumption associated with this activity — estimated at 175–195 TWh per annum by the Cambridge Centre for Alternative Finance (2024) — represents a material environmental externality and a source of ongoing regulatory scrutiny. Bitcoin's scripting language (Bitcoin Script) is intentionally non-Turing-complete, deliberately limiting the range of executable operations to enhance security and predictability. This distinguishes Bitcoin fundamentally from Ethereum, whose Turing-complete smart contract language (Solidity) enables arbitrary computation but introduces qualitatively different attack vectors (Buterin, 2014).

The UTXO model furthermore differs from Ethereum's account-based model in that the UTXO approach provides stronger privacy at the transaction level and simplifies parallel verification of unrelated transactions. The OP_RETURN opcode permits the embedding of up to 80 bytes of arbitrary data in a Bitcoin transaction, enabling non-financial applications such as document timestamping, although this feature is subject to ongoing debate regarding blockchain bloat.

2.3 Bitcoin as a Monetary Instrument: A Critical Assessment

Classical monetary theory, as synthesised by Mishkin (2019), requires a monetary instrument to fulfil three functions: medium of exchange, unit of account, and store of value. Bitcoin satisfies none of these functions reliably in its current form. As a medium of exchange, it is constrained by a theoretical throughput of seven transactions per second (TPS) under the base layer protocol — in practice, 3–5 TPS — compared with approximately 1,700–25,000 TPS for payment networks such as Visa. Transaction fees during periods of high network congestion reached 50–80 US dollars per transaction in 2021 and 2024. As a unit of account, Bitcoin's extreme daily price volatility — commonly 5–15% — renders price denomination in Bitcoin impractical for commercial use. The Lightning Network second-layer protocol addresses throughput limitations for small, frequent transactions, but adoption remains limited relative to the broader payments ecosystem.

The store-of-value thesis — arguably the most credible monetary claim advanced for Bitcoin — rests on its fixed-supply architecture and censorship resistance. The empirical record, however, is inconsistent: Bitcoin's price correlation with CPI inflation has been statistically weak and directionally unreliable (Baur et al., 2018; Corbet et al., 2018). During the inflationary episode of 2021–2022, Bitcoin declined by 77% whilst inflation was at its highest, directly contradicting the inflation-hedge narrative. The fixed supply schedule, whilst credibly enforced by the protocol, does not itself constitute an intrinsic

value anchor absent a return-generating mechanism. Urquhart (2016) tests the efficient market hypothesis for Bitcoin using variance ratio and runs tests, finding significant evidence of return autocorrelation and market inefficiency — particularly in the early period — with tentative improvement towards efficiency in later years. Dwyer (2015) provides a comparative economic assessment of Bitcoin alongside historical private currencies, noting the credibility of the fixed-supply rule whilst documenting the inherent price volatility of currency without a lender of last resort. Narayanan, Bonneau, Felten, Miller, and Goldfeder (2016) offer the most comprehensive technical treatment of Bitcoin's cryptographic and economic architecture, establishing the academic foundations for the technical discussion in Section 2.2.

Gold has served as a monetary anchor for approximately 5,000 years, underpinning the classical gold standard (c. 1870–1914) and the Bretton Woods system (1944–1971). The Nixon shock of August 1971 — the unilateral suspension of US dollar convertibility into gold — inaugurated the current era of purely fiat monetary systems. Eichengreen (1992) and Bordo and Kydland (1995) document gold's stabilising role within fixed-rate regimes, whilst simultaneously identifying the deflationary rigidity that contributed to the Great Depression. Since 1971, gold has retained its function as a reserve asset: official holdings stood at approximately 35,500 tonnes as of mid-2024 (IMF, 2024), and central banks were net purchasers in every year between 2010 and 2024. Erb and Harvey (2013) provide the most comprehensive empirical assessment of gold's inflation-hedging properties, finding that gold's effectiveness as an inflation hedge is robust over multi-decade horizons but unreliable over the shorter investment periods typical for institutional portfolio mandates. Hayek (1976), in "Denationalisation of Money", provides the theoretical underpinning for competing private currencies as an alternative to state-issued money — a framework that Bitcoin advocates have subsequently applied to digital assets.

Bitcoin's design explicitly references the failures of fiat currency: the genesis block embeds the Times headline of 3 January 2009 — "Chancellor on brink of second bailout for banks" — as a commentary on the fragility of centralised monetary institutions. Ammous (2018), in "The Bitcoin Standard", provides the most systematic exposition of the "Bitcoin as sound money" thesis, arguing that its algorithmically enforced supply cap constitutes a superior monetary architecture to both gold and state-issued fiat. Dyhrberg (2016) was among the first academic studies to test the gold analogy empirically, examining GARCH volatility structures and finding that Bitcoin shares some hedging properties with gold against the US dollar, whilst exhibiting different dynamics in equity market downturns. Klein, Thu, and Walther (2018) challenge this analogy directly, demonstrating that Bitcoin and gold respond asymmetrically to market stress and that Bitcoin does not replicate gold's safe-haven characteristics during equity market sell-offs. Bouri, Molnár, Azzi, Roubaud, and Hagfors (2017) similarly find that Bitcoin's hedging properties are sensitive to the time window and market regime, with results substantially weaker for the post-2017 period encompassing both the 2018 and 2022 bear markets. The divergence

between theory (fixed supply as value anchor) and empirical performance (70–85% drawdowns) is the central tension in the Bitcoin-as-gold-alternative literature.

Table 2 compares gold and Bitcoin across the key criteria relevant to their respective claims as alternatives to fiat money.

Table 2: Comparative assessment of gold and Bitcoin as alternatives to fiat money

Criterion	Gold	Bitcoin
Supply mechanism	Geological scarcity; mining adds ~1.5% p.a. to above-ground stock (~215,000 t)	Algorithmically capped at 21 million BTC; supply growth halves every ~4 years ("halvings")
Monetary track record	~5,000 years; gold standard 1870–1914; Bretton Woods 1944–1971	Since 2009 (~15 years); no history as monetary standard; El Salvador legal tender since 2021
Inflation hedge (empirical)	Effective over multi-decade horizons; unreliable short-term (Erb & Harvey, 2013)	Weak CPI correlation; declined 77% during 2021–2022 inflation peak (Baur et al., 2018)
Annualised volatility	~15–20% p.a.	~50–80% p.a.
Portability	Low (physical weight, customs, logistics)	High (digital transmission globally within minutes)
Divisibility	Limited (physical subdivision costly; 0.1 troy oz minimum practical unit)	Highly divisible (to 1 satoshi = 0.00000001 BTC)
Censorship resistance	Moderate (physical confiscation possible; historically occurred)	High (cryptographic self-custody; private key ownership)
Industrial / utility demand	~50% of supply; jewellery, electronics, dentistry, medicine	None (purely monetary and speculative demand)
Central bank acceptance	Yes (~35,500 tonnes in official reserves, IMF 2024)	Limited; no G20 central bank holds BTC as reserve; some feasibility studies
Regulatory status (EU)	Fully regulated; physical gold ETFs since 2003; VAT-exempt	MiCA-regulated crypto-asset; spot ETPs available since 2019; no UCITS vehicle possible
Energy consumption	Significant (mining, refining, transportation, vaulting)	Significant (~120–150 TWh p.a., Cambridge CCAF, 2024; proof-of-work consensus)
Intrinsic value foundation	Partial: industrial utility demand and long-established cultural monetary function	None: no cash flows, no utility demand; value rests entirely on network consensus

Source: own presentation based on data from Eichengreen (1992); Erb and Harvey (2013); Dyhrberg (2016); Klein et al. (2018); Bouri et al. (2017); Ammous (2018); Baur et al. (2018); Cambridge CCAF (2024); IMF (2024).

2.4 Bitcoin Hard Forks: Market Impact, Investor Returns, and the Scarcity Narrative

A Bitcoin hard fork occurs when a portion of the network's participants permanently adopt an incompatible set of protocol rules, thereby creating a divergent blockchain that shares Bitcoin's complete transaction history up to the point of separation but subsequently evolves independently. Hard forks differ from soft forks -- which remain backward-compatible -- in that they produce two mutually exclusive chains and, where the fork achieves sufficient adoption, two distinct tradeable assets. Since the seminal Bitcoin Cash fork in August 2017, more than 100 Bitcoin protocol forks have been launched; of these, fewer than ten have achieved lasting market liquidity. Table 3 summarises the four forks of material economic significance.

Table 3: Major Bitcoin hard forks of economic significance

Fork / Ticker	Date	Core Rationale	Peak Value vs. BTC	Approx. Value mid-2026 vs. BTC
Bitcoin Cash (BCH)	Aug 2017	Block size increase (1 MB to 8 MB, later 32 MB) to raise throughput	~25%	~0.3%
Bitcoin Gold (BTG)	Oct 2017	Equihash PoW algorithm (GPU-friendly, ASIC-resistant)	~12%	~0.03%
Bitcoin SV (BSV)	Nov 2018	128 MB blocks; "Satoshi Vision" - no SegWit, no Lightning	~10%	~0.05%
eCash / BCHA (XEC)	Nov 2020	Split from Bitcoin Cash; Avalanche consensus layer added	<1%	<0.01%
All completed forks combined	-	Over 100 Bitcoin protocol forks launched since 2017	-	~0.4% (BCH dominant)

Notes: Peak values are expressed as a percentage of the BTC price at the time, at the height of the launch period. Estimates for mid-2026 are taken from CoinMarketCap.
Source: own compilation based on data from CCAF (2024) and public market data, as at mid-2026.

The price dynamics surrounding hard forks exhibit a characteristic pattern. In the weeks preceding a widely anticipated fork, the Bitcoin price tends to appreciate as investors accumulate BTC specifically to obtain an equivalent quantity of the future fork coin at zero marginal cost -- a phenomenon documented across the Bitcoin Cash, Bitcoin Gold, and Bitcoin SV events (Auer and Claessens, 2018). This pre-fork demand premium reflects the market's expectation that fork coins will carry positive initial value. Post-fork, the newly created coins are typically sold rapidly by those who acquired Bitcoin primarily for this purpose, exerting downward pressure on the fork coin and frequently on Bitcoin itself

as arbitrage positions are unwound. The net effect on Bitcoin's long-run price is ambiguous: the departure of transaction throughput advocates into competing chains may improve Bitcoin's narrative coherence as digital gold, whilst simultaneously fragmenting developer resources and hash power in the short term.

From an investor return perspective, the analogy between Bitcoin forks and corporate stock dividends or spin-offs is superficially appealing but economically misleading. When a listed company distributes shares in a subsidiary, the parent's enterprise value is restructured -- an identifiable pool of assets is separated -- and the combined post-distribution value should, under efficient markets, equal the pre-distribution value. Bitcoin forks, by contrast, create a competing monetary protocol from an identical initial ledger state, without transferring any productive capacity. The fork coin's value is entirely contingent on achieving independent network effects -- a substantially more uncertain proposition. The empirical record confirms this asymmetry: Bitcoin Cash reached a peak of approximately 25% of Bitcoin's value in late 2017 but has since declined to approximately 0.3% by mid-2026. Bitcoin Gold and Bitcoin SV have fared worse still, having declined to approximately 0.03% and 0.05% of Bitcoin's value respectively. Investors who retained rather than sold fork coins have in almost every case suffered material opportunity costs.

A more nuanced question concerns whether Bitcoin hard forks undermine the 21-million-coin supply ceiling -- the architectural constraint most frequently cited as a rationale for Bitcoin's store-of-value properties. In a narrow, protocol-specific sense, the answer is no: the Bitcoin protocol itself enforces a supply cap of 21 million coins, and no fork alters this constraint within the original chain. However, in a broader economic sense -- if one regards the aggregate supply of all Bitcoin-family assets as the relevant monetary base -- forks constitute a form of supply expansion. Bitcoin Cash, Bitcoin SV, and Bitcoin Gold each impose their own 21-million caps, effectively creating additional units of digital scarcity that compete with Bitcoin for the same store-of-value investment thesis. Cong, Li, and Wang (2021) model the tokenomics of competing blockchain protocols and demonstrate that the equilibrium value of each token depends critically on its relative network adoption, with low-adoption tokens converging towards near-zero value regardless of their fixed supply schedule. The practical implication is that the 21-million cap functions as a credible scarcity constraint only insofar as the Bitcoin protocol retains dominant network adoption -- a condition that appears robust as of mid-2026 but is not guaranteed in perpetuity.

The behavioural pattern of investors following hard forks has been consistently characterised by rapid monetisation of fork coin receipts. Analysis of on-chain transaction data following the Bitcoin Cash launch reveals that the majority of BCH received by large Bitcoin holders was sold within the first 30 days (Auer and Claessens, 2018). This rapid disposal behaviour reflects rational considerations: the higher security of Bitcoin's dominant hash power relative to nascent fork chains, uncertain regulatory treatment of

fork coins, and the technical complexity of claiming fork coins through custodians. Crucially, for investors holding Bitcoin through regulated exchange-traded products -- including the BlackRock iShares Bitcoin Trust (IBIT), the Fidelity Wise Origin Bitcoin Fund (FBTC), and European ETPs such as ETC Group's BTCE -- hard fork coin distributions are generally not passed through to end investors. The prospectuses of these products typically grant the issuer discretion to retain, sell, or otherwise deal with fork coins, meaning institutional investors are economically shielded from fork coin dynamics but also forfeit any residual positive fork coin value that individual self-custody holders may realise. This structural difference represents an often overlooked asymmetry between direct Bitcoin ownership and ETP-mediated exposure.

From a portfolio risk perspective, hard forks represent a low-probability but non-negligible source of protocol and operational risk. Replay attacks -- whereby a valid transaction on one chain is maliciously or inadvertently broadcast and executed on the other -- have occurred in practice and required exchanges and wallet providers to implement replay protection mechanisms, sometimes with delays that froze user funds. The fragmentation of hash power across competing chains temporarily reduces the security of each chain by lowering the cost of a 51% attack, a concern empirically realised for Bitcoin Gold in May 2018, when the chain suffered a double-spend attack involving approximately 18 million US dollars. For equity fund managers, these operational risks reinforce the preference for regulated custodians and ETP structures over direct on-chain exposure, as these intermediaries bear the technical burden of fork management, replay protection, and regulatory classification of newly created assets.

3 Risk Profile: Volatility, Drawdowns, and Correlation

3.1 Historical Volatility and Drawdown Characteristics

Bitcoin's risk profile is categorically distinct from that of conventional equity instruments. The annualised historical volatility of BTC/EUR over the period 2016–2026 is approximately 54% p.a., compared with 13–16% p.a. for a global equity fund with approximately 70% US allocation (represented by EUNL.DE, iShares Core MSCI World UCITS ETF, Xetra). This implies a volatility multiple of approximately 3.5×, with significant time-variation: Bitcoin's 30-day rolling volatility has ranged from approximately 30% to over 100% p.a. across the observation period. Table 4 places this volatility in the context of conventional asset classes.

The drawdown characteristics of Bitcoin are equally extreme. The four completed major market cycles have each produced peak-to-trough declines averaging −85%, with the 2021–2022 cycle producing a −77% drawdown from the November 2021 peak of approximately 69,000 US dollars to the December 2022 trough of approximately 15,600 US dollars. For context, the MSCI World Index declined approximately 18% in 2022 — a

severe but structurally different order of magnitude. An equity fund with a 10% Bitcoin allocation at peak would have contributed approximately 8 percentage points of loss from the Bitcoin component alone during this period, before accounting for the equity component's concurrent decline. Table 5 compares the four completed bear market cycles with the 2022 MSCI World drawdown.

Table 4: Annualised volatility comparison across asset classes

Asset	Annualised Volatility (p.a.)	Comment
Bitcoin (BTC/EUR, 2016–2026)	~54%	Based on daily returns; peaks >100% in acute phases
Global equity fund (USA share ~70%)	10–20%	Representative band; MSCI World EUR proxy: ~13–16% p.a.
MSCI World EUR (EUNL.DE proxy)	~13–16%	Daily returns, 2016–2026; low end in 2017, high end in 2022
S&P 500 (USD)	~15–18%	Long-run average; elevated in 2020 and 2022
10-year US Treasury	~5–8%	Duration-driven; significantly elevated in 2022 rising-rate environment
Gold (XAU/USD)	~13–17%	Store-of-value proxy; lower tail risk than Bitcoin

Notes: The iShares Core MSCI World UCITS ETF (EUNL.DE) had an average US equity weighting of approximately 70 per cent over the observation period 2016–2026 — significantly higher than the 50 per cent sometimes assumed for 'balanced' global equity portfolios. This figure corresponds to the actual country allocation of the MSCI World Index and is used throughout the text of this study; the empirical calculations remain unaffected by this, as EUNL.DE daily returns form the actual data set.
Source: own calculations based on data from Yahoo Finance (EUNL.DE); Bloomberg; Cambridge CCAF (daily returns, 2016–2026).

Table 5: Major Bitcoin bear markets (completed cycles) compared with MSCI World 2022 drawdown

Bear Market	Peak ($)	Trough ($)	Drawdown (%)	Duration
2011 cycle	$31	$2	−94%	5 months
2013–2015 cycle	$1,163	$152	−87%	13 months
2017–2018 cycle	$19,783	$3,122	−84%	12 months
2021–2022 cycle	$69,045	$15,599	−77%	12 months
Average (completed cycles)	–	–	−85%	~11 months
MSCI World (2022)	–	–	−18%	12 months

Source: own presentation based on data from CoinMarketCap; Bloomberg; MSCI; own calculations. USD peak/trough values; durations approximate.

3.2 Correlation with Global Equity Markets

The unconditional monthly correlation between Bitcoin and the MSCI World EUR over the full observation period (January 2015 – June 2026) is approximately 0.31, suggesting limited linear dependence. This low correlation provides the theoretical basis for a diversification argument. However, the regression of monthly Bitcoin returns on MSCI World EUR monthly returns yields a beta coefficient of $\beta = 1.68$ with a coefficient of determination of $R^2 = 0.098$. The low R^2 confirms weak unconditional correlation, whilst the beta greater than unity indicates that in those periods when both assets decline simultaneously, Bitcoin tends to amplify equity losses by a factor of approximately 1.7. This combination — low average correlation, high conditional beta — is the statistical manifestation of the crisis autocorrelation risk described in Section 3.3.

The correlation structure of Bitcoin with conventional financial assets has attracted growing academic attention. Bouri, Molnar, Azzi, Roubaud, and Hagfors (2017) find that Bitcoin provides a partial hedge against global uncertainty in short-run horizons, but document substantial time-variation in hedging effectiveness. Dyhrberg (2016), employing GARCH volatility modelling, identifies Bitcoin as possessing characteristics intermediate between gold and the US dollar — partly consistent with a diversification role in tranquil markets. Klein, Pham Thu, and Walther (2018) challenge this analogy directly, demonstrating that Bitcoin's conditional correlation with equities increases sharply during distress episodes — the inverse of gold's behaviour — undermining the hedge narrative at the moments it would be most valuable. Fang, Bouri, Gupta, and Roubaud (2019) document that global economic uncertainty indices are significant predictors of Bitcoin's conditional volatility, establishing a macroeconomic mechanism for the crisis co-movement documented in Section 3.3. These findings collectively suggest that unconditional correlation statistics systematically understate Bitcoin's portfolio risk in stress scenarios — a bias that the rolling-window methodology of Section 5.3 addresses by incorporating the full 2022 bear market in the most recent optimisation windows.

3.3 Crisis Autocorrelation: The Structural Diversification Risk

The most significant portfolio risk associated with Bitcoin allocation above 10% is the documented tendency for correlation between Bitcoin and global equities to rise sharply during market stress episodes. During the COVID-19 market crash of March 2020, Bitcoin lost approximately 57% of its value within 48 hours — a period during which global equity markets also experienced acute stress. The correlation between daily Bitcoin and S&P 500 returns during the acute phase (March–April 2020) reached 0.7–0.9, compared with an unconditional value of approximately 0.3. A similar pattern emerged during the 2022 global equity/bond bear market.

This phenomenon is consistent with the theoretical framework of Brunnermeier and Pedersen (2009), who demonstrate that asset correlations rise during liquidity crises as leveraged investors are forced to liquidate positions across asset classes simultaneously. Bitcoin, as a highly liquid, 24/7 tradable risk asset with substantial leverage embedded through perpetual futures markets, is particularly susceptible to this dynamic. The practical implication is that a Bitcoin allocation provides diversification benefit during normal market conditions — when it is least needed — and fails precisely when portfolios are under the greatest stress and diversification would be most valuable. This asymmetric conditional correlation structure represents the core structural argument against allocations significantly above 10%.

4 Fundamental Valuation: The Absence of Intrinsic Value

From the perspective of fundamental analysis, Bitcoin presents an irresolvable valuation challenge. A conventional equity security represents a claim on the future cash flows of an enterprise, which may be valued using discounted cash flow (DCF) analysis, price-to-earnings (P/E) multiples, or price-to-book (P/B) ratios. The equity risk premium — the excess return investors demand for holding equities over risk-free assets — can be derived from observable corporate earnings yields and growth expectations. According to Damodaran (NYU Stern, January 2026), the weighted return on equity for global large-cap enterprises stands at approximately 12–14% p.a. (North America: ~20%; Europe: ~10–12%; Japan: ~8–10%), providing a fundamental basis for long-run equity return expectations.

Bitcoin possesses none of these value anchors. It generates no revenues, no operating income, no free cash flow, and no dividends. There is no balance sheet equity, no management team creating economic value, and no product or service from which future cash flows might be derived. The entire price formation mechanism is determined by the behaviour of current and prospective buyers — a reflexive, expectation-driven pricing dynamic in the sense of Shiller (2015), consistent with speculative asset price formation in the absence of fundamental anchors. Cheah and Fry (2015) provide formal empirical evidence of speculative bubble dynamics in Bitcoin markets, confirming the absence of a fundamental value anchor. Yermack (2015) reaches a similar conclusion from a monetary economics perspective, arguing that Bitcoin fails the conventional criteria for currency status and that its price behaviour is more consistent with a speculative asset than a monetary instrument. This does not preclude Bitcoin from achieving positive returns: any asset whose supply is constrained and demand is growing will appreciate. However, it does mean that return expectations are not analytically groundable, distinguishing Bitcoin categorically from income-producing assets in the context of portfolio allocation.

The practical investment implication of absent intrinsic value is not that the asset cannot be held, but that the portfolio weight assigned to it must reflect the epistemological

uncertainty inherent in its pricing. Liu and Tsyvinski (2021) demonstrate formally that, under standard risk aversion parameters and absent momentum effects, the optimal Bitcoin weight in a portfolio of risky assets ranges from 1% to 6%. The present study's empirical optimisation (Section 5.3) confirms and extends this range: in the most recent five-year windows (2021–2026), the empirically optimal allocation averages 8%, reflecting both Bitcoin's residual momentum and the attenuation of the extraordinary bull-market returns observed in the 2016–2021 period.

5 Portfolio Analysis and Empirical Optimisation

5.1 Model Assumptions and Variance Effects

To quantify the volatility impact of Bitcoin allocation, a two-asset portfolio model is employed. The model parameters are calibrated to observable market data: fund volatility $\sigma(F) = 15\%$ p.a. — as used in equation (2) — (midpoint of the 10–20% band characteristic of globally diversified equity funds with approximately 70% US allocation); Bitcoin volatility $\sigma(B) = 54\%$ p.a. (empirical five-year rolling average, 2020–2025); normal-market correlation $\rho(\text{normal}) = 0.30$; stress-market correlation $\rho(\text{stress}) = 0.75$ (based on observed correlations during March 2020 and H2 2022). Portfolio volatility is given by the standard two-asset variance formula — see equations (1) and (2):

Return:
$$\mu_P = (1 - w) \cdot \mu_F + w \cdot \mu_B \tag{1}$$

Risk:
$$\sigma_P = \sqrt{(1 - w)^2 \cdot \sigma_F^2 + w^2 \cdot \sigma_B^2 + 2 \cdot (1 - w) \cdot w \cdot \sigma_F \cdot \sigma_B \cdot \rho} \tag{2}$$

Table 6 demonstrates the non-linear volatility impact of Bitcoin inclusion. At a 10% allocation, normal-market portfolio volatility rises from 15.0% to 15.8% — a modest increase of 0.8 percentage points. Under stress conditions ($\rho = 0.75$), the same 10% allocation raises portfolio volatility to 17.4% — an increase of 2.4 percentage points. Beyond 20%, the stress-volatility escalation accelerates materially, with a 30% allocation producing a stress volatility of 26.1% — well above the upper bound of the characteristic 10–20% volatility band of global equity funds. These results establish 10% as a volatility-consistent ceiling for Bitcoin allocation in equity portfolios with the described risk profile.

Table 6: Portfolio volatility under varying Bitcoin allocations

BTC Weight	Portfolio σ (Normal)	Portfolio σ (Stress)	Drawdown Contribution	Change vs. Base
0% (base)	15.0%	15.0%	0.0%	—
5%	15.2%	16.0%	4.0%	+1.0 pp
10%	15.8%	17.4%	8.0%	+2.4 pp
15%	16.8%	19.2%	12.0%	+4.2 pp
20%	18.1%	21.3%	16.0%	+6.3 pp
30%	21.6%	26.1%	24.0%	+11.1 pp
50%	31.5%	36.7%	40.0%	+21.7 pp

Notes: Portfolio volatility under varying Bitcoin allocations, calibrated to a representative global equity fund (Vol = 15% p.a.). Stress correlation $\rho = 0.75$. Drawdown contribution calculated as weight × 80% (historical median maximum drawdown).
Source: own calculations.

The mean-variance framework employed above derives directly from Markowitz (1952, 1959), whose seminal contribution to modern portfolio theory (MPT) demonstrated that rational investors, preferring higher expected returns for a given level of risk, will select portfolios lying on the efficient frontier — the set of portfolios offering maximum expected return for each level of variance. Tobin's (1958) two-fund separation theorem established that the optimal risky portfolio is independent of individual risk preferences, and that all investors combine this single tangency portfolio with the risk-free asset in proportions determined by their risk aversion. The Capital Asset Pricing Model (CAPM), independently derived by Sharpe (1964), Lintner (1965), and Mossin (1966), operationalises this framework by expressing each asset's expected return as a linear function of its systematic risk (beta) relative to the market portfolio. Fama (1970) subsequently embedded CAPM in the efficient market hypothesis, arguing that in an efficient market, prices fully reflect all available information — a condition that Urquhart (2016) finds to be violated for Bitcoin, particularly in early periods. In the present context, Bitcoin's empirically estimated beta of $\beta = 1.68$ relative to the MSCI World EUR implies that, under CAPM, Bitcoin would require a risk premium of 168% of the equity market's — a threshold that recent cycle (2021–2026) returns fail to meet, reinforcing the case for a conservative allocation ceiling. Ang, Chen, and Xing (2006) extend the variance framework to capture downside risk specifically, showing that assets with elevated downside beta — of which Bitcoin, at −85% average peak-to-trough drawdown, is a paradigm case — demand a higher risk premium than unconditional beta implies, providing theoretical underpinning for the volatility ceiling identified above.

5.2 Return Effects and Sharpe Ratio Analysis

Alongside the variance effect, the return and risk-adjusted return implications of Bitcoin allocation require examination. Since Bitcoin generates no cash flows, its contribution to portfolio return is entirely dependent on capital appreciation scenarios. Three scenarios are evaluated: (1) optimistic: 30% p.a. return — consistent with sustained institutional adoption momentum; (2) base: 10% p.a. — Bitcoin develops in line with equity markets as adoption growth decelerates; (3) conservative: 0% p.a. — Bitcoin stagnates at current valuation levels. The Sharpe ratio is computed as: (Portfolio return − 3%) / Portfolio volatility, with a risk-free rate of 3% p.a. representing the approximate current real risk-free rate environment. Table 7 quantifies these return and Sharpe ratio effects systematically across three Bitcoin return scenarios.

Table 7: Return and Sharpe ratio effects under varying Bitcoin allocations and return scenarios.

BTC Weight	Return (BTC: 30%)	Return (BTC: 10%)	Return (BTC: 0%)	Sharpe (BTC: 30%)	Sharpe (BTC: 0%)
0%	10.0% p.a.	10.0% p.a.	10.0% p.a.	0.47	0.47 (base)
10%	12.0% p.a.	10.0% p.a.	9.0% p.a.	0.56 (+0.09)	0.38 (−0.09)
20%	14.0% p.a.	10.0% p.a.	8.0% p.a.	0.60 (+0.13)	0.27 (−0.20)

Notes: Base fund return: 10% p.a.; risk-free rate: 3% p.a.; $\sigma(F) = 15\%$ p.a. in accordance with Equation (2) (normal market). Deviations from the base Sharpe ratio of 0.47 are shown in brackets.
Source: own calculations.

The analysis reveals a pronounced asymmetry. If Bitcoin delivers 30% p.a., the Sharpe ratio improves monotonically from 0.47 to 0.60 as the allocation rises — a justification for higher weights. However, if Bitcoin stagnates (0% p.a.), the Sharpe ratio deteriorates sharply: from 0.47 to 0.38 at 10% Bitcoin (−19%), and to 0.27 at 20% (−43%). The critical insight is that the scenario probability distribution is fundamentally non-symmetric: equity fund returns are anchored by corporate earnings growth and can be estimated using established valuation frameworks. Bitcoin returns have no such fundamental anchor. The expected value of future Bitcoin returns is therefore highly uncertain, whilst the downside scenarios (stagnation, further sharp drawdown) carry material probability weights that purely momentum-based analyses tend to underweight.

5.3 Empirical Portfolio Optimisation: Rolling Efficient Frontier (2016–2026)

5.3.1 Methodology and Data Sources

The theoretical analysis of Sections 5.1 and 5.2 is complemented by a fully empirical rolling portfolio optimisation using real market data. Data sources: daily BTC/EUR prices (Yahoo

Finance) and the iShares Core MSCI World UCITS ETF 1C (EUNL.DE; Xetra Frankfurt; EUR-denominated, accumulating; Yahoo Finance) as a proxy for the global equity universe in euros. Note that EUNL.DE is an accumulating ETF (dividends reinvested), which causes it to systematically outperform the MSCI World EUR price index; the equity proxy therefore flatters the equity component's performance, making the analysis conservative with respect to Bitcoin's relative attraction. The common dataset covers 2,981 trading days from September 2014 to June 2026.

Methodology: 61 rolling five-year windows are computed. The first window runs from 31 May 2016 to 31 May 2021; each subsequent window advances by one calendar month, so that the final window runs from 31 May 2021 to 31 May 2026. For each of the 61 windows, 101 portfolio combinations are evaluated (0%–100% Bitcoin in 1% steps), with annualised return and volatility computed from daily returns using the 252-trading-day convention. The optimal portfolio is defined as the maximum-Sharpe-ratio portfolio, with a risk-free rate of 0%.

The application of Markowitz's (1952) mean-variance framework to Bitcoin portfolios has attracted significant academic interest, providing a directly comparable methodological backdrop for the present analysis. Briere, Oosterlinck, and Szafarz (2015) conducted one of the earliest such studies using 2010–2013 data, finding that even a 3–5% Bitcoin allocation improved the efficient frontier for a diversified multi-asset portfolio. Eisl, Gasser, and Weinmayer (2015) confirm diversification benefits but emphasise that optimal weights are highly sensitive to the estimation window chosen — a finding that motivates the rolling-window approach employed here. Kajtazi and Moro (2019), in a multi-country study spanning the US, China, and the EU, document positive diversification effects from Bitcoin but note that these benefits are concentrated in shorter-term horizons and diminish substantially in longer holding periods. Platanakis and Urquhart (2019) incorporate transaction costs into the Markowitz optimisation and find that the optimal Bitcoin allocation contracts significantly once realistic execution costs are applied — an argument for maintaining allocations closer to the lower end of the empirical optimum range. Guesmi, Saadi, Abid, and Ftiti (2019), employing a DCC-GARCH model, find time-varying optimal Bitcoin weights frequently in the range of 3–8% — closely consistent with the present study's finding for the 2021–2026 period. Trimborn, Li, and Hardle (2019) incorporate liquidity constraints and find further reductions in optimal weights under realistic market conditions. The cross-study consensus is clear: the case for Bitcoin inclusion in diversified portfolios is empirically substantiated, but the optimal weight is substantially lower than advocates typically claim and is highly sensitive to the observation window — precisely the time-varying sensitivity that the rolling-window methodology of the present study is designed to quantify and report transparently.

5.3.2 Empirical Results

The full-period results reveal a counterintuitive finding on the surface: the average optimal Bitcoin allocation across all 61 windows is 68.3% (median: 100%). This result is methodologically coherent but practically misleading: it reflects exclusively the ex-post optimal allocation during the extraordinary Bitcoin bull market of 2016–2021, during which Bitcoin generated an average annualised return of 102.6% p.a. No rational ex-ante investor could have predicted these returns, and projecting them forward as a basis for current allocation decisions would constitute a severe recency and survivorship bias.

The critical finding for forward-looking portfolio construction emerges from the most recent windows. For the five windows with start dates of January–May 2021 — the five-year periods covering 2021–2026, which fully encompass the 2022 Bitcoin bear market (−77%), the FTX collapse (November 2022), and the subsequent partial recovery — the average optimal Bitcoin allocation is 8.8% (median: 8%; range: 6–15%). This constitutes an empirically grounded, forward-relevant anchor for the recommended 10% allocation ceiling. Table 8 sets out the results for all 61 windows by sub-period.

The data additionally confirm a critical monotonic relationship: as the observation period extends further into the post-bull-market era, the optimal Bitcoin allocation converges towards values consistent with the theoretical 10% recommendation. The early windows (2016–2018 start dates) are dominated by Bitcoin's extraordinary historical performance; the most recent windows (2021 start dates) represent a more balanced market environment including the full 2022 downturn.

Table 8: Rolling portfolio optimisation results by sub-period

Analysis Period	Windows	Avg. Opt. BTC Weight	Avg. Sharpe (opt.)	Avg. Sharpe (10% BTC)	Avg. BTC Return p.a.
Early: 2016–2018 (window starts)	32	74.9% (median: 100%)	1.659	1.131	122.8%
Mid: 2019–2020 (window starts)	24	72.0% (median: 100%)	1.483	1.237	90.9%
Recent: 2021 (window starts, 2021–2026)	5	8.8% (median: 8%)	0.997	0.993	29.6%
Full: 2016–2026 (all 61 windows)	61	68.3% (median: 100%)	1.536	1.161 (+37.9%)	102.6%

Source: own presentation based on data from BTC/EUR (Yahoo Finance) and EUNL.DE as MSCI World EUR proxy (Yahoo Finance). 61 rolling five-year windows, monthly roll, 31 May 2016 – 31 May 2026. Sharpe ratio: risk-free rate = 0%, annualised using 252-trading-day factor.

5.3.3 Sharpe Ratio Analysis: 10% Bitcoin Improves All Windows

A particularly robust empirical finding is that a 10% Bitcoin allocation improved the Sharpe ratio relative to a pure equity portfolio (0% Bitcoin) in all 61 rolling windows — a 100% hit rate. The average Sharpe improvement is +0.318 (from 0.843 to 1.161), with a minimum improvement of +0.017 in the least favourable window. Even in the windows that encompass the full 2022 Bitcoin bear market, a 10% allocation delivered superior risk-adjusted returns compared with an unallocated equity portfolio. Figure 1 illustrates the efficient frontier and Sharpe ratio curves for the five most recent windows.

Relative to the unconstrained optimum (average Sharpe 1.536 at average 68% Bitcoin), the 10% constraint sacrifices an average of 0.374 Sharpe points (approximately 24% of the theoretical maximum potential). However, this Sharpe differential is achievable only by assuming that Bitcoin's extraordinary 2016–2021 returns will persist — an assumption the present study regards as inadmissible for forward-looking portfolio construction. When the analysis is restricted to the most recent windows (2021–2026), the unconstrained optimal allocation of 8.8% is barely distinguishable from the recommended 10% ceiling in Sharpe ratio terms (0.993 vs. 0.997 — a difference of 0.4%). Figure 2 shows the full distribution of optimal allocations across all 61 windows alongside the Sharpe ratio comparison across five benchmark strategies.

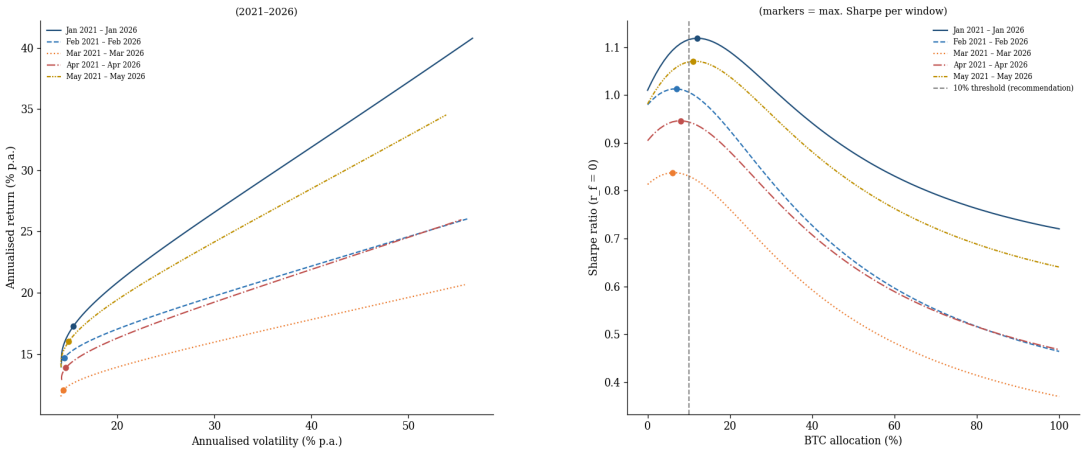

Figure 1: Efficient frontier for the five most recent five-year windows (2021–2026, left panel) and Sharpe ratio as a function of Bitcoin allocation by sub-period (right panel). Stars indicate the Sharpe-maximising allocation for each window. Shaded bands show the 25th–75th percentile range.
Source: Own calculations.

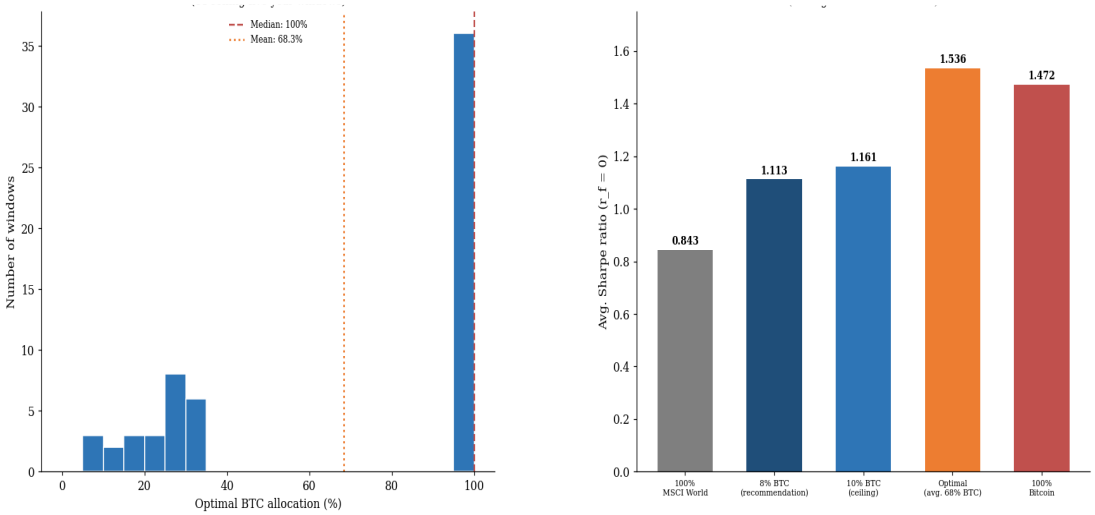

Figure 2: Distribution of the optimal Bitcoin allocation across 61 rolling five-year windows (histogram) and Sharpe ratio comparison across three portfolio strategies (right panel).
Source: Own calculations.

Figure 3 traces the evolution of the optimal Bitcoin allocation across all 61 rolling window start dates, illustrating how the unconstrained optimum declines as observations of the 2022 bear market enter each window.

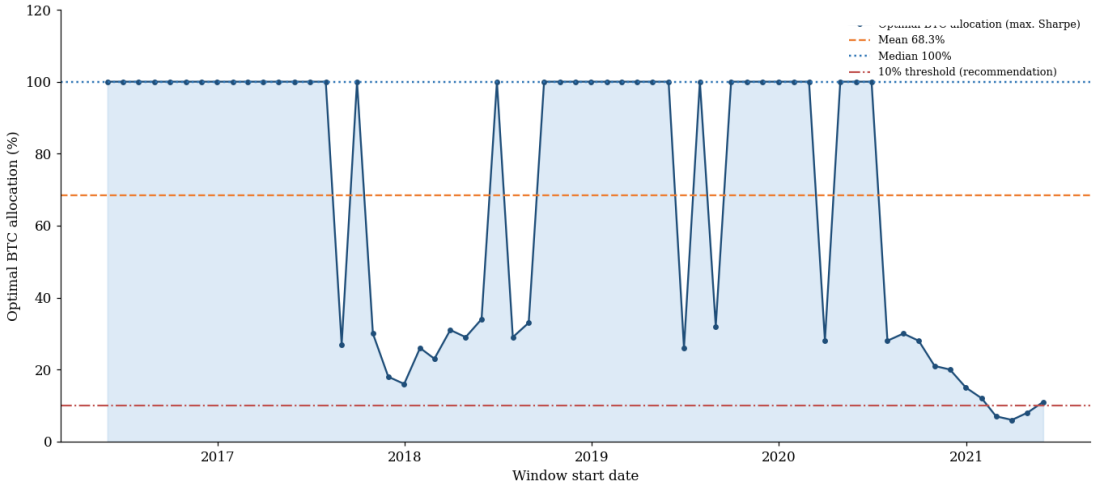

Figure 3: Optimal Bitcoin allocation (maximum Sharpe ratio) by rolling window start date, May 2016 to May 2021. The horizontal dashed line at 10% indicates the recommended allocation ceiling.
Source: Own calculations.

5.3.4 Regression and Correlation Analysis

The regression of monthly BTC/EUR returns on monthly MSCI World EUR returns (January 2015 – June 2026; n = 137 monthly observations) yields: BTC monthly return = 1.68 × MSCI World EUR monthly return + 0.065; $R^2 = 0.098$; standard error of the slope

= 0.31; p-value < 0.001. The low R^2 confirms that approximately 90% of the variation in monthly Bitcoin returns is unexplained by MSCI World EUR returns — consistent with the low unconditional correlation ($\rho \approx 0.31$). The beta of 1.68 indicates that in those months when both assets move in the same direction, Bitcoin moves 68% further — an amplification effect that materialises most acutely in crisis periods. Figure 4 plots the monthly return pairs underpinning this regression. Figure 5 presents the efficient frontier across all 61 rolling windows, with the average frontier highlighted as a thick black line.

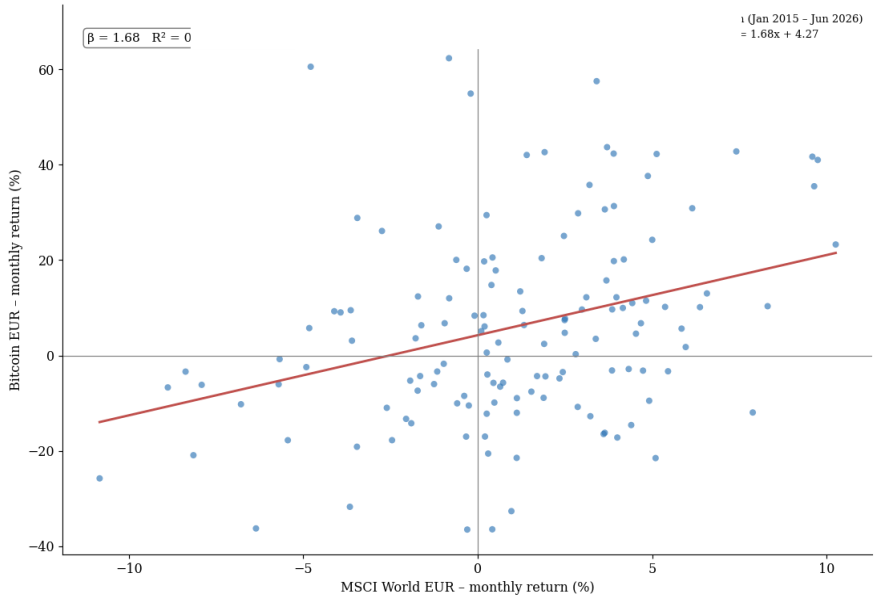

Figure 4: Regression of monthly Bitcoin EUR returns on monthly MSCI World EUR returns (January 2015 – June 2026). $\beta = 1.68$; $R^2 = 0.098$. Each point represents one month.
Source: Own calculations based on Yahoo Finance data.

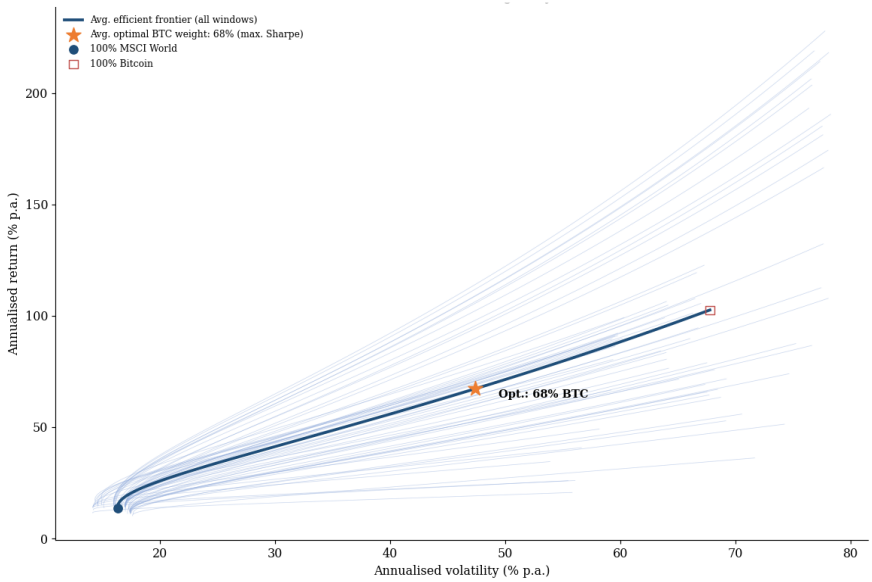

Figure 5: Efficient frontier for all 61 rolling five-year windows (grey lines) and average efficient frontier across all windows (blue). Star: average optimal portfolio.
Source: Own calculations.

Figure 6 isolates the five most recent windows (2021–2026) on a single efficient frontier chart and marks the average 8% optimal Bitcoin allocation with a star, providing a focused view of the current-period risk–return profile.

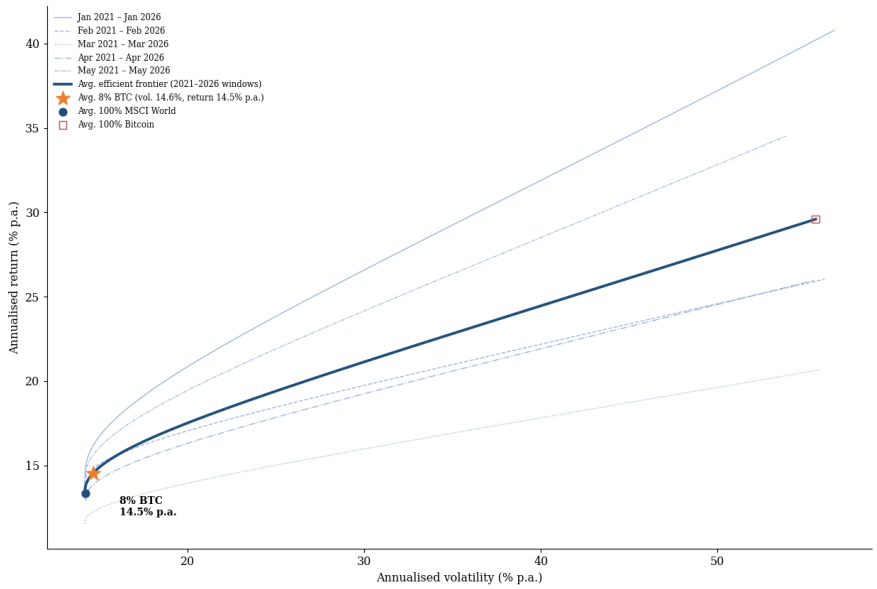

Figure 6: Efficient frontier for the five most recent rolling five-year windows (2021–2026). The star (★) marks the average optimal portfolio at an 8% Bitcoin allocation, which maximises the Sharpe ratio for the most recent observation period.
Source: own calculation.

6 Bitcoin Investment Products

6.1 Exchange-Traded Products and Spot ETFs

The most significant regulatory development in recent years was the SEC's approval of spot Bitcoin ETFs in the United States on 10 January 2024. Within twelve months, assets under management exceeded 115 billion US dollars, led by the iShares Bitcoin Trust (IBIT, BlackRock) and the Fidelity Wise Origin Bitcoin Fund (FBTC). These instruments hold physical Bitcoin, trade on regulated stock exchanges, and are subject to SEC reporting requirements. For European investors, US spot ETFs are generally inaccessible due to the absence of a PRIIPs-compliant key information document.

In Europe, a growing range of physically-backed Exchange Traded Products (ETPs) has been available since 2019. The ETC Group Physical Bitcoin (BTCE) trades on Xetra Frankfurt and the Vienna Stock Exchange; the 21Shares Bitcoin ETP (ABTC) is listed on Xetra and Euronext; WisdomTree Physical Bitcoin (WBTC) provides further coverage. It should be noted that a UCITS-compliant Bitcoin fund is structurally impossible: UCITS Directive Article 52 prohibits a concentration exceeding 20% in a single issuer, and Bitcoin is not eligible as a transferable security under Article 50(1)(a). ETPs are therefore legally structured as debt instruments of the issuer, secured by physical Bitcoin — they are not Sondervermögen (segregated fund assets) under the German and Austrian investment fund legislation. Table 9 provides a structured overview of the main product types, their regulatory frameworks, and investor suitability.

Table 9: Overview of Bitcoin investment product types, examples, regulatory framework, and investor suitability

Product	Examples	Exchange / Venue	Regulation	Suitability
Spot ETF (US)	IBIT (BlackRock), FBTC (Fidelity)	NYSE Arca / Nasdaq	SEC (1940 Act)	Institutional (US access)
ETP (Europe)	BTCE, ABTC (21Shares), WBTC (WisdomTree)	Xetra Frankfurt, Vienna	MiCA / EMIR	Retail & institutional (EU)
CME Futures	BTC, MBT (micro)	CME Group, Chicago	CFTC	Institutional hedging
Options	BTC options on CME; Deribit	CME / Deribit (Amsterdam)	CFTC / AFM	Professional counterparties
Certificates	Vontobel, DZ BANK, Société Générale, HSBC	EUWAX, Frankfurt Stock Exchange	BaFin / FMA	Retail (issuer risk applies)

Notes: Regulatory status as at June 2026.
Source: own compilation based on data from BlackRock's SEC filing (2024); Fidelity's SEC filing (2024); CME Group; ETC Group; 21Shares.

6.2 Derivatives, Futures, and Structured Products

The Chicago Mercantile Exchange (CME) has offered regulated Bitcoin futures (ticker: BTC) since December 2017 and Micro Bitcoin Futures (MBT; contract size: 0.1 BTC) since May 2021. Both products are cash-settled and supervised by the CFTC. CME Bitcoin options (since January 2020) complete the regulatory derivatives offering. Deribit (Amsterdam; regulated under MiFID II by the AFM) is the leading platform for crypto options by open interest, handling daily volumes of several billion US dollars. Unregulated perpetual futures on platforms such as Binance, Bybit, or OKX — which offer leverage up to 125:1 — are not recommended for equity fund investors and fall outside prudent institutional risk management frameworks. In the German- and Austrian-speaking markets, exchange-listed certificates from Vontobel, DZ BANK, Société Générale, and HSBC provide retail-accessible structured exposure, though counterparty risk inherent in certificate structures makes physically-backed ETPs the preferred instrument for material allocations.

7 Custody Solutions and Trading Venues

7.1 Custody Architecture

Bitcoin ownership is not established by name registration but by possession of the corresponding private key — a 256-bit random number from which a Bitcoin address is derived. This principle gives rise to the central dictum of crypto custody: 'Not your keys, not your coins' (Antonopoulos, 2017). A party holding Bitcoin on an exchange is legally a creditor of that exchange, not the holder of a property right — a distinction dramatically illustrated by the FTX collapse in November 2022, in which over one million customers lost temporary or permanent access to assets nominally in their accounts.

Hardware wallets — dedicated devices (Ledger Nano X/Flex, Trezor Safe 3, Coldcard; Ledger SAS, 2024; Trezor, 2024) that store private keys in secure element chips and never expose them to internet-connected environments — represent the gold standard for self-custody of material Bitcoin holdings. Transactions are signed on the device in an air-gapped environment; only the signed transaction is transmitted to the network. Multi-signature (multi-sig) arrangements (e.g., 2-of-3, 3-of-5 key configurations, implemented through services such as Casa and Unchained Capital) eliminate the single-point-of-failure risk inherent in single-key arrangements. For institutional investors, regulated custodians — Coinbase Custody, BitGo, and Fidelity Digital Assets — provide cold storage with SOC-2 certification, insurance coverage, and regulatory oversight under OCC or state trust charters. All seed phrases (BIP39 mnemonic sequences of 12 or 24 words, encoding the master private key per BIP32/44 derivation standards) must be stored securely offline in multiple physical locations; their loss is equivalent to permanent loss of the corresponding Bitcoin holdings. Table 10 compares the main custody architectures by security characteristics, regulatory status, and recommended investor category.

Table 10: Bitcoin custody options by type, security characteristics, regulatory status, and recommended investor category

Custody Type	Examples	Security Level	Regulation	Recommended From
Hardware Wallet	Ledger Nano X/Flex, Trezor Safe 3, Coldcard	Very high (air-gap)	Self-regulated	Experienced retail
Software Wallet	Electrum, Sparrow, BlueWallet	Medium (internet-connected)	None	Small amounts only
Multi-Signature	Casa, Unchained Capital (2-of-3 / 3-of-5)	High (no single point of failure)	Contractual	HNW individuals
Inst. Custodian	Coinbase Custody, BitGo, Fidelity Digital Assets	Very high (SOC-2, insured)	OCC / state charter	Institutional investors
Regulated Exchange	Bitpanda (FMA Vienna), Coinbase, Kraken, Bitstamp	Medium (counterparty risk)	MiCA / FinCEN	Entry-level investors

Source: own presentation based on data from Ledger SAS; Trezor; Coinbase Institutional; BitGo.

7.2 Trading Venues and Investor Recommendations

Regulated exchanges in Europe operating under MiCA include Bitpanda (Vienna; licensed by the Austrian FMA), Coinbase (licensed in multiple EU member states), Kraken, and Bitstamp. Traditional retail brokers — including Scalable Capital and Trade Republic (both Germany/EU) — have introduced Bitcoin ETP access, reducing the operational barrier for retail investors. Institutional OTC desks (Cumberland, Jump Trading) serve large-volume transactions with reduced market impact. Table 11 synthesises product and custody recommendations by investor profile.

Table 11: Product and custody recommendations by investor profile

Investor Type	Product Recommendation	Custody Recommendation
Retail investor (entry, <€10,000)	ETP via online broker (Scalable Capital, Trade Republic, Bitpanda)	Regulated exchange (Coinbase, Bitpanda)
Retail investor (experienced, >€10,000)	ETP on Xetra or direct purchase	Hardware wallet (Ledger, Trezor) as primary custody
Institutional investor (EU)	ETP on Xetra (BTCE, ABTC, WBTC)	Regulated custodian (Coinbase Custody, BitGo)
Institutional investor (US access)	Spot ETF (IBIT BlackRock, FBTC Fidelity)	ETF custody via prime broker
Fund manager / family office (EU)	ETP combined with CME futures for hedging	Prime broker with integrated custody service

Notes: Recommendations as at June 2026; the regulatory environment is subject to change as part of the implementation of MiCA.
Source: own compilation based on data from the Austrian Financial Market Authority (FMA); Coinbase; Bitpanda; Ledger.

8 Institutional Perspectives and Regulatory Environment

8.1 Views of Major Financial Institutions

The institutional investment community remains divided on Bitcoin's portfolio role. BlackRock (2024) — itself the issuer of the world's largest Bitcoin ETF — recommends a Bitcoin allocation of 1–2% in a multi-asset portfolio, explicitly citing the diversification benefit and the extreme skewness of return distributions. Fidelity Investments (2024) takes a more constructive view, suggesting that Bitcoin warrants dedicated consideration as an alternative asset alongside commodities and real assets, particularly in inflationary environments. JPMorgan (2024) acknowledges Bitcoin's diversification properties but notes that at its current market capitalisation, a 1% crypto allocation in an institutional portfolio represents a balanced exposure. Goldman Sachs (2024) emphasises the speculative character and the absence of a fundamental earnings yield. Deutsche Bank (2024) and UBS (2025) adopt broadly cautious postures, noting regulatory uncertainty and the risk of further regulatory crackdowns in major emerging markets as primary concerns.

8.2 Regulatory Environment: MiCA and Global Developments

The European Union's Markets in Crypto-Assets Regulation (MiCA, Regulation (EU) 2023/1114) entered into force on 29 June 2023 and became fully applicable to crypto-asset service providers (CASPs) on 30 December 2024. MiCA establishes authorisation requirements for CASPs, disclosure obligations analogous to prospectus requirements, market integrity provisions (prohibition of market manipulation and insider dealing), and

reserve requirements for asset-referenced tokens and e-money tokens. For Bitcoin specifically, MiCA's disclosure requirements for 'other crypto-assets' create a more standardised investor information framework across the EU.

In the United States, the approval of spot Bitcoin ETFs under the Securities Exchange Act represents a significant regulatory normalisation, although the SEC's broader characterisation of crypto-assets as securities (rather than commodities) remains contested through litigation. El Salvador's adoption of Bitcoin as legal tender (September 2021) and the subsequent IMF-conditioned partial reversal (2024) illustrate the political and macroeconomic complexities of sovereign Bitcoin adoption. Japan maintains a licensing framework for crypto exchanges under the Payment Services Act. No major developed-market jurisdiction has implemented an outright Bitcoin ban in force as of June 2026, though several emerging markets (China, India at various points) have imposed material restrictions.

9 A Balanced Assessment

Table 12 presents the principal arguments for and against a Bitcoin allocation in globally diversified equity funds, drawn from the preceding analysis and the extant academic literature.

Table 12: Arguments for and against Bitcoin allocation in globally diversified equity funds

Arguments in Favour of an Allocation (Pro)	Arguments Against a High Weighting (Contra)
Decentralised, censorship-resistant system without an issuer	No intrinsic value: no cash flows, dividends, interest, or earnings
Fixed maximum supply: 21 million BTC (algorithmic scarcity)	Return source exclusively from price appreciation; entirely sentiment-driven
Store-of-value thesis: inflation hedge under constrained supply	Empirical correlation with inflation historically inconsistent (Baur et al., 2018)
Growing institutional adoption; spot ETF inflows >$ 115bn (2025)	Correlation with equities rises to 0.7–0.9 during crisis periods
Diversification potential in low-correlation market phases	Historical peak-to-trough losses average −85% (completed cycles)
24/7 liquidity; global tradability without currency conversion	Energy consumption ~175–195 TWh p.a. (Cambridge CCAF, 2024)
Lightning Network substantially improves transaction throughput	Regulatory risk: MiCA implementation, SEC uncertainty, ban risk in emerging markets
Maturing regulatory framework (MiCA in EU; US spot ETFs approved)	Price formation driven primarily by investor behaviour; no fundamental anchor
Global reserve asset discussion (El Salvador, sovereign wealth funds)	Concentration risk: top 1% of addresses hold >25% of all BTC

Source: own compilation based on data from Nakamoto (2008); Antonopoulos (2017); Baur et al. (2018); Liu and Tsyvinski (2021); Corbet et al. (2018); BlackRock (2024); Cambridge CCAF (2024); own assessment.

A balanced reading of the evidence suggests that Bitcoin's case as a portfolio component is materially weaker than its advocates claim, but not wholly without foundation. The diversification benefit is real in normal market conditions, as documented by the low unconditional correlation ($R^2 = 0.098$) and the universal Sharpe ratio improvement from a 10% allocation across 61 rolling windows. The inflation-hedge narrative, however, lacks empirical support. The structural risk — crisis autocorrelation and the complete absence of intrinsic value — delimits the allocation to a range that preserves the diversification option whilst precluding a weight large enough to materially threaten the fund's risk profile during Bitcoin's periodic deep drawdowns.

10 Conclusion and Recommendation

10.1 Synthesis and Answer to the Research Question

The central research question of this paper was: at what allocation level does a Bitcoin position improve the risk-adjusted return of a globally diversified equity fund without compromising portfolio stability? The results of the rolling optimisation, the two-asset variance model, and the structural risk analysis converge on a single answer: a maximum Bitcoin allocation of 10% is appropriate for globally diversified equity funds with a typical

portfolio volatility of 10–20% p.a. and a US equity share of roughly 70%, corresponding to the average country allocation of the MSCI World Index (proxy: EUNL.DE) over the 2016–2026 observation period. This threshold is validated empirically by the rolling optimisation (most recent optimal allocation: 8%), supported by the structural risk arguments of Chapters 3 and 4, and consistent with the broader academic literature (Liu and Tsyvinski, 2021: 1–6% at standard risk aversion; own empirical optimisation: 6–15% in recent cycles). Allocations below this threshold — ideally in the 3–10% range, actively managed and regularly reviewed — can serve as a strictly limited, speculative diversification sleeve. Investors should be explicitly aware that any Bitcoin allocation constitutes exposure to an asset with no intrinsic value, average historical drawdowns of −85%, and a documented tendency towards adverse correlation with equities in systemic crises.

High crisis autocorrelation and absent intrinsic value preclude a Bitcoin allocation above 10% in globally diversified equity funds. The empirically determined optimal allocation for 2021–2026 is 8%. The recommended maximum is 10%.

10.2 Limitations and Outlook

The reach of these results is bounded. The empirical basis covers only about one decade (2016–2026) and thus few complete market cycles; the rolling optimisation rests on 61 windows with a substantial overweight of bull phases. The analytical framework is limited to two assets (Bitcoin, a global equity index); transaction costs, taxes, and liquidity risks in stress periods remain unmodelled. Moreover, Bitcoin's correlation structure is not stable: the documented crisis autocorrelation rests on few observations and may continue to change as institutionalisation progresses.

Several avenues for further research follow directly: regime-dependent correlation and tail-risk models (such as Markov-switching approaches, DCC-GARCH, or quantile regressions), out-of-sample tests of the allocation threshold derived here across future halving cycles, and a multi-asset extension that optimises Bitcoin jointly with gold and inflation-linked bonds.

Above all, it remains open whether the institutionalisation accelerated by spot ETFs permanently raises Bitcoin's equity correlation and thereby erodes precisely the diversification benefit that empirically justifies its inclusion. Answering this question over the next full market cycle will determine whether the 10% ceiling derived here proves too high or too low.

References

Ammous, S. (2018): The Bitcoin Standard: The Decentralised Alternative to Central Banking, Wiley.

Antonopoulos, A. M. (2017): Mastering Bitcoin: Programming the Open Blockchain (2nd Ed.). O'Reilly Media.

Auer, R., and S. Claessens (2018): Regulating Cryptocurrencies: Assessing Market Reactions, BIS Quarterly Review, September 2018, 51–65, Bank for International Settlements, Basel.

Baur, D. G., K. H. Hong, and A. D. Lee (2018): Bitcoin: Medium of Exchange or Speculative Assets? Journal of International Financial Markets, Institutions and Money, 54, 177–189.

BlackRock Inc. (2024): iShares Bitcoin Trust (IBIT): Registration Statement Filed with the SEC, Retrieved from https://www.sec.gov/.

Bordo, M. D., and F. E. Kydland (1995): The Gold Standard as a Rule: An Essay in Exploration, Explorations in Economic History 32 (4), 423–464.

Bouri, E., P. Molnar, G. Azzi, D. Roubaud, and L. I. Hagfors (2017): On the Hedge and Safe Haven Properties of Bitcoin: Is It Really More Than a Diversifier? Finance Research Letters, 20, 192–198.

Briere, M., K. Oosterlinck, and A. Szafarz (2015): Virtual Currency, Tangible Return: Portfolio Diversification with Bitcoin, Journal of Asset Management 16 (6), 365–373.

Brunnermeier, M. K., and L. H. Pedersen (2009): Market Liquidity and Funding Liquidity, Review of Financial Studies 22 (6), 2201–2238.

Buterin, V. (2014): A Next-Generation Smart Contract and Decentralized Application Platform [Ethereum White Paper], Retrieved from https://ethereum.org/.

Cambridge Centre for Alternative Finance (CCAF). (2024): Cambridge Bitcoin Electricity Consumption Index, University of Cambridge Judge Business School.

Cheah, E. T., and J. Fry (2015): Speculative Bubbles in Bitcoin Markets? An Empirical Investigation into the Fundamental Value of Bitcoin, Economics Letters, 130, 32–36.

Cong, L. W., Y. Li, and N. Wang (2021): Tokenomics: Dynamic Adoption and Valuation, The Review of Financial Studies 34 (3), 1105–1155.

Corbet, S., A. Meegan, C. Larkin, B. Lucey, and L. Yarovaya (2018): Exploring the Dynamic Relationships between Cryptocurrencies and Other Financial Assets, Economics Letters, 165, 28–34.

Damodaran, A. (2026): Return on Equity by Sector (Global), as of January 2026, NYU Stern School of Business, retrieved from https://pages.stern.nyu.edu/~adamodar/.

Deutsche Bank Research (2024): Cryptocurrency Outlook: From Speculation to Institutionalisation, Frankfurt am Main: Deutsche Bank AG.

Dwyer, G. P. (2015): The Economics of Bitcoin and Similar Private Digital Currencies, Journal of Financial Stability, 17, 81–91.

Dyhrberg, A. H. (2016): Bitcoin, Gold and the Dollar: A GARCH Volatility Analysis, Finance Research Letters, 16, 85–92.

Eichengreen, B. (1992): Golden Fetters: The Gold Standard and the Great Depression, 1919–1939. Oxford University Press.

Eisl, A., S. M. Gasser, and K. Weinmayer (2015): Caveat Emptor: Does Bitcoin Improve Portfolio Diversification? SSRN Working Paper 2408997. Retrieved from https://ssrn.com/abstract=2408997.

Erb, C. B., and C. R. Harvey (2013): The Golden Dilemma, Financial Analysts Journal 69 (4), 10–42.

European Parliament and Council of the EU (2023): Regulation (EU) 2023/1114 on Markets in Crypto-Assets (MiCA). Official Journal of the European Union, L 150, 9 June 2023.

Fama, E. F. (1970): Efficient Capital Markets: A Review of Theory and Empirical Work, Journal of Finance 25 (2), 383–417.

Fidelity Investments (2024): Fidelity Wise Origin Bitcoin Fund (FBTC): Registration Statement Filed with the SEC, Retrieved from https://www.sec.gov/.

Goldman Sachs (2024): Equity Outlook 2026: The Path Ahead, Goldman Sachs Global Investment Research.

Hayek, F. A. (1976): Denationalisation of Money: The Argument Refined, Institute of Economic Affairs.

IMF (2024): El Salvador: Staff Concluding Statement of the 2024 Article IV Consultation, International Monetary Fund.

JPMorgan Asset Management (2024): 2025 Long-Term Capital Market Assumptions, J.P. Morgan Asset Management.

Kajtazi, A., and A. Moro (2019): The Role of Bitcoin in Well Diversified Portfolios: A Comparative Global Study, International Review of Financial Analysis, 61, 143–157.

Klein, T., H. Pham Thu, and T. Walther (2018): Bitcoin Is Not the New Gold: A Comparison of Volatility, Correlation, and Portfolio Performance, International Review of Financial Analysis 59, 105–116.

Ledger SAS (2024): Ledger Hardware Wallet Technical Documentation, Retrieved from https://www.ledger.com/.

Lintner, J. (1965): The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets, Review of Economics and Statistics 47 (1), 13–37.

Liu, Y., and A. Tsyvinski (2021): Risks and Returns of Cryptocurrency, Review of Financial Studies 34 (6), 2689–2727.

Markowitz, H. (1952): Portfolio Selection, Journal of Finance 7 (1), 77–91.

Markowitz, H. (1959): Portfolio Selection: Efficient Diversification of Investments, Yale University Press.

Mishkin, F. S. (2019): The Economics of Money, Banking, and Financial Markets (12th Ed.). Pearson.

Modigliani, F., and M. H. Miller (1958): The Cost of Capital, Corporation Finance, and the Theory of Investment, American Economic Review 48 (3), 261–297.

Mossin, J. (1966): Equilibrium in a Capital Asset Market, Econometrica 34 (4), 768–783.

Nakamoto, S. (2008): Bitcoin: A Peer-To-Peer Electronic Cash System, Retrieved from https://bitcoin.org/bitcoin.pdf.

Platanakis, E., and A. Urquhart (2019): Portfolio Management with Cryptocurrencies: The Role and Importance of Transaction Costs, Finance Research Letters, 29, 362–369.

Sharpe, W. F. (1964): Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk, Journal of Finance 19 (3), 425–442.

Sharpe, W. F. (1966): Mutual Fund Performance, Journal of Business 39 (S1), 119–138.

Shiller, R. J. (2015): Irrational Exuberance (3rd Ed.). Princeton University Press.

Tobin, J. (1958): Liquidity Preference as Behavior Towards Risk, Review of Economic Studies 25 (2), 65–86.

Trezor (2024): Trezor Hardware Wallet Documentation, Retrieved from https://trezor.io/.

UBS Global Wealth Management (2025): Year Ahead 2025: Navigating Transitions, UBS AG.

Urquhart, A. (2016): The Inefficiency of Bitcoin, Economics Letters, 148, 80–82.

Yermack, D. (2015): Is Bitcoin a Real Currency? An Economic Appraisal, In D.L.K. Chuen (Ed.), Handbook of Digital Currency (pp. 31–43). Academic Press.