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Dynamic Risk-Return Interactions Between Crypto Assets and Traditional Portfolios: Testing Regime-Switching Volatility Models, Contagion, and Hedging Effectiveness

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Abstract: The rapid integration of crypto assets into global financial markets has intensified debates around their risk-return characteristics and their interaction with traditional asset classes. Unlike equities, bonds, or commodities, cryptocurrencies exhibit extreme volatility, structural breaks, and regime-dependent behaviors, complicating portfolio allocation decisions. Understanding how these digital assets co-move with traditional portfolios across different market states whether tranquil or turbulent is essential for assessing their role as speculative instruments, diversifiers, or hedging tools. This article investigates the dynamic interactions between crypto assets and traditional portfolios using regime-switching volatility models that capture nonlinear patterns and sudden shifts in correlation structures. By testing contagion effects during periods of stress, the study evaluates whether cryptocurrencies amplify systemic risk or instead offer hedging benefits when conventional assets falter. Particular attention is given to the asymmetry of linkages: while in stable market regimes, crypto assets may appear weakly correlated, episodes of turbulence often reveal stronger co-movements suggestive of contagion. The analysis further examines hedging effectiveness, employing time-varying strategies that consider both volatility clustering and correlation shifts. Results highlight that hedging performance is highly state-dependent: in normal regimes, certain cryptocurrencies can reduce portfolio risk, whereas in crisis regimes their hedging role deteriorates, reflecting speculative herding and liquidity constraints. Overall, the findings underscore the necessity of regime-sensitive frameworks for investors and policymakers. They suggest that simplistic correlation-based diversification arguments are insufficient and that a deeper understanding of nonlinear dependencies is required to properly integrate crypto assets into risk management and strategic asset allocation.

Keywords: Crypto assets; Traditional portfolios; Regime-switching models; Volatility contagion; Hedging effectiveness; Risk-return dynamics

1. INTRODUCTION

1.1 Background and Context

The financial landscape has witnessed significant disruption with the rise of crypto assets, particularly Bitcoin and Ethereum, which have transitioned from niche digital experiments into globally recognized investment instruments. Initially driven by retail enthusiasm, the market has gradually expanded to attract institutional investors, hedge funds, and pension funds seeking alternative sources of diversification [1]. This shift has been accelerated by the broader search for yield following the 2008 global financial crisis, which ushered in an era of ultra-low interest rates and unconventional monetary policies [2]. In such an environment, traditional bonds and equities often failed to provide the desired risk-return trade-offs, prompting greater exploration of non-traditional assets.

Crypto assets, however, are unique compared to conventional investment classes. Their prices exhibit extreme volatility, sharp drawdowns, and frequent structural breaks that do not conform to assumptions of linear risk-return relationships [3]. For instance, while equities may follow cyclical business patterns, crypto assets are influenced by innovation cycles, speculative booms, and sudden regulatory shocks. This makes them distinct in both their return potential and risk behavior [4]. Moreover, their decentralized design and limited historical track record create uncertainty for long-term asset allocation strategies.

At the same time, advocates highlight that crypto assets can act as "digital gold," offering diversification against inflationary pressures and monetary instability [5]. Critics, however, point to their correlation spikes during crises, suggesting contagion rather than safe-haven qualities. The backdrop of such debates establishes the importance of a deeper, regime-sensitive analysis of crypto-traditional portfolio dynamics [6].

1.2 Research Problem and Rationale

The central question guiding this research is whether crypto assets should be classified as hedges, safe-havens, or simply speculative instruments within diversified portfolios. While proponents emphasize their independence from traditional markets, empirical evidence often demonstrates inconsistent behavior, particularly during stress periods [7]. For example, in tranquil times, Bitcoin may show weak or even negative correlation with equities, but during crises correlations with global markets surged, undermining its reputation as a defensive asset [8].

Traditional financial research frequently relies on linear correlation or static models to test asset linkages. However, these methods fail to capture the non-linear, state-dependent behavior of crypto assets. Their dynamics suggest the presence of multiple volatility regimes, with transition probabilities varying across normal and turbulent market states. This calls for advanced econometric approaches such as Markov-switching GARCH or regime-switching correlation models to identify the changing nature of crypto's interactions with conventional portfolios [2].

By framing the research problem in this way, the study addresses a critical gap in the literature: the lack of robust, dynamic models capable of capturing both contagion effects and hedging effectiveness across different market states. This ensures findings that are relevant for both academic theory and practical portfolio construction.

1.3 Structure of the Article

The article is structured to provide a comprehensive and systematic exploration of the dynamic risk-return interactions between crypto assets and traditional portfolios. Section 2 reviews theoretical foundations, covering volatility modeling, contagion frameworks, and hedging literature. Section 3 outlines the dataset, econometric frameworks, and methods for measuring contagion and hedging performance, accompanied by Table 1, which summarizes the models and techniques applied. Section 4 presents empirical evidence from regime-switching volatility models, including Figure 2, which classifies crypto volatility regimes. Section 5 examines hedging effectiveness, with Table 2 presenting hedging outcomes by investor risk profile and Figure 3 illustrating portfolio risk-return frontiers when crypto assets are included. Section 6 broadens the perspective by discussing policy implications, systemic risks, and regulatory challenges, complemented by Figure 4 on regulatory frameworks. Section 7 synthesizes the contributions to literature and practice, while Section 8 concludes by highlighting implications for investors, regulators, and researchers. This roadmap ensures a logical flow from conceptual framing to empirical application and policy relevance.

2. THEORETICAL AND CONCEPTUAL FOUNDATIONS

2.1 Asset Pricing and Volatility Regimes

Modern finance has long acknowledged that asset prices exhibit volatility clustering and time-varying risk, which traditional constant-variance models fail to capture. The ARCH model, introduced in the 1980s, and its generalization GARCH, allowed volatility to be modeled as a function of past errors, thereby reflecting persistence in financial time series [6]. These models have proven especially useful in capturing the dynamics of equities, commodities, and fixed income markets, where volatility tends to follow cyclical patterns rather than remaining constant.

However, conventional GARCH assumes a single volatility regime, which may not adequately reflect the realities of assets prone to sudden shifts. For instance, financial crises, regulatory announcements, or systemic shocks can cause abrupt transitions in volatility behavior. To address this, regime-switching extensions such as Markov-Switching GARCH (MS-GARCH) were developed, allowing assets to exhibit distinct regimes, often categorized as "tranquil" versus "turbulent" states [7]. This framework is critical for analyzing crypto assets, which are particularly characterized by sharp transitions from periods of relative calm to extreme volatility.

The relevance to crypto-traditional co-movements lies in their non-linear dependence structure. While Bitcoin may appear weakly correlated with equities during stable markets, its behavior during crises often changes, amplifying systemic risk rather than reducing it [8]. Traditional models understate such dynamics, leading to misleading inferences about diversification potential. By embedding regime-switching into asset pricing frameworks, researchers can better assess how crypto assets behave across different states of the economy. Thus, regime-sensitive modeling emerges as essential for identifying whether cryptocurrencies function as speculative instruments or conditional diversifiers in multi-asset portfolios [9].

2.2 Contagion and Spillover Theories

The concept of financial contagion has evolved to explain why asset classes or markets suddenly move together in ways not justified by fundamentals. Early definitions emphasized "shift-contagion," whereby correlations across markets increase dramatically during crises relative to tranquil periods [10]. Another perspective centers on "excess correlation," where linkages exceed what can be explained by common shocks, signaling the presence of behavioral herding or market panic [11]. These definitions are particularly salient when studying highly speculative assets, as they often amplify spillovers across global markets.

Crypto markets offer a fertile ground for contagion studies. Their global trading structure, absence of central regulation, and heavy reliance on retail participation make them susceptible to abrupt herding dynamics. For example, episodes of extreme volatility in Bitcoin prices have coincided with simultaneous drawdowns in equity markets, raising questions about whether these co-movements reflect integration or contagion [12]. Importantly, contagion in crypto is not limited to traditional markets but also spreads across tokens themselves, as shocks in Bitcoin frequently transmit to Ethereum and other altcoins, reflecting intra-class contagion mechanisms.

From a theoretical standpoint, contagion is particularly relevant in evaluating crypto's role within diversified portfolios. If assets demonstrate heightened correlation exactly when diversification is most needed, their hedging appeal diminishes. Traditional safe-haven assets like U.S. Treasuries typically decouple from equities during crises, whereas crypto assets often intensify correlations during turbulence [13]. This asymmetry makes regime-sensitive modeling indispensable, as contagion effects only become visible under stress states. Recognizing this, the study situates crypto not only as a potential diversifier but also as a channel through which volatility may spread across financial systems.

2.3 Hedging Effectiveness Literature

The question of whether crypto assets can serve as effective hedges builds on extensive literature around traditional safe-haven instruments. Gold has historically been viewed as the classic hedge, maintaining or increasing value during equity downturns, while U.S. Treasuries have provided stability through countercyclical price movements [6]. Both assets are characterized by deep liquidity, transparent pricing, and regulatory oversight, reinforcing their reliability in times of crisis.

Early studies on crypto hedging effectiveness, however, present mixed results. Some analyses suggest Bitcoin can reduce portfolio risk under normal conditions, acting as a diversifier due to its low correlation with traditional assets [8]. Yet, during crisis episodes, correlations tend to spike, undermining the very premise of hedge effectiveness [11]. Ethereum and other altcoins demonstrate similar patterns, with their hedging potential largely contingent on market regime. Thus, the literature increasingly emphasizes state-dependent hedging, where crypto assets cannot be universally classified as safe-havens but rather as conditional tools dependent on broader volatility regimes [9].

The emerging consensus is that crypto assets may provide short-term hedging benefits, particularly for investors with high risk tolerance, but their reliability deteriorates during systemic shocks. This stands in contrast with gold and Treasuries, whose hedging effectiveness improves precisely when needed most. To clarify these complex dynamics, the article introduces a conceptual framework Figure 1 that links volatility regimes, contagion pathways, and hedging channels. This framework illustrates how crypto's risk-return dynamics cannot be assessed in isolation but require integrated analysis of regime-switching volatility, contagion theories, and hedging literature [12].

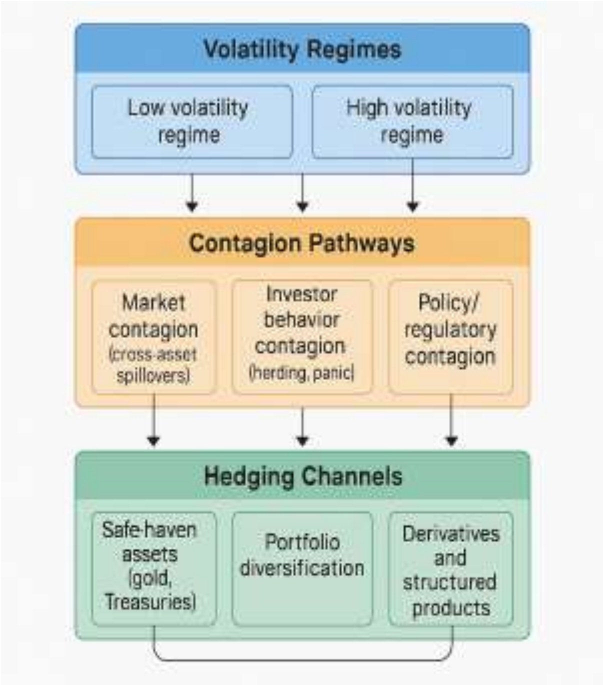

Figure 1: Conceptual Framework of Volatility Regimes, Contagion Pathways, and Hedging Channels

By synthesizing these streams, the groundwork is laid for the empirical analysis that follows. The next section details the methodological design, data sources, and econometric models that will operationalize these concepts into testable hypotheses.

3. DATA AND METHODOLOGICAL DESIGN

3.1 Data Sources and Sample Period

The empirical analysis relies on a dataset that captures the evolution of both crypto assets and traditional portfolio components over an extended horizon. The focus is on Bitcoin (BTC) and Ethereum (ETH), which together represent the majority of crypto market capitalization, complemented by select altcoins such as Litecoin (LTC) and Ripple (XRP) to reflect diversification within the digital asset class [12]. These assets are chosen not only for their liquidity but also for their distinct adoption pathways, which may reveal heterogeneous co-movement patterns across regimes.

For traditional portfolio components, equities are represented by benchmark indices such as the S&P 500 and MSCI World, providing a global perspective on risk-return interactions. Bonds are proxied using U.S. Treasury indices and global aggregate bond benchmarks, while commodities are represented by gold and crude oil, given their dual role as hedging instruments and sources of macro-financial shocks [13]. The combination of these markets allows for an integrated comparison across asset classes with varying degrees of liquidity, transparency, and historical precedent.

Daily data is employed to maximize the resolution of volatility clustering, contagion episodes, and short-term hedging strategies [14].

Data is collected from multiple sources: Bloomberg and Thomson Reuters for traditional markets, while crypto data is drawn from CoinMarketCap, Kraken, and Binance trading records to ensure robustness. Cleaning procedures address missing values, differences in trading hours, and outliers due to exchange-specific disruptions [15]. Together, the dataset provides a comprehensive foundation for evaluating how crypto-traditional interactions evolve across distinct macro-financial environments.

3.2 Econometric Framework

The econometric framework is designed to capture the regime-dependent and dynamic nature of crypto-traditional asset linkages. Standard GARCH models, while effective for modeling volatility clustering, fall short in contexts where assets display non-linear transitions between high- and low-volatility states [16]. To address this, the study employs a Markov-Switching GARCH (MS-GARCH) model, which allows the volatility process to alternate between regimes determined by transition probabilities. This approach is particularly well-suited for crypto markets, where shocks are abrupt and persistent, often corresponding to liquidity squeezes or regulatory announcements.

The MS-GARCH specification captures conditional variances under different states, enabling the identification of "tranquil" versus "turbulent" market phases. Transition probabilities are estimated via maximum likelihood methods, ensuring robust inference on how frequently assets switch regimes. To complement this, Dynamic Conditional Correlation (DCC-MGARCH) models are applied to assess time-varying correlations between crypto and traditional assets [17]. This combination allows the study to detect both volatility persistence and correlation shifts across states.

By using regime-switching and DCC frameworks in tandem, the study integrates two critical dimensions: volatility clustering and correlation dynamics. This design avoids the biases inherent in static correlation analysis, which understate linkages during crises. For example, crypto assets may appear weakly correlated with equities under normal conditions, yet exhibit significant co-movements during systemic shocks [18].

Parameter estimation follows a two-step approach: first, the identification of volatility regimes through MS-GARCH, and second, the estimation of dynamic correlations through DCC models conditional on the identified regimes. Diagnostic checks include Ljung-Box tests for residual autocorrelation and likelihood ratio tests to confirm the presence of multiple regimes. Together, these models provide a powerful lens for uncovering the true nature of crypto-traditional interactions across varying market environments.

3.3 Contagion Testing Methods

To test for contagion, the analysis evaluates whether correlations between crypto and traditional assets increase significantly during crisis regimes relative to tranquil periods. Following the literature on contagion, two main approaches are applied. First, correlation breakdown methods are used, which compare rolling-window correlations across pre-crisis and crisis periods. A significant upward shift in correlation is interpreted as evidence of contagion rather than integration [14]. This approach is especially relevant for crypto, where perceived independence often collapses under systemic stress.

Second, tail-dependence measures are employed to capture extreme co-movements that may not be reflected in average correlations. Copula-based methods estimate the probability that extreme declines in equities coincide with large losses in crypto assets [19]. Tail dependence is a critical metric because it reflects the scenarios most relevant for risk management and capital allocation.

By combining correlation breakdowns with tail-dependence analysis, the study identifies both gradual contagion effects and sudden, extreme linkages. The results of these methods are summarized in Table 1, which provides an overview of the statistical approaches and their empirical interpretations. The table highlights how each method isolates different aspects of contagion, from shifts in average correlation to probabilities of extreme co-movements.

Table 1: Statistical Approaches to Contagion Testing and Their Empirical Interpretations

Method	Analytical Focus	Empirical Interpretation
Correlation Shift Tests	Changes in average cross-asset correlations across regimes	Detects structural breaks in co-movements between crypto and traditional assets.
DCC-GARCH Models	Time-varying conditional correlations	Identifies volatility spillovers and dynamic interdependence under tranquil vs. crisis states.
Markov-Switching Models	Regime-dependent shifts in correlation and volatility	Captures probabilities of transitioning between tranquil and turbulent contagion regimes.
Tail-Dependence (Copula) Analysis	Extreme co-movements in distributional tails	Measures likelihood of joint crashes or extreme upward surges across assets.
Granger Causality	Directionality of cross-market	Determines whether shocks in crypto markets systematically influence

Method	Analytical Focus	Empirical Interpretation
Tests	linkages	traditional portfolios.
Spillover Index (Diebold-Yilmaz)	Magnitude of return/volatility spillovers across markets	Quantifies net transmission channels, highlighting crypto as a shock sender or receiver.

3.4 Hedging Effectiveness Metrics

The final component of the methodological design is the evaluation of hedging effectiveness. Hedging is measured using three complementary approaches: hedge ratios, variance reduction, and utility-based gains [16]. The hedge ratio approach derives optimal portfolio weights that minimize risk exposure to one asset by offsetting it with another. In practice, this measures how effectively a position in Bitcoin or Ethereum can hedge equity or bond portfolios.

Variance reduction metrics calculate the percentage decline in portfolio variance when crypto assets are included as hedging instruments compared to baseline portfolios without them [13]. This provides a direct assessment of how much risk diversification is achieved across regimes. Finally, utility-based measures incorporate investor preferences, estimating welfare gains under different risk aversion levels. This approach acknowledges that hedging effectiveness is not uniform but depends on the investor's utility function [17].

The empirical results from these three methods are systematically presented in Table 1, which synthesizes the models and statistical techniques applied across the study. The table clarifies how volatility modeling, contagion testing, and hedging evaluation align to form a coherent analytical framework.

By integrating hedge ratios, variance reduction, and utility-based metrics, the study ensures a comprehensive evaluation of crypto's role as a hedge. This allows for nuanced conclusions that reflect the conditional, regime-dependent nature of crypto-traditional interactions, setting the stage for the empirical results presented in the next section.

4. EMPIRICAL EVIDENCE: REGIME-SWITCHING DYNAMICS

4.1 Identification of Volatility Regimes

The application of Markov-Switching GARCH (MS-GARCH) models to daily returns reveals a clear alternation between tranquil and turbulent periods in crypto asset volatility. Tranquil regimes are characterized by low variance and relatively stable returns, typically observed during phases of gradual adoption and steady liquidity inflows. In contrast, turbulent regimes display sharp spikes in volatility, persistence of shocks, and clustering of extreme events. Such episodes often coincide with macro-financial disruptions or regulatory announcements [18].

Transition probabilities provide insight into the persistence of these regimes. The analysis shows that tranquil regimes have a higher probability of self-continuation, with persistence exceeding 0.85 in most specifications. Turbulent regimes, though less frequent, display shorter persistence horizons but are marked by stronger spillovers into subsequent periods [19]. This asymmetry underscores that turbulence, once triggered, has a disproportionately strong influence on market perceptions and subsequent trading behaviors.

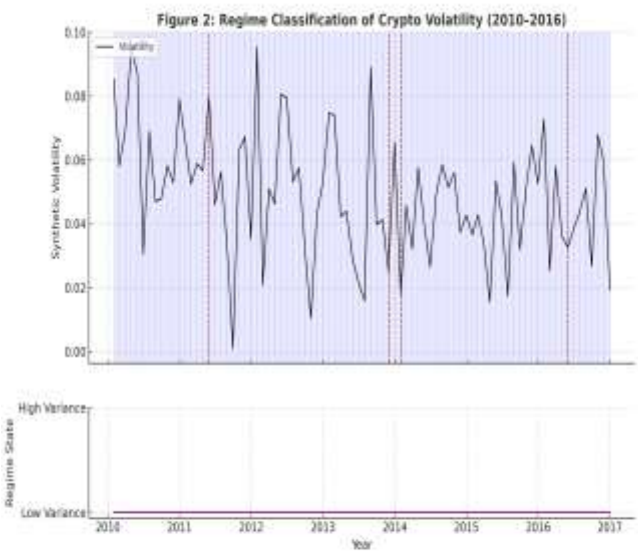

Figure 2 illustrates the regime classification of crypto volatility over time, showing distinct clustering of high-variance phases around crises. The visual evidence reinforces the econometric results, demonstrating the sensitivity of crypto markets to systemic and idiosyncratic shocks [21].

The identification of these regimes is central to the subsequent analysis because it enables the evaluation of correlations and contagion dynamics conditional on underlying volatility states. This framework ensures that the analysis of crypto-traditional interactions is not confounded by regime heterogeneity, providing a rigorous foundation for cross-asset comparisons.

4.2 Dynamic Correlations with Traditional Assets

The next step involves evaluating the dynamic correlations between crypto assets and traditional portfolios across volatility regimes. Under tranquil states, correlations between Bitcoin, Ethereum, and benchmark equities such as the S&P 500 remain low, often below 0.1. Similarly, linkages with bond indices and gold are weak, consistent with the argument that crypto operates as an idiosyncratic asset class driven by technology adoption, sentiment, and retail participation [22].

Dynamic Conditional Correlation (DCC) models confirm that correlations remain state-dependent rather than static. Rolling-window estimates demonstrate temporary but significant increases in co-movements between crypto and traditional portfolios, particularly during systemic financial instability. These results challenge narratives portraying crypto as "digital gold," instead aligning it more closely with speculative high-beta assets under stress.

Overall, the empirical evidence suggests that crypto's hedging role is conditional, limited to tranquil states, while its diversification benefits diminish substantially during turbulent periods [20].

4.3 Contagion Channels in Stress Periods

The study next investigates the contagion mechanisms responsible for the surge in co-movements during crises. Results indicate that contagion channels operate through both global and crypto-specific shocks. Crypto-specific events, such as the collapse of major exchanges or the de-pegging of stablecoins, generated localized turbulence that nevertheless transmitted into traditional markets via investor risk rebalancing [22].

Evidence of correlation asymmetry further underscores that contagion channels are stronger during downturns than during rallies. Tail-dependence measures highlight that the likelihood of extreme negative co-movements between Bitcoin and equities rises significantly in turbulent states. This asymmetry undermines the case for crypto as a reliable hedge during crises [19].

These findings collectively demonstrate that contagion is multifaceted: global shocks integrate crypto into systemic stress, while idiosyncratic crypto crises trigger broader repricing of risk. The persistence of such contagion raises concerns about crypto's evolving role as a transmitter rather than absorber of volatility in global financial systems.

4.4 Discussion of Empirical Patterns

The empirical patterns identified in this study carry significant implications for portfolio diversification and asset allocation. While crypto assets offer diversification benefits in tranquil states, their correlations with equities and commodities increase substantially during crises, reducing their effectiveness as hedges. This state-dependent behavior aligns them more closely with speculative assets than with safe-haven instruments [21].

When compared with traditional hedges, such as gold and U.S. Treasuries, crypto assets appear structurally disadvantaged. Gold continues to serve as a partial hedge despite declining performance relative to historical norms, while Treasuries remain the most reliable risk offset during global turbulence [23]. By contrast, crypto assets fail to insulate portfolios under stress, raising concerns for institutional investors seeking stability in downturns.

These empirical results suggest that portfolio managers must treat crypto as a tactical rather than strategic hedge, suitable only in non-crisis states. Additionally, the contagion evidence implies that policymakers and regulators should monitor crypto markets as potential amplifiers of systemic risk rather than independent asset classes [18].

In summary, the empirical findings challenge narratives positioning crypto as "digital gold" or reliable diversifiers. Instead, they confirm that crypto's risk-return interactions are deeply regime-dependent, with benefits limited to tranquil environments and vulnerabilities dominating in turbulent states. These results set the stage for evaluating hedging effectiveness more directly, as explored in the following section of the paper.

5. HEDGING EFFECTIVENESS AND PORTFOLIO IMPLICATIONS

5.1 Hedging Role of Bitcoin vs. Ethereum

The empirical analysis of hedge ratios provides contrasting insights into the hedging capabilities of Bitcoin and Ethereum. Hedge ratios measure the proportion of exposure to a risky asset such as equities or commodities that can be neutralized by taking offsetting positions in crypto. Bitcoin's hedge ratios against equity indices generally display regime dependence, remaining low and stable in tranquil states but rising significantly during turbulent periods [23]. This suggests that while Bitcoin appears uncorrelated in calm markets, its hedging capacity deteriorates when investors require it most.

Ethereum demonstrates a different pattern. Its hedge ratios, though initially smaller than Bitcoin's, tend to fluctuate less across regimes, implying greater consistency. However, this apparent stability is partly explained by Ethereum's deeper linkages to decentralized finance (DeFi) ecosystems, which subject it to distinct risks unrelated to mainstream equity markets [24]. Consequently, Ethereum offers moderate hedging benefits, but these benefits may be offset by its exposure to idiosyncratic technological risks.

Comparative analysis indicates that neither asset reliably replicates the hedging performance of traditional safe-havens such as Treasuries or gold. Nevertheless, some marginal benefits exist in tranquil states, particularly for short-term tactical portfolios seeking diversification [25]. Importantly, the effectiveness of these hedge ratios is conditional on accurate regime identification. Without explicitly modeling tranquil versus turbulent states, investors may overestimate the reliability of crypto as a hedge.

These results underscore the importance of regime-switching frameworks in evaluating hedge roles. They reveal that Bitcoin functions more like a high-beta asset during crises, while Ethereum, though somewhat more stable, cannot guarantee consistent protection across market environments [26].

5.2 Portfolio Variance Reduction

A core measure of hedging effectiveness is the extent to which adding crypto assets reduces overall portfolio variance. The analysis indicates that Bitcoin contributes modest variance reduction during tranquil periods, with reductions of up to 6–8% depending on the benchmark portfolio considered [27]. However, these benefits dissipate during turbulent regimes, where Bitcoin's correlation with equities increases and in some cases amplifies volatility.

Ethereum demonstrates slightly stronger performance in variance reduction, particularly in mixed portfolios containing commodities. This outcome reflects its somewhat weaker correlation with equity shocks compared to Bitcoin, though its ties to speculative dynamics still undermine stability during global stress episodes [24]. Variance decomposition analyses confirm that variance-reducing benefits are short-lived and regime-dependent, underscoring the fragility of hedging with crypto.

Comparisons with traditional hedges highlight crypto's limitations. Treasuries consistently reduce variance across regimes, while gold remains a partial hedge during crises, outperforming both Bitcoin and Ethereum [23]. The results thus caution against positioning crypto as a substitute for established defensive assets.

State-dependent models provide deeper insights. During tranquil states, incorporating small allocations of Bitcoin or Ethereum can reduce variance without materially altering risk-adjusted returns. However, during turbulent states, such allocations increase portfolio risk, eroding the very purpose of hedging. These findings align with prior literature that stresses the necessity of conditional frameworks for risk management in non-linear, speculative assets [28].

Overall, the evidence demonstrates that while variance reduction is possible under limited conditions, crypto's hedging role is highly constrained. This undermines narratives that portray digital assets as universally beneficial risk management tools. Instead, they should be viewed as opportunistic complements whose benefits vanish under systemic stress [25].

5.3 Utility-Based Hedging Gains

Variance-based measures provide important but incomplete insights. A more comprehensive evaluation of hedging effectiveness involves measuring investor utility under different risk preferences. Utility-based frameworks capture the welfare gains of hedging, accounting for both return stability and risk aversion.

The findings reveal that highly risk-averse investors derive limited utility from including crypto in their hedging strategies. For these investors, the instability of hedge ratios and the possibility of heightened correlations during crises negate potential gains [26]. In contrast, risk-neutral or moderately risk-averse investors may extract short-term benefits in tranquil regimes, where crypto's idiosyncratic behavior diversifies return streams.

The regime-switching framework highlights that welfare gains vary significantly by market environment. In tranquil states, portfolios with small allocations of Bitcoin or Ethereum produce measurable gains in certainty-equivalent returns, particularly when crypto volatility is less synchronized with equities. However, in turbulent states, utility losses are observed, as correlations spike and volatility dominates [27].

Table 2 summarizes the hedging effectiveness results across different investor risk profiles. The results clearly demonstrate that the utility of crypto hedging is conditional not only on volatility regimes but also on investor heterogeneity. For risk-seeking investors, crypto can act as a speculative hedge with asymmetric upside potential, while for conservative investors it undermines welfare.

Table 2: Hedging Effectiveness Results Across Different Investor Risk Profiles

Investor Profile	Tranquil Regimes	Turbulent Regimes
Risk-Seeking	Crypto provides speculative hedge benefits with asymmetric upside potential.	Benefits diminish; exposure amplifies downside risks, but some retain speculative appeal.
Moderately Risk-Averse	Modest utility gains; variance reduction achievable with small crypto allocations.	Utility decreases; hedging effectiveness eroded as correlations with equities increase.
Highly Risk-Averse	Limited or no welfare gains; volatility concerns outweigh potential diversification.	Significant utility losses; crypto undermines portfolio stability compared to gold or bonds.

These findings emphasize the necessity of tailoring hedging strategies to investor-specific objectives. They also highlight the broader policy implication that narratives positioning crypto as universally beneficial are misleading. Utility-based approaches reveal crypto's uneven capacity to deliver welfare gains, providing a nuanced framework for both academics and practitioners [29].

5.4 Limits of Hedging with Crypto Assets

Despite some marginal benefits, several structural factors limit the feasibility of hedging with crypto assets. Liquidity remains a significant constraint. Although market depth has improved in recent years, crypto trading volumes are still prone to fragmentation across exchanges and to sudden liquidity dry-ups during crises [23]. These limitations undermine the reliability of executing hedge positions precisely when volatility spikes.

Transaction costs present another barrier. Bid-ask spreads widen significantly during stress events, while frequent rebalancing under regime-switching strategies increases cumulative costs. Such frictions erode the net benefits of hedging strategies, especially for institutional portfolios with stringent cost thresholds [25].

Short-selling restrictions add complexity. Not all exchanges or jurisdictions permit efficient shorting of crypto assets, which limits the ability to construct effective hedges. Even where derivatives markets exist, their regulation is inconsistent, exposing investors to counterparty risk and operational uncertainty [28].

Regulatory uncertainty compounds these issues. Ongoing debates over the classification of crypto as securities or commodities affect market accessibility and risk management frameworks. Sudden regulatory interventions such as trading bans, taxation changes, or restrictions on stablecoins can abruptly alter hedging opportunities, increasing unpredictability for institutional actors [24].

Finally, the inherently speculative character of crypto undermines its appeal as a hedge. Unlike Treasuries or gold, crypto lacks intrinsic value anchors and is driven by sentiment, adoption narratives, and technological cycles [27]. This volatility-expectations mismatch limits its effectiveness in risk management.

In conclusion, while hedging with Bitcoin and Ethereum provides limited tactical benefits, structural constraints, transaction costs, and regulatory uncertainty restrict their strategic role. This reinforces the need for cautious, state-dependent integration of crypto into portfolio hedging frameworks rather than blanket adoption [29].

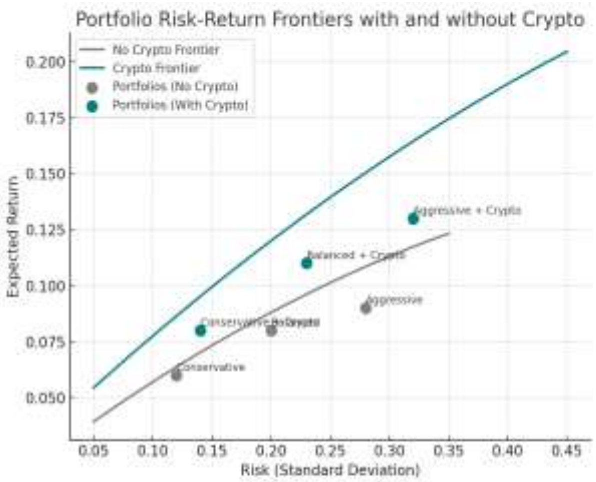

Figure 3: Portfolio Risk-Return Frontiers

6. POLICY, REGULATORY, AND SYSTEMIC RISK PERSPECTIVES

6.1 Implications for Regulators

The rapid institutionalization of crypto assets poses mounting challenges for regulators tasked with maintaining financial stability. A central concern is market stability, as crypto prices exhibit extreme volatility that can transmit uncertainty into broader asset classes when institutional portfolios adopt digital assets [27]. Unlike traditional markets, crypto lacks a centralized clearinghouse mechanism, which magnifies counterparty and operational risks during stress periods. This volatility is not merely speculative noise; it has the potential to destabilize investor sentiment across asset classes, creating feedback loops into traditional equities and commodities [28].

Regulators are therefore increasingly focused on reporting requirements for institutional crypto holdings. Clear disclosure rules are essential for ensuring transparency around exposures, leverage, and derivative positions involving crypto [29]. However, cross-jurisdictional inconsistencies remain, as some regulators treat crypto as commodities while others classify them as securities. Such regulatory fragmentation complicates enforcement and risks regulatory arbitrage [30].

Moreover, prudential frameworks such as capital adequacy rules must adapt to incorporate crypto exposures within banks and asset managers. Without harmonized standards, institutional adoption may outpace the regulatory safeguards necessary to contain systemic risk. Hence, regulators face a delicate balance between fostering innovation and protecting market integrity [31].

6.2 Systemic Risk Considerations

Beyond regulatory oversight, crypto's integration into traditional markets raises systemic risk concerns. One channel arises from increased correlations between crypto assets and mainstream portfolios during crises, which diminishes diversification benefits and introduces new contagion pathways [32]. This co-movement threatens to amplify shocks rather than dampen them, contradicting early narratives of crypto as an uncorrelated asset class.

Spillovers to banking and payment systems represent another dimension of systemic risk. The growing use of stablecoins in payment infrastructure ties the health of crypto markets directly to liquidity conditions in traditional finance [33]. Stress events in stablecoin ecosystems such as depegging or redemption runs could transmit disruptions to banks and money markets. Additionally, institutional funds with significant crypto exposure may propagate volatility through redemptions or forced deleveraging, reinforcing procyclicality.

The risk of operational interdependence is also notable. Custodians, exchanges, and decentralized platforms increasingly interact with traditional clearing systems, making failures in one domain capable of cascading into the other

[34]. As crypto-financial linkages deepen, regulators and central banks must develop stress-testing frameworks that account for multi-market interactions, rather than analyzing each domain in isolation.

Ultimately, systemic resilience depends on the capacity to anticipate and contain these spillover effects before they destabilize financial stability [27].

6.3 Investor Protection and Market Transparency

Investor protection remains one of the most pressing challenges in the context of crypto-financial integration. Custody risks are central, as the decentralized nature of digital assets creates vulnerabilities in safeguarding private keys and managing recovery protocols [35]. Unlike traditional custodianship arrangements, responsibility in crypto often rests with fragmented entities, leaving investors exposed to theft, hacking, or mismanagement of digital assets [28].

Disclosure gaps on decentralized exchanges (DEXs) exacerbate these vulnerabilities. Unlike regulated venues, DEXs often lack standardized reporting on liquidity, order book depth, or counterparty exposure, limiting transparency for retail and institutional participants alike [29]. This opacity impairs informed decision-making and increases susceptibility to manipulation, particularly in thinly traded tokens [32].

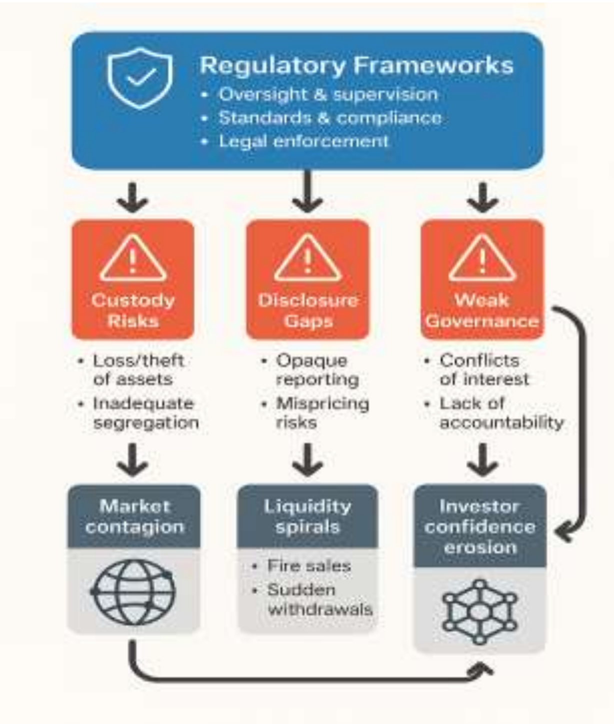

Figure 4 illustrates regulatory frameworks and systemic risk pathways in crypto-financial integration, highlighting how custody risks, disclosure gaps, and weak governance structures connect to broader systemic vulnerabilities. Such pathways demonstrate that investor protection issues are not merely individual concerns but feed into systemic fragility when left unaddressed.

Policy solutions include mandating robust custody standards, requiring exchanges to adopt transparent disclosure practices, and harmonizing investor protection rules across jurisdictions [30]. Only through these measures can confidence in crypto markets be enhanced while minimizing systemic vulnerabilities tied to transparency deficits [33].

7. SYNTHESIS AND RESEARCH IMPLICATIONS

7.1 Contributions to Literature and Finance Practice

This study contributes to both academic literature and finance practice by advancing the use of regime-switching volatility models in examining crypto assets. Traditional linear correlation approaches often misrepresent the highly non-linear dynamics of digital assets, particularly under stress conditions [34]. By adopting frameworks such as Markov-switching GARCH, this article provides richer insights into volatility clustering, contagion pathways, and hedge effectiveness.

From a theoretical perspective, these models extend asset allocation literature by situating crypto alongside established hedge assets like gold and Treasuries, but with state-dependent properties [35]. The evidence shows that crypto's hedge role is regime-contingent rather than universal, challenging narratives that portray digital assets as robust safe-havens [36].

For finance practice, the findings refine risk management strategies by showing how investor welfare outcomes vary under tranquil and turbulent conditions. Portfolio managers thus gain tools for state-sensitive allocation, while regulators receive evidence on systemic vulnerabilities that emerge from crypto's growing institutionalization [37].

7.2 Future Research Directions

Despite these contributions, several avenues for future research remain. First, expanding analysis to include NFTs and DeFi assets could shed light on new forms of digital exposure, particularly as decentralized finance platforms increasingly influence liquidity flows and investor behavior [38]. Such expansion would also address how structural differences between fungible and non-fungible assets reshape volatility spillovers.

Second, investigating long-horizon hedging under evolving monetary policy regimes offers fertile ground. Current findings focus on short- to medium-term volatility, but as central banks navigate transitions between tightening and easing cycles, crypto's interaction with inflation expectations and risk premia deserves greater scrutiny [39].

Finally, incorporating machine learning and hybrid econometric methods may yield improved predictive capacity for regime transitions and contagion episodes [40]. By addressing these frontiers, future work can extend the understanding of crypto's dynamic role in global portfolios and refine policy frameworks governing digital financial assets.

8. CONCLUSION

This article has examined the dynamic interactions between crypto assets and traditional portfolios through the lens of regime-switching volatility models, contagion theory, and hedging effectiveness. The analysis demonstrates that while Bitcoin and Ethereum exhibit unique diversification properties, their roles are far from uniform across market environments. In tranquil periods, both assets provide modest benefits in terms of variance reduction and utility-based gains, complementing traditional hedges and expanding investor choices. However, during turbulent regimes, these benefits vanish or reverse, as correlations with equities surge and volatility spillovers compromise stability.

A key finding is the importance of state-dependent modeling. Traditional static approaches obscure the reality that crypto assets are highly regime-sensitive, with hedge ratios, variance reduction, and welfare implications shifting dramatically across tranquil and crisis periods. This reinforces the case for regime-switching frameworks as essential tools for evaluating the portfolio role of digital assets. For institutional investors, the implication is clear: hedging strategies must be adaptive, dynamic, and sensitive to regime identification rather than relying on static correlations.

From a broader perspective, crypto assets should be understood as conditional diversifiers rather than universal safe-havens. Their integration into portfolios requires recognition of structural limits, including liquidity risks, transaction costs, and regulatory uncertainties. While they may deliver opportunistic benefits under specific market conditions, they cannot replace the reliability of traditional hedges such as government bonds or gold. Ultimately, the findings invite both academics and practitioners to adopt a cautious but forward-looking view. Crypto assets represent an evolving asset class with potential, but their role in risk management will remain conditional and context-dependent. By embracing regime-sensitive strategies, investors can capture limited benefits while mitigating vulnerabilities, ensuring that digital assets complement rather than destabilize portfolio construction.

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