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The Dynamic Correlation and Hedging Effectiveness of Bitcoin against Brent Crude Oil under the Influence of Global Economic Policy Uncertainty

Abstract

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List of Abbreviations

AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
BRT	Brent Crude Oil (will be addressed as Brent oil in main text)
BTC	Bitcoin
DCC-GARCH	Dynamic Conditional Correlation - Generalized Autoregressive Conditional Heteroskedasticity
DCC-MIDAS	Dynamic Conditional Correlation - Mixed Data Sampling
ETF	Exchange-Traded Fund
GEPU	Global Economic Policy Uncertainty
MPT	Modern Portfolio Theory
OPEC	Organization of the Petroleum Exporting Countries
USD	US Dollar

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1. Introduction

1.1. Background

In conditions characterized by economic volatility, investors are naturally inclined to pursue security and stability, such as looking for a foothold in turbulent waters. Such underlying motivation is at the root of increased attention to digital financial instruments, such as Bitcoin, as a hedge against traditional assets like equities, bonds, and commodities (Das et al., 2019; Bedowska-Sojka and Kliber, 2022; Ren et al., 2022; Foroutan and Lahmiri, 2024). In its initial stages, Bitcoin was distinguished by its decentralized structure, finite supply, and blockchain-based technology, which led to its position as an alternative to fiat currencies (Yermack, 2015) and a possible hedge against inflationary pressures and currency depreciation (Rodríguez and Colombo, 2024). Empirical studies initially highlighted Bitcoin’s low or even negative correlations with traditional assets, reinforcing its potential function as a diversifier, safe-haven, or hedging asset during financial distress (Bouri et al., 2017; Klein et al., 2018).

Then, Bitcoin’s role in portfolio construction has evolved significantly, particularly with growing institutional adoption and changes in market behaviors. A 2024 survey conducted by PwC reported that, thanks to regulatory advancements and the introduction of cryptocurrency ETFs, 47% of traditional hedge funds now invest in digital assets, up from 29% in 2023, revealing accelerating integration of Bitcoin into mainstream financial markets, and contributing to an increase in its correlation with traditional assets (Bouri et al., 2021). According to FTSE Russell (2024), Bitcoin’s correlation with equities and high-yield credit markets rose from near zero in the pre-COVID era to 0.5–0.6 over the period 2020–2024, indicating that post-COVID, Bitcoin is more responsive to broader market conditions, diminishing its historical ability to act as a standalone diversifier in portfolios.

Several reasons explain this shift in Bitcoin's correlation with traditional assets’ patterns. Growing participation of retail and institutional investors has linked Bitcoin's price movements more closely to macroeconomic trends, liquidity cycles, and global financial conditions (Kinateder and Papavassiliou, 2019). Bitcoin was largely retail-driven during its early years, and price movements had little relation to traditional financial assets. However, institutional adoption has increased Bitcoin's exposure to systemic financial risks, making it behave more and more like a risky traditional asset (Bouri et al., 2017; Stensås et al., 2019). Additionally, speculative trading, security weaknesses, and fraud within the blockchain ecosystem have undermined investor confidence in Bitcoin's intrinsic value, making it even more volatile and risky (Corbet et al., 2018a; Demir et al., 2020). These trends indicate that Bitcoin has evolved from a niche, independent asset into one that increasingly mimics the price dynamics of risky traditional financial instruments. Although once considered a potential hedge against financial instability, its evolving correlation with traditional markets raises doubts about whether it can still serve this purpose, particularly during economic stress.

While extensive literature has examined the hedging properties of Bitcoin within the equity and bond markets, its relationship with traditional commodities, particularly Brent oil, remains largely unexplored. Brent oil is a strategic global commodity whose price reflects geopolitical risks, supply-demand deficiencies, and inflationary pressures and hence is considerably more volatile and uncertain than equities or bonds (Kilian, 2005; Hamilton, 2009). Contrary to financial assets, oil prices react violently towards wars, Organization of the Petroleum Exporting Countries (OPEC) policies, and macroeconomic shocks, hence offering new hedging challenges (Baumeister and Kilian, 2016). Traditional hedges like gold and Treasury bonds offer unstable protection, raising the need for alternative assets (Shahzad et al., 2019). If Bitcoin's correlation with oil remains negatively low, it could be a new hedging tool, but its effectiveness remains uncertain across different market conditions, so more research is needed.

A historical examination of Bitcoin and Brent oil price behavior during two major market stress periods, 2020 and 2022, shows stark differences, suggesting that the hedging effectiveness of Bitcoin might be dependent on broader economic conditions and specific nature of crises.

In 2020, in the initial months of the COVID-19 pandemic, global markets experienced historic disruptions, as lockdowns triggered a collapse in demand and severe supply chain disruptions. Brent oil prices turned negative for the first time in history, to –$37 per barrel in April, due to storage constraints and evaporating consumption (Narayan, 2020; Kilian and Zhou, 2022). Bitcoin itself, though, despite a sudden drop in March 2020 of nearly 50% over a day, bounced back strongly, aided by institutional demand, accommodative monetary policies, and shifting investor sentiment (Goodell and Goutte, 2021; Cheema et al., 2022). Unlike oil, which suffered from a physical storage crisis, Bitcoin's supply constraints remained unaffected, allowing it to recover quickly and behave more like a speculative financial asset rather than a commodity-bound hedge.

In contrast, the 2022 market crisis was supply-driven, marked by soaring inflation, post-pandemic supply chain disruptions, and geopolitical instability following the Russia-Ukraine war. These factors fueled a surge in Brent oil prices to $139 per barrel in March, reflecting severe energy shortage and macroeconomic uncertainty (IEA, 2022; Kilian and Zhou, 2022). However, Bitcoin did not show the same resilience as in 2020. Opening 2022 at approximately $46,000, Bitcoin initially rose to $47,500 in March but then fell to roughly $20,000 by June, coinciding with Federal Reserve interest rate hikes, tightening liquidity, and wide risk-asset selloffs (Choi and Shin, 2022). While Bitcoin's inelastic supply theoretically insulates it from inflation, empirical evidence shows that its response to inflationary pressure is inconsistent, serving as a risk-on speculative asset or a possible hedge depending on macroeconomic conditions.

Contrastive market reactions are indicative of weak correlation between Bitcoin and Brent oil, and imply that the hedging characteristic of Bitcoin is regime dependent. While Bitcoin might serve as a hedge in supply-driven crises such as the COVID-19 pandemic, it does not offer protection in supply-driven shocks, where inflation, monetary policy, and liquidity constraints drive asset performance (Shahzad et al., 2019; Wang et al., 2022). These findings underscore the contingent nature of Bitcoin's hedging effectiveness, posing questions on its reliability in hedging oil price volatility under various macroeconomic conditions.

Shifting the discussion toward academic research on Bitcoin's hedging roles reveals a mixed picture, with scholars arriving at differing conclusions. Some scholars believe that Bitcoin, along with digital assets in general, has the potential to serve as a hedge against traditional assets such as Brent oil, during economic downturns. Studies have shown that Bitcoin often has a low or even negative correlation with traditional financial markets, especially during times of crisis. For example, Baur, Hong, and Lee (2018) found that Bitcoin's returns showed little to no correlation with traditional equity markets during major financial shocks, suggesting its potential as a "safe haven" during financial instability. Likewise, Shahzad et al. (2019), who examined Bitcoin's safe-haven characteristics across different markets, and Bouri et al. (2017), who analyzed Bitcoin's low correlation with other assets, both concluded that Bitcoin remained uncorrelated with stock markets and commodities, even during crises. This supports the premise that Bitcoin may function as an effective alternative hedge against the volatility of conventional asset prices. This scenario presents the possibility of Bitcoin assisting in portfolio diversification, specifically for investors who want to minimize their risk exposure due to the volatility of conventional commodities like oil.

While, conversely, other counterarguments from researchers highlighting Bitcoin's excessive volatility and speculative nature, which may invalidate its effectiveness as a hedge (Corbet et al., 2018a; Stensås et al., 2019). One such is Bitcoin's susceptibility to market sentiment and speculative trading, which causes instantaneous price fluctuations. For example, Kjærland et al. (2018), Ullah et al. (2024) found that the price volatility of Bitcoin was more volatile than most commodities, including oil, making it an unreliable hedge and unstable store of value. Their study suggests that, unlike commodities like Brent oil, which are largely supply- and demand-driven as well as political events, Bitcoin's price is very speculative, being subject to regulatory statements and investor sentiment. Cheah and Fry (2015), Ahsan et al. (2024) further note that Bitcoin's price is heavily impacted by speculative investment, as reflected in the 2022 price crash, making its positioning as a safe-haven asset more challenging during turbulent markets.

Furthermore, there are also significant perspectives believing that the ability of Bitcoin to hedge oil price volatility is not linear, but varies among different market conditions, and is affected by other determinative factors such as research methodologies, and time horizons of examination. Wang et al. (2022) examined the correlation between Bitcoin and Brent crude oil prices from 2018 to 2022 and reported contradictory results. During periods of heightened market stress, such as the onset of the COVID-19 pandemic and the 2022 geopolitical crisis, Bitcoin exhibited a stronger correlation with oil, suggesting lower diversification benefits and a greater role as a direct exposure hedge under extreme market conditions. However, during periods of market stability, Bitcoin's hedging properties against oil price volatility changed significantly, as its price became predominantly influenced by speculative trading rather than fundamental economic factors. Similarly, Al-Yahyaee et al. (2020) also asserted that the hedging function of Bitcoin is contingent upon the broader market situation and that Bitcoin would behave like a speculative asset during periods of low market volatility. Such findings leave Bitcoin's actual application as a stable long-run hedge remains questionable.

Based on this, the current research will investigate how the dynamics between Bitcoin and Brent oil evolve in different global economic conditions from 2016 to 2024, especially under the impact of Global Economic Policy Uncertainty (GEPU) and structural breaks, from which the hedging effectiveness of Bitcoin towards Brent oil can also be assessed. The GEPU Index is a GDP-weighted average of national Economic Policy Uncertainty (EPU) indices for 21 countries, constructed by Davis (2016), including major economies such as the US, China, and the EU, serves as a critical measure of policy-related uncertainty. By quantifying the frequency of news articles containing terms related to the economy, uncertainty, and policy, the GEPU Index provides valuable insights into how economic uncertainty affects Bitcoin's hedging effectiveness in different market conditions.

1.2. Problem Statement

1.2.1. Lack of empirical research on Bitcoin as a hedge for oil price volatility

Despite the popularity of Bitcoin as an asset class growing even today, its role as a hedge against Brent oil price volatility remains largely unknown. The literature on Bitcoin hedging properties has primarily addressed its correlation with equity markets and other financial assets rather than its interaction with traditional commodities like oil (Bouri et al., 2017, Baur et al., 2018; Shahzad et al., 2019; Stensås et al., 2019; Ullah et al. 2024). Still, the relationship between oil and Bitcoin is worth examining further, given that oil prices are determined by a different set of factors, geopolitical tensions, supply-demand shocks, and central bank policies—that completely differ from the drivers of equity market (Ji et al., 2019; Liu et al., 2023). Considering the oil market's inherent volatility and geopolitical sensitivity, Bitcoin’s potential to serve as a hedge herein is a critical but unexplored topic.

Some evidence from studies suggests Bitcoin may exhibit hedging characteristics against oil price volatility, especially in times of crisis (Corbet et al., 2018b; Stensås et al., 2019). There are, however, few empirical investigations of how Bitcoin may effectively hedge Brent oil price fluctuations. Specifically, there is a lack of rigorous testing on whether Bitcoin can function as a hedge through direct exposure (negative correlation, offsetting oil price fluctuations) or portfolio diversification (close to zero correlation, reducing aggregate risk exposure within a diversified asset portfolio) for portfolio construction strategies in real world (Al-Yahyaee et al., 2020; Wang et al., 2022).

This study attempts to fill this gap by empirically evaluating Bitcoin’s performance as a hedge against Brent oil prices through direct exposure hedging mechanism. By doing so, the study offers new insights into Bitcoin’s possible application in energy market risk management, extending beyond its traditional classification as a speculative digital asset.

1.2.2. The role of GEPU in Bitcoin’s hedging behavior

One of the significant limitations of existing research is that they do not take account of broader macroeconomic conditions, such as applying measurements like GEPU when evaluating Bitcoin's hedging effectiveness. Most studies analyze Bitcoin behavior while overlooking the effect of political uncertainty events, financial distress, and policy uncertainty changes on its price and hedging capabilities (Bouri et al., 2017; Shahzad et al., 2019; Demir et al., 2020). Bitcoin, often compared to gold as a potential store of value, may possess heterogeneous hedging characteristics in various global economic settings (Klein et al., 2018; Ji et al., 2019). Empirical findings indicate that Bitcoin does not always function as a safe haven during periods of heightened macroeconomic uncertainty. Its response to unanticipated events varies based on market liquidity, investor sentiment, and monetary policies (Corbet et al., 2018a; Kinateder and Papavassiliou, 2022). For instance, during the COVID-19 pandemic, Bitcoin initially displayed high volatility and strong correlation with risk assets, then later decoupled and exhibited partial safe-haven properties (Goodell and Goutte, 2020).

Similarly, geopolitical tensions, namely the Russia-Ukraine war, have demonstrated that Bitcoin's reaction to crises is dynamic and dependent on the nature of the macroeconomic shock. While some studies argue that Bitcoin absorbs geopolitical risk under specific conditions (Wang et al., 2022), there is research which establishes its character as a speculative asset leaves it susceptible to liquidity contractions during crises (Demir et al., 2020; Kinateder et al., 2021).

With such complexities, it is necessary to incorporate GEPU as a controlling variable in assessing Bitcoin's ability to hedge oil price risk. By incorporating GEPU in examination, this study provides a more robust and comparative assessment of Bitcoin's hedging behavior under several different global economic environments, with implications on how it is being reshaped as a tool for risk management beyond simple asset correlations.

1.2.3. Advancing methodology by developing DCC-MIDAS-X model and structural break

Traditional DCC-GARCH models have been widely applied to estimate correlations of financial assets. However, these models do not effectively capture both short-term market volatility and long-term macroeconomic influences. To address this shortcoming, this study employs the DCC-MIDAS-X model that integrates Dynamic Conditional Correlation (DCC) with Mixed Data Sampling (MIDAS), and low-frequency variables (X), for:

- Simultaneous analysis of high-frequency asset prices (Bitcoin and Brent oil) and lower-frequency macroeconomic indicators (GEPU).
- More precise estimation of time-varying correlations between Bitcoin and Brent oil.

In addition, due to the abrupt shifts in global financial conditions, such as the COVID-19 oil price shock and ongoing geopolitical tensions, this study also includes structural breaks into the DCC-MIDAS-X model. This enhancement accounts for abrupt regime changes, better capturing how external shocks, such as economic crises or sudden policy changes, influence Bitcoin's role as an oil price hedge. Finally, covering a unique and extensive study period from 2016 to 2024 is crucial when observing Bitcoin's performance across several economic cycles and major global events. Such a broad time frame warrants a clearer understanding of the role that Bitcoin plays as a hedge during stability and crisis, as well as how it conducts commodity market risk under different scenarios.

Overall, this research fills significant gaps in the existing literature by evaluating Bitcoin's role as a hedge for Brent crude oil, addressing the lack of commodity market-focused studies on its hedging effectiveness. It further incorporates GEPU to assess how macroeconomic uncertainty influences Bitcoin's risk-mitigation potential. Methodologically, the advanced DCC-MIDAS-X model integrates short-term volatility with long-term macroeconomic effects, offering a more comprehensive analysis. It also accounts for structural breaks to capture abrupt shifts in global financial conditions, ensuring a more accurate representation of Bitcoin's dynamic hedging behavior.

1.3. Research Objectives

This study aims to empirically examine the effectiveness of Bitcoin as a hedge against Brent oil price volatility, either through direct exposure hedging or portfolio diversification. It also investigates the effect of GEPU on Bitcoin's hedging capabilities, acknowledging the role of macroeconomic shocks. Methodologically, the research uses the DCC-MIDAS-X model, combining high- and low-frequency data with provision for structural breaks to be able to capture abrupt shifts in global financial conditions. From an observation of Bitcoin's hedging behavior in 2016–2024, the research provides a cautious, evidence-driven explanation of its application in commodity risk management across various economic states.

1.4. Research Questions

The study presents three research questions (RQ) with corresponding alternative hypotheses (H1) for statistical tests formulated. These RQs consider various structural breaks of macroeconomic indicators potentially caused by notable events such as the US-China trade war, COVID-19 pandemic, the Russia-Ukraine war, and monetary policy shifts.

RQ1: How does the dynamic **volatility** between Bitcoin and Brent oil evolve, particularly under different levels of GEPU (2016 – 2024), across different macroeconomic regimes set by GEPU structural break?

H1: The dynamic volatility between Bitcoin and Brent oil is time-varying and influenced by GEPU.

RQ2: How does the dynamic **correlation** between Bitcoin and Brent oil evolve, particularly under different levels of GEPU (2016 – 2024), across different macroeconomic regimes set by GEPU structural break?

H2: The dynamic correlation between Bitcoin and crude oil is time-varying and influenced by GEPU.

RQ3: How **effective** is Bitcoin as a hedge against Brent oil price fluctuations considering GEPU and how does this hedging effectiveness change when considering different macroeconomic regimes set by GEPU structural break?

H3: Bitcoin serves as an effective hedge against Brent oil price fluctuations.

1.5. Thesis Outline

This chapter provided a concise description of the problem as indicated, the purpose of the study and provided hypotheses concerning the research questions. The following four chapters: Chapter 2 presents a comprehensive review of the literature. Chapter 3 illustrates the method to analyze the relationships between the variables. Chapter 4 presents empirical findings and discussion. Finally, Chapter 5 gives the conclusion of the study.

2. Literature Review

2.1. Theoretical Fundamentals Backing Hedging Characteristics of Assets

Hedging strategies are crucial to mitigating risk in investment portfolios, particularly where assets are volatile and uncertain, as with traditional commodities like Brent oil (Dyhrberg 2016; Bouri et al., 2017). Hedging involves taking a position in an asset that will fluctuate inversely with another asset, therefore minimizing potential losses. This is particularly crucial during GEPU times when markets are vulnerable to dynamic changes, geopolitical turmoil, or supply chain interruptions. The basic motivation for hedging is to reduce risk exposure by employing financial products that are negatively correlated or of lower risk compared to the underlying product. They need to be distinguished with diversification strategies, which on the other hand, try to reduce risk by incorporating assets that behave differently in various market conditions. For this purpose, cryptocurrencies like Bitcoin have been considered as hedging products against traditional commodities like oil. Bitcoin, as a decentralized, finite supply cryptocurrency, independent of the traditional fiat currencies, has the potential to be a store of value substitute in times of economic uncertainty. The effectiveness of Bitcoin as an oil price volatility hedge is however complex and extremely market-sensitive, driven by investor sentiment, and susceptible to economic shock (Conlon et al., 2024).

One of the key factors in selecting a suitable asset with which to hedge is how closely correlated it is with the asset being hedged, and its volatility pattern. Researchers have discovered that the more negative correlation an asset has with the asset being hedged, the more effective it will be in terms of diminishing risk (Markovitz, 1952). Empirical evidence has shown that Bitcoin can potentially offer diversification value to portfolios holding traditional assets like equities and commodities, especially during periods of financial stress. According to Baur et al. (2018), the safe-haven features of Bitcoin are more pronounced in periods of financial stress because price movements in cryptocurrency tend to deviate from the overall financial market.

The theoretical foundation for undertaking such hedging is taken from modern theories of finance to explain the workings of risk management. One of the cornerstones of these theories is that of Optimal Hedging, which examines the interaction between the hedging asset and the asset to be hedged and prescribes the ratio of each to maintain total risk to a minimum. John Maynard Keynes, Robert Merton, and William Sharpe developed this theory with the hypothesis that hedging asset, when optimally allocated, can adequately counter risk if combined with hedged, especially under conditions of high market uncertainty. Besides, Dynamic Hedging with Time-Varying Correlations theory, formulated by Robert Merton and Edward O. Thorp, calls for the need to adjust the hedge ratio over a period of time in response to time-varying market conditions. As Bitcoin and Brent oil have varying levels of correlation with different global economic conditions (Salisu et al., 2023), the dynamicity of the assets requires continuous re-investigation of the hedge strategy to ascertain its effectiveness. This theory highlights the importance of hedging flexibility, particularly for those assets whose price fluctuations are volatile and unpredictable, like Bitcoin and oil.

Several academic works provide empirical support in testing the effectiveness of Bitcoin as an oil hedge. Dutta et al. (2020), Ren et al. (2022) and Shaik et al. (2024) found that Bitcoin was poorly correlated with Brent oil during market stress events, such as the COVID-19 pandemic and the Russia-Ukraine war geopolitical risk. Their study also identified, however, that the speculative nature of Bitcoin limited its hedging potential under periods of stability in the markets since its price is subject to variation irrespective of the forces motivating the price of oil. Such findings highlight the contingent hedging ability of Bitcoin wherein its desirability as a risk mitigation is highly vulnerable to prevailing market conditions and volatility of both instruments. These empirical analyses underscore the difficulty of using Bitcoin as a hedge, whose behavior is subject to different economic regimes and periods of market turmoil.

In conclusion, the theoretical and empirical underpinnings of hedging strategies, particularly hedging Bitcoin against Brent oil, are intricate. Although theory indicates that Bitcoin might provide diversification advantages during times of high market volatility, its speculative character and volatility make it ineffective as a long-term hedge. Therefore, through the integration of such modern finance theories as MPT, Optimal Hedging, and Dynamic Hedging, we will know better when Bitcoin can hedge oil price volatility effectively. This research will contribute to the understanding of Bitcoin's hedging capability and its relevance to traditional portfolio risk management.

2.2. Factors Affecting the Dynamic Correlation between Bitcoin and Brent Oil: The Pivotal Role of GEPU

The dynamic correlation between Brent oil and Bitcoin is shaped by macroeconomic, geopolitical, and market factors. Their price movements respond differently to global conditions, creating a complex relationship. Investors seeking to hedge oil price fluctuations with Bitcoin need to understand these correlation drivers.

GEPU is the focal point for the dynamic correlation between Bitcoin and Brent oil (Fang et al., 2018; Hazgui et al., 2021). Monetary and fiscal policy changes, along with economic crises, increase market volatility and strengthen the correlation between virtual assets like Bitcoin and traditional commodities like oil (Baur et al., 2018; Doumenis et al., 2021). Baur and colleagues have examined the hedges offered by Bitcoin during times of high uncertainty, noting that Bitcoin imitates commodities like gold in times of economic distress, especially when inflation or devaluation fears arise. The COVID-19 pandemic presents an instructive example: as global economies went into lockdown mode and stimulus packages were rolled out, the price of Bitcoin initially dropped but subsequently rebounded as investors switched to other stores of value whilst Brent oil prices plummeted due to lower demand and oversupply. Wang et al. (2024) further support this finding, reporting that the reaction of Bitcoin to GEPU is like that of traditional commodities, but the price volatility tends to amplify the effect, resulting in episodes of both positive and negative correlation with oil. This implies that both Bitcoin and Brent oil will react together during times of systemic risk or significant economic shocks as investors move to safer or alternative assets to protect themselves from alleged risks to the global financial system.

The geopolitical environment is an important driver of the relationship between Bitcoin and Brent oil. Oil is geopolitically sensitive due to its direct link to global supply chains and political forces that constitute oil-producing nations. The Russian-Ukrainian war in 2022, for instance, led to a sharp rise in Brent oil prices as sanctions on Russian oil disrupted global supply. But Bitcoin responded more subtly: its volatility was influenced by market sentiment rather than supply-demand dynamics, as it is a speculative asset. As Cheah & Fry (2015) argue, Bitcoin would behave like a speculative asset during periods of geopolitical tensions, responding more to investor sentiment and risk appetite and less to tracking oil's supply-demand dynamics. This break in correlation shows that while both the assets are affected by geopolitical risks, how strongly they correlate can be a factor of the nature of the crisis and the sentiment of investors. In the Russia-Ukraine war, Bitcoin's correlation with oil temporarily disintegrated because Bitcoin was more driven by general market risks and less by the specific geopolitical forces of oil.

Macroeconomic indicators, more precisely inflation and interest rates, also have a notable influence on the dynamic correlation between Bitcoin and Brent oil. Bitcoin tends to be viewed as a hedge against inflation (Smales, 2023; Fernandis, 2024; Rodriguez and Colombo, 2024).

Conversely, Brent oil prices are heavily correlated with global economic activity (Lescaroux and Mignon, 2008; Baffes et al., 2015; Vochozka et al., 2020; Ahmed et al., 2023): as economic growth progresses and demand for oil builds, the prices increase, and during recessions, demand for oil drops and prices decline. Therefore, the correlation between Bitcoin and Brent oil becomes more positively correlated in inflationary stress. Selmi et al. (2018) noted that the relationship between Bitcoin and oil strengthens during inflationary times, as both react to rising commodity prices and expected future money tightening. On the other hand, when interest rates rise—such as the US Federal Reserve actions in 2022 to combat inflation—oil prices can be pushed by diminished world growth and reduced demand, while the price of Bitcoin can reflect changes in sentiment among investors, meaning that volatility tends to be amplified. This two-way influence demonstrates how inflationary and monetary policy factors make Bitcoin and oil more correlated but also highlight different mechanisms underlying their price dynamics.

From an academic financial theoretical perspective, Financial Network Theory explains the market interconnectedness and contagion effect of financial shocks, which can explain the shift in correlation between Bitcoin and Brent oil. Bitcoin and other altcoins are becoming more integrated into mainstream finance, which increasingly drives their price action with macro market forces. Allen and Gale (2000) argue that money asset markets are interconnected so that shocks in one asset class can spill over into other asset classes. As Bitcoin gains acceptance into institutional portfolios, its price action is now more susceptible to the same macro drivers that affect traditional assets like oil. During financial contagion, such as the 2022 global sell-off, Bitcoin and Brent oil were more correlated since both assets were driven by the shifts in global risk sentiment (Wang et al., 2024). This finding emphasizes the contagion effect across the financial markets, whereby the cryptocurrencies, once perceived as independent of the traditional markets, now react to the same macroeconomic shocks and systemic risks that influence commodities like oil (Salisu et al., 2023; Foroutan and Lahmiri, 2024).

Furthermore, Structural Break Theory, which focuses on regime change and moving market forces, is also critical in understanding correlation changes between Bitcoin and oil. A structural break occurs when there is a big economic or geopolitical event that alters the relationship between assets (Xiong et al., 2024). For example, the Russia-Ukraine conflict generated a structural discontinuity in the oil market that led to a precipitous supply shock, thereby pushing oil prices to historic highs. Bitcoin's response, nonetheless, was subject to overall market anxiety, like the specter of worldwide economic stagnation and heightened inflation. The theory argues that during regime change periods, the relationship between Bitcoin and oil can either strengthen or weaken, depending on the performance of each asset in reaction to the new economic regime (Pindyck and Rotemberg, 1990). During the 2022 geopolitical crisis, the oil supply market suffered a shock, whereas the price of Bitcoin responded to broad financial concerns, resulting in their correlation to fluctuate.

In summary, the dynamic relationship between Bitcoin and Brent oil is shaped by a multi-dimensional array of determinants that vary from international economic shocks and geopolitical incidents to macroeconomic developments, sentiment, and increasing incorporation of Bitcoin into mainstream financial markets. Examples of such theories include Global Economic Shocks and Systemic Risk, Financial Network Theory, and Structural Break Theory, which are insightful paradigms on the way these variables interact and influence the relationship between Bitcoin and oil. Empirical research by Baur and Dimpfl (2021) and Wang et al. (2024) yields robust evidence that the dynamic and reversible correlation between oil and Bitcoin is susceptible to fluctuation with macroeconomic and geopolitical shocks. All these findings confirm that investors need to carefully monitor the drivers of this dynamic relationship, particularly during times of global economic strain or systemic risk.

3. Data and Methodology

3.1. Data

The data used in this study comprises daily and monthly data expressed in USD, spanning from January 1, 2016, to September 30, 2024. The daily Bitcoin prices are obtained from CoinMarketCap, while the daily Brent oil prices are sourced from Investing.com. The monthly GEPU indices are retrieved from PolicyUncertainty.com. The empirical analysis employs the log-return series for both Bitcoin and Brent oil, with the GEPU indices retained in its raw form, as it is already stationary as tested by the augmented Dickey-Fuller (ADF) test. All collected data have been meticulously reviewed and processed to ensure a clean dataset for subsequent analysis. Table 1 displays descriptive statistics of the analyzed data.

	Ln_return_BTC	**Ln_return_BRT**	**GEPU**
Observation	3,196	3,196	105
Mean	0.0016	0.0002	231.2051
Median	0.0014	0.0000	228.4537
Minimum	(0.4973)	(0.2798)	124.8386
Maximum	0.2276	0.1908	431.7455
Standard Deviation	0.0372	0.0211	60.6779
Kurtosis	13.4398	26.3602	0.2104
Skewness	(0.8168)	(1.3244)	0.5422
ADF Statistic	-41.5528***	-12.5398***	-3.1262***

Table 1: Descriptive statistics

Note: ***, ** and * denote statistical significance at 1%, 5%, and 10% levels, respectively. This applies to all tables in the paper.

3.2. Methodology

The research employs the DCC-MIDAS-X model with structural breaks, a close imitation of the methodology of Xiong et al. (2024). The model offers a robust framework for time-varying correlation between various assets analysis and assessing the effectiveness of the assets as hedgers, controlling for the influence of lower-frequency macroeconomic variables in the MIDAS component and structural breaks. While adopting the same methodological framework as Fang et al. (2018) and Xiong et al. (2024), the present paper is unique in its focus on the pairwise correlation between Bitcoin and Brent oil across different time horizons. The DCC-

MIDAS-X model requires a two-stage estimation process: the univariate volatility estimated initially by the GARCH-MIDAS-X model and the pairwise correlation by the DCC-MIDAS-X, both modified for structural breaks. Lastly, the output from the model with and without structural breaks would be compared to justifying the model effectiveness as well as to test the robustness of the findings.

3.2.1. GARCH – MIDAS – X model with structural break

Firstly, the GARCH-MIDAS model proposed by Engel et al. (2013) and Conrad and Loch (2015) is applied to investigate the volatilities of Bitcoin and Brent oil in both short-run and long-run. Short-run component follows a mean reverting high-frequency daily GARCH process whilst long-run component incorporates explanatory variables of low frequency, namely realized volatility (RV) and GEPU, using the Beta weighting schemes. The model can be described as:

$$r_{i,t} = \mu_i + \sqrt{\tau_t g_{i,t}}\, \varepsilon_{i,t} \quad (1)$$

$$\varepsilon_{i,t} | \Gamma_{i-1} \sim N(0,1)$$

where $r_{i,t}$ denotes the log returns of assets i in a period t=1,…, T; μ_i is the mean return; $g_{i,t}$ is the short-run component on day t; and τ_t is defined as the long-run components that vary with monthly frequency. The short-run component $g_{i,t}$ accounting for daily fluctuations that are assumed to be short-lived (Chordia et al., 2002) follows a standard GARCH (1,1) process:

$$g_{i,t} = (1 - \alpha_i - \beta_i) + \alpha_i \frac{(r_{i-1,t} - \mu_i)^2}{\tau_t} + \beta_i g_{i-1,t} \quad (2)$$

with the constraints of $\alpha_i > 0$, $\beta_i \geq 0$ and $\alpha_i + \beta_i < 1$.

The long-term volatility component with a single explanatory variable is given by:

$$log(\tau_t) = m_i + \theta_i \sum_{k=1}^{K} \varphi_k(\omega_v)\, RV_{t-k} \quad (3)$$

$$RV_t = \sum_{i=1}^{N_t} r_{i,t}^2 \quad (4)$$

where m is the intercept term, measures unconditional long-term volatility. K is the number of periods over which volatility is smoothed. Regarding equation (4), RV is computed using a rolling window of squared daily log returns in which N is the rolling window with the length equal to the number of days within the month.

Equation (3) is further modified by involving the GEPU index, represented by the X term, along with the RV to study the impact of this macroeconomic variable on the long-run return variance (Asgharian et al., 2013):

$$log(\tau_t) \ = \ m_i + \theta_{i,RV} \sum_{k=1}^{K} \varphi_k \, (\omega_v^{RV}) \, RV_{t-k} \ + \ \theta_{i,X} \sum_{k=1}^{K} \varphi_k \, (\omega_v^{X}) \, X_{t-k} \quad (5)$$

The Beta weighting scheme is described by beta lag polynomial (Ghysels et al., 2007):

$$\varphi_k(\omega_i) = \frac{(1-\frac{k}{K})^{\omega_i - 1}}{\sum_{s=1}^{K}(1-\frac{s}{K})^{\omega_i - 1}} \, , \forall k = 1, \dots , K \quad (6)$$

The weights φ_k are constructed to assign greater or lesser importance to different lags, depending on the parameter values ω_i. The Beta weighting schemes can generate decaying, hump-shaped, or U-shaped weights.

Weight function can be design in two approach:

+ beta weight: phi(w1 = 1, w2 = x)

Moreover, to account for structural changes in macroeconomic indicators, the long-term volatility component is further modified by adjusting the parameter θ_{RV} and θ_X . The modified component incorporates dummy variables designed to capture structural breaks, as follows:

$$log(\tau_{i,t}) \ = \ m_v + (\theta_{RV} \ + \sum \theta_{RV,j} D_j) \sum_{k=1}^{K} \varphi_k \, (\omega_v^{RV}) \, RV_{t-k} + \ (\theta_X \ + \sum \theta_{X,j} D_j) \sum_{k=1}^{K} \varphi_k \, (\omega_v^{X}) \, X_{t-k}^{X} \quad (7)$$

$$log(\tau_{i,t}) \ = \ m_v + (\theta_{RV} \ + \ \theta_{RV0} D_0 \ + \theta_{RV1} D_1 \ + \ \theta_{RV2} D_2 \,) \sum_{k=1}^{K} \varphi_k \, (\omega_v^{RV}) \, RV_{t-k} + \ (\theta_X \ + \sum \theta_{X,j} D_j) \sum_{k=1}^{K} \varphi_k \, (\omega_v^{X}) \, X_{t-k}^{X} \quad (7)$$

Considering the effect of the macroeconomic structural break by using the Bai and Perron (2003) to detect structural changes in the GEPU series, subsequently dividing the sample period into subsamples (Xiong et al., 2024). The first subsample period, preceding the first structural break, is designated as the base subsample (subsample 0) with $j = 0$ to avoid the dummy variable trap. Here, j represents the subsample period, meaning that D_1 is equal to one between the first and second breakpoints (called subsample 1) and zero otherwise. The settings for D_2 to D_n follow the same method. The coefficients $\theta_{RV,j}$ and $\theta_{X,j}$ represent the increments in the parameter θ_{RV} and θ_X during subsample period j, compared to those in the base subsample.

3.2.2. DDC – MIDAS – X model with structural break

The DCC-MIDAS model (Colacito et al., 2011) extends the GARCH-MIDAS specification to capture dynamic correlations, making it particularly suitable for datasets with mixed frequencies. Like Fang et al. (2018), only minor modifications to the specification of Conrad et al. (2014) are conducted by allowing the long-run correlation to be directly influenced by the lagged values of GEPU index.

The conditional correlation is firstly given as $R_t = diag(Q_t)^{-1/2} * Qt * diag(Q_t)^{-1/2}$, where Q_t is the short-run correlation component which is specified as:

$$q_{ij,t} = (1 - \text{a} - \text{b})\overline{\rho_{ij,\tau}} + \text{a}\xi_{i,t-1}\xi_{j,t-1} + \text{b}q_{ij,t-1} \quad (8)$$

where $\xi_{i,t-1}$ and $\xi_{j,t-1}$ are the standardized residuals from GARCH-MIDAS model of different return series. $\overline{\rho_{ij,\tau}}$ is a slowly moving long-run correlation that remains unchanged. Apply the Fisher-z transformation of the correlation coefficient (Christodoulakis and Satchell, 2002) to get the following equation:

$$\overline{\rho_{ij,\tau}} = \frac{\exp(2z_{ij,\tau}) - 1}{\exp(2z_{ij,\tau}) + 1} \quad (9)$$

$$z_{ij,\tau} = m_c + \theta_{RC} \sum_{k=1}^{K_c} \varphi_k (\omega_c^{RC}) RC_{t-k} + \theta_X \sum_{k=1}^{K_c} \varphi_k (\omega_c^{X}) X_{t-k} \quad (10)$$

The research also modifies the long-term component of the DCC-MIDAS-X model to account for structural breaks by incorporating dummy variables, following a similar approach as outlined in the GARCH-MIDAS-X section. This modification is expressed as follows:

$$z_{ij,\tau} = m_c + \left(\theta_{RC} + \sum \theta_{RC,j} D_j\right) \sum_{k=1}^{K_c} \varphi_k (\omega_c^{RC}) RC_{t-k} + \left(\theta_X + \sum \theta_{X,j} D_j\right) \sum_{k=1}^{K_c} \varphi_k (\omega_c^{X}) X_{t-k} \quad (11)$$

3.2.3. Bitcoin's hedging effectiveness

In this section, the GEPU index will be incorporated to investigate the direct exposure hedging effectiveness of Bitcoin against Brent oil considering the influence of GEPU with structural break. The Hedging Effectiveness (HE) ratio is utilized to evaluate the performance of hedging strategies. This ratio measures the portfolio risk reduction achieved by the hedging strategy using Bitcoin versus the unhedged portfolio containing Brent oil only.

$$HE = \frac{var_{unhedged} - var_{hedged}}{var_{unhedged}} \quad (12)$$

where $var_{unhedged}$ is the variance of the unhedged portfolio return $R_{O,t}$; var_{hedged} is the variance of the hedged portfolio return $R_{H,t}$. A higher HE ratio indicates greater hedging effectiveness, signifying a superior risk-reduction strategy. The return on a hedge portfolio is defined as:

$$R_{H,t} = R_{O,t} - \gamma_t R_{B,t} \quad (13)$$

where $R_{B,t}$ is the return on Bitcoin position at time t; $R_{O,t}$ is the return on Brent oil position at time t; and γ_t is the hedge ratio. The variance of the hedged portfolio conditional on the information set at time t−1 is given by:

$$var\ (R_{H,t} \mid O_{t-1}) = var(R_{B,t} \mid O_{t-1}) - 2\gamma_t cov(R_{B,t}, R_{O,t} \mid O_{t-1}) + \gamma_t^2\ var(R_{O,t} \mid O_{t-1}) \quad (14)$$

The Optimal Hedge Ratio (γ_t^*) minimizes the conditional variance of the hedged portfolio and is calculated as:

$$\gamma_t^* | O_{t-1} = \frac{cov(R_{B,t}, R_{O,t} \mid O_{t-1})}{var(R_{B,t} \mid O_{t-1})} \quad (15)$$

The DCC-GARCH model considering structural break is applied to estimate the conditional variances and covariances under the assumption of two assets, the conditional covariance matrix H_t is symmetric (2×2) with diagonal elements representing the conditional variances and off-diagonal elements representing the conditional covariance.

4. Empirical Analysis and Results

4.1. GEPU Structural Break Test

Breakpoint 1	Breakpoint 2	SupF Test	ExpF Test	AveF Test
May 2019	Jan 2021	63.693***	28.393***	19.997***

Table 2: Structure breaks test for GEPU series

Table 2 presents the results of the structural break tests for the GEPU index with 2 structural breakpoints that coincide with the occurrence of major economic crises. These breakpoints divide the initial period into three sub-periods, which are potentially characterized by the major shift in the global macroeconomic regime that influences investment behavior, monetary policies, and financial stability. The statistics from the Supremum F-test, Exponential F-test, and Average F-test for structural breaks reject the absence of breaks at 1% significance level.

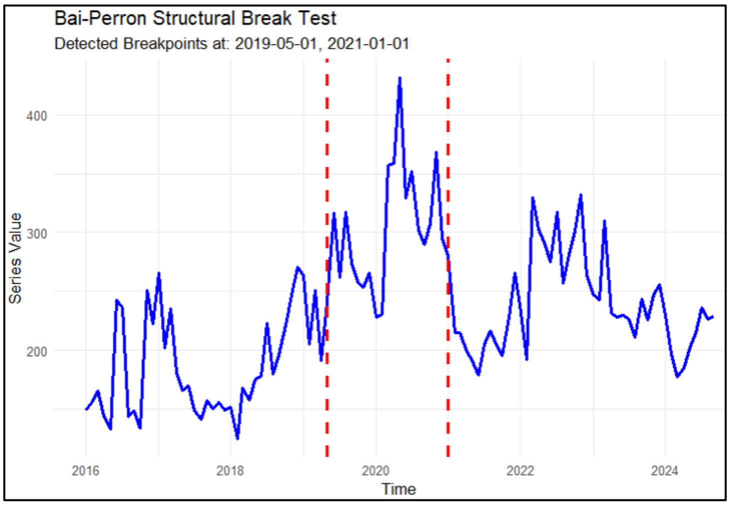

Figure 1: Bai-Perron structural break test on GEPU index

The first break is in May 2019 when the US imposed tariffs of 25% on $200 billion worth of Chinese import goods. This event has escalated trade tensions between the world's two largest economies. Empirical studies have revealed that trade wars impose uncertainty shocks, causing volatility to increase in economic policy decisions, trade, and financial markets (Davis, 2016). The GEPU index responds to these shocks as firms, investors, and policymakers rethink risk, influencing investment, monetary policies, and financial markets (Caggiano et al., 2020). Besides, the United Nations briefing (2019) acknowledged slowing world economic activity that spurred central banks to move towards more accommodative monetary policy. These issues prompted central banks to adopt more accommodative policies, including rate reductions and liquidity injections, to mitigate downside risks. Break analysis has shown that breaks in economic policy uncertainty indices happen at the same time as large monetary policy changes, as investor sentiment and policy direction are determined by shifts in central bank policy (Qi et al., 2021).

The second break occurred in January 2021 amidst the post-COVID-19 pandemic and economic recovery efforts. Explicitly, the International Monetary Fund's World Economic Outlook projected a 5.5% growth of the world economy in 2021, reflecting optimism due to vaccine rollouts and continued monetary stimulus and fiscal interventions supporting the end of the pandemic in large economies. This shift from pandemic-induced economic recession (2020) to hopes of recovery (2021) is a turning point in global policy uncertainty trends (Altig et al., 2020). This breakpoint also aligns with previous studies that improving economic conditions and a shift towards policy predictability tend to indicate downward breaks in uncertainty (Baker at al., 2016).

Talking about the Russian-Ukraine war, despite its geopolitical significance, was not detected as a structural break in the GEPU index as its impact might be regionally concentrated rather than global. While it disrupted European energy markets, international trade adapted swiftly. Structural breaks in GEPU typically stem from global uncertainty shocks (e.g., 2008 financial crisis, COVID-19). Additionally, GEPU measures policy uncertainty, not military conflicts, explaining why the war may not cause a break like the 2019 US-China trade war or financial crises (Bekaert et al., 2013; Davis, 2016; Ahir et al., 2022).

4.2. Impact of GEPU on Assets' Dynamic Volatility

The GARCH-MIDAS-X model with structural break estimates of Bitcoin (Table 3) capture the dynamics of the volatility components of Bitcoin over time, particularly focusing on the contribution of short-run and long-run volatility. First, the short-run volatility suggests a very high volatility persistence, with the β coefficient of 0.8057. This indicates that past volatility has a significant impact on current volatility levels, reflecting a common characteristic of financial markets, where past shocks are persistent. The relatively modest and muted response to previous volatility shocks, indicated by the α coefficient of 0.1251, suggests that past shocks do impact current volatility. However, their intensity declines over time.

Second, concerning the long-run volatility component, the model reveals that RV (θ_{RV}) and GEPU (θ_X) have significant positive impacts on Bitcoin's long-run volatility. These variables reflect the impact of global macroeconomic sentiment and conditions on Bitcoin price dynamics. The outcome is also consistent with Frank Knight's Uncertainty and Risk Aversion Theory (1921): A rise in economic uncertainty leads to a perceived increase in financial market risks. As a result, investors become less confident about future economic conditions. They are more likely to re-weight their portfolios; and risky assets, like Bitcoin, tend to exhibit higher volatility in tandem with general financial markets.

BTC	Estimate	Std. Error	t value	Pr(>|t|)
μ	0.0015***	0.0007	2.3744	0.0176
α	0.1251***	0.0256	4.8824	0.0045
β	0.8057***	0.0352	22.8908	0.0000
m	-11.4168***	1.7862	(6.3917)	0.0002
θ_{RV}	14.8815***	2.2205	6.7020	0.0000
θ_{RV1}	0.4367***	0.0874	4.9963	0.0002
θ_{RV2}	-0.1640**	0.0686	(2.3936)	0.0167
ω_{RV}	1.5874**	0.6626	2.3959	0.0166
θ_X	0.8069**	0.3594	2.2451	0.0248
θ_{X1}	-48.5140***	0.9868	(49.1637)	0.0000
θ_{X2}	19.1533***	3.7424	5.1179	0.0001
ω_X	1.0010	1.3673	0.7321	0.4641
AIC: 12,488 | BIC: 12,561 | Log(L): -6,232.22				

Table 3: Empirical results of GARCH-MIDAS-X model with structural breaks for Bitcoin

Third, the presence of structural breaks, indicated by the significantly different from zero of θ_{RV1}, θ_{RV2}, θ_{X1}, θ_{X2} over subsample periods—demonstrates the compounding effect of these drivers over time. More significantly, while RV and GEPU both have a strong positive impact on Bitcoin's long-run volatility in the base subsample (θ_{RV} = 14.8815***, θ_X = 0.8069***), this impact varies in magnitude across the subsamples. In particular, the negative impact of GEPU on Bitcoin's long-term volatility in the second subsample (θ_{X1} = -48.5140***) which coincides with the period of the US-China trade war that led the GEPU to peaks, is of theoretical interest.

This could be explained that, during a period of extreme uncertainty, investors tend to shift their focus toward assets perceived as safe havens, such as gold or government bonds, rather than assets with speculative features, which leads to decreasing trading activities and volatility of Bitcoin. Although Bitcoin has been considered a hedge against traditional financial systems, investors might prefer more stable assets in response to specific risks such as global trade disruptions, currency depreciation, and other macroeconomic shocks (Dyhrberg, 2016).

BRT	Estimate	Std. Error	t value	Pr(>|t|)
μ	0.0002	0.0004	0.5471	0.5843
α	0.0623***	0.0162	3.8607	0.0001
β	0.9166***	0.0227	40.3717	0.0003
m	-0.8581***	0.2412	(3.5576)	0.0002
θ_{RV}	0.2137	25.3386	0.0084	0.9933
θ_{RV1}	0.2104***	0.0693	3.0363	0.0024
θ_{RV2}	0.1318**	0.0518	2.5469	0.0109
ω_{RV}	1.0084***	0.2202	4.5803	0.0000
θ_X	-1.3882**	0.0746	(18.6015)	0.0205
θ_{X1}	0.3220	4.8398	0.0665	0.9469
θ_{X2}	0.1938	25.4624	0.0076	0.9939
ω_X	1.0011	4.4468	0.2251	0.8219
AIC: 16,537 | BIC: 16,610 | Log(L): -8,256.79				

Table 4: Empirical results of GARCH-MIDAS-X model with structural breaks for Brent oil

For Brent oil, similar results were observed, with Brent's returns showing strong volatility and persistence (β = 0.9166***). There is some weak but statistically significant impact of historical volatility shocks on the short-run component (α = 0,0623***), and there is a positive, significant impact of RV on the long-run component (θ_{RV1} = 0.2104***, θ_{RV2} = 0,1318**). However, unlike Bitcoin, a rise in GEPU is associated with a decline in Brent's long-run volatility (θ_X = -1.3882**) and the effect is statistically significant at the 5% level. The magnitude of the θ_X coefficient for Brent is around or less than 1, significantly smaller than that of Bitcoin, suggesting that the impact of GEPU on Brent's long-run volatility is economically less significant than its impact on Bitcoin volatility.

This is particularly supported by the study of Kilian and Park (2009), who expounded that oil markets tend to have reduced price volatility in the long-term during periods of global economic uncertainty. Greater GEPU generally points to potential economic slowdowns, which lead to lower demand for oil, therefore, lower volatility. Additionally, because oil markets are less prone to speculation forces, price oscillations are damped in response to economic uncertainty. Bitcoin, in contrast, is more responsive to GEPU, as evidenced by its greater estimated θ_X coefficients. This can be attributed to the speculative nature of Bitcoin and higher volatility, where its price responds more to external economic conditions and historical trends of volatility, as discussed by Catania et al. (2019).

BTC	Estimate	Std. Error	t value	Pr(>|t|)
μ	0.0014**	0.0006	2.2375	0.0171
α	0.1827***	0.0367	4.9786	0.0002
β	0.8094***	0.0327	24.7570	0.0000
m	-11.6515***	1.2016	(9.7023)	0.0001
θ_{RV}	16.2415**	7.2834	2.2299	0.0258
ω_{RV}	1.0010	0.8103	1.2354	0.2167
θ_X	3.6697***	1.0719	3.4236	0.0006
ω_X	1.0010	3.9093	0.2561	0.7979
AIC: 12,456 | BIC: 12,505 | Log(L): -6,220.36				

Table 5: Empirical results of GARCH-MIDAS-X model without structural breaks for Bitcoin

BRT	Estimate	Std. Error	t value	Pr(>|t|)
μ	0.0001	0.0004	0.5603	0.5431
α	0.0723***	0.0186	3.8903	0.0001
β	0.9164***	0.0139	66.0867	0.0000
m	-12.3746***	1.0347	(11.9613)	0.0002
θ_{RV}	-9.6964***	0.2755	(35.1992)	0.0000
ω_{RV}	2.7802*	1.5992	1.7386	0.0821
θ_X	3.0008***	0.7894	3.8012	0.0006
ω_X	3.8770***	0.8632	4.4914	0.0000
AIC: 16,567 | BIC: 16,615 | Log(L): -8,275.63				

Table 6: Empirical results of GARCH-MIDAS-X model without structural breaks for Brent oil

Regarding GARCH-MIDAS-X model without structural break, Table 5 and 6 show the volatility estimation for Bitcoin and Brent oil respectively. A similar result to the model including structural break is observed, where most of the coefficient's estimates are statistically significant with the equivalent sign and magnitude. This is except for the case where the model without structural shows a strong negative impact of RV (θ_{RV} = -9.6964***) and strong positive of GEPU on Brent long run volatility (θ_X = 3.0008***) (Table 6) which is opposite to what implied by the structural break model (Table 4). Despite the conflict estimates, it is rational to follow the result from the GARCH-MIDAS-X with structural break (Table 4) given its larger log-likelihood and smaller AIC and BIC criteria values compared to those from the model without structural break (Table 6).

4.3. Impact of GEPU on the Dynamic Correlation between Bitcoin and Brent Oil

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
α	0.0072	0.0051	1.4354	0.1512
β	0.9757***	0.0137	71.4138	0.0000
m	-1.915*	1.1090	(1.7273)	0.0841
θ_{RC}	-0.579	0.9458	(0.6127)	0.5401
θ_{RC1}	0.1029	1.0795	0.0954	0.9240
θ_{RC2}	0.2577	0.3109	0.8290	0.4071
ω_{RC}	1.0014	4.0869	0.2450	0.8064
θ_X	0.3704*	0.2073	1.7867	0.0740
θ_{X1}	1.5183**	0.6679	2.2735	0.0230
θ_{X2}	0.7486*	0.4435	1.6880	0.0914
ω_X	7.7766	4.8534	1.6023	0.1091
AIC: 11,167 | BIC: 11,234 | Log(L): -5,572.84				

Table 7: Empirical results of DCC-MIDAS-X model with structural breaks

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
α	0.0084	0.0066	1.2715	0.2036
β	0.9732***	0.0393	24.7633	0.0000
m	-2.906	3.0687	(0.9471)	0.3436
θ_{RC}	-0.381	0.8458	(0.4514)	0.6517
ω_{RC}	1.0017	2.6860	0.3730	0.7092
θ_X	1.7738	1.8368	0.9657	0.3342
ω_X	10.000	66.9335	0.1494	0.8812
AIC: 11,191 | BIC: 11,234 | Log(L): -5,588.91				

Table 8: Empirical results of DCC-MIDAS-X model without structural breaks

Table 7 and Table 8 present the results of the DCC-MIDAS-X model with and without structural breaks. By breaking down correlation into short and long-term components under the influence of GEPU across three subsamples, the model provides further insights into the time-varying correlation and the hedging effectiveness of Bitcoin against Brent oil. Including structural break (Table 7) improves model reliability, as indicated by lower AIC and higher statistics and more statistically significant coefficient estimates compared to Table 8. From that, the findings reveal two notable dynamics: (1) the short-run persistence of past correlations and (2) the long-run impact of GEPU, both of which alter under alternative macroeconomic regimes based on structural breaks.

First, Table 7 shows that historical correlation patterns between Bitcoin and Brent oil strongly contribute to short-run volatility, with a statistically significant β of 0.9736***, which implies that historical correlation shocks continue to shape future correlation. This persistence aligns with Financial Network Theory (Allen and Gale, 2000), which emphasizes systemic linkages in financial markets, causing interdependencies to last. With Bitcoin integrating deeper into the financial world, it increasingly follows historical asset patterns, reinforcing historical correlation trends (Shilov and Zubarev, 2021; Wątorek et al., 2023). This has also been validated through empirical findings by Bejaoui et al. (2022) and Bâra et al. (2024), who show that the correlation between Bitcoin and Brent oil contains strong autoregressive properties amidst financial contagion periods.

Second, the result from DCC-MIDAS-X also reveals the impact of GEPU on long-term correlation between the studied assets. Structural break model identifies that GEPU has a strengthening effect across the subsample, as reflected in the statistically significant Theta coefficients (θ_X = 0.3704*, θ_{X1} = 1.5183**, θ_{X2} = 0.7486*). Before the US-China trade war, the Bitcoin market was new and primarily a speculative asset with relatively weak connectedness to the crude oil market and macroeconomic situation (θ_X = 0.3704*). This is consistent with the study of Baur et al. (2018), Gajardo et al. (2018) and Ji et al. (2019) which indicated that Bitcoin was largely uncorrelated with commodities when it was in its early stage of financial adoption.

However, the development of the cryptocurrency market has been growingly integrated into financial markets and the spread of the US-China trade war (subsample 1) had caused the impact of GEPU on Bitcoin-Brent oil correlation to intensify (θ_X = 1.5183***). This period was particularly characterized by peaking GEPU as well as surging correlation between the two assets. In other words, Bitcoin was mirroring traditional risky assets amid rising systematic risk due to economic turmoil; and thus, evidencing its diminishing hedging effectiveness. Study of Wang et al. (2024) has confirmed that in periods of financial contagion, such as the global sell-off or pandemic spread-out, Bitcoin's correlation with stock indices, bonds, and commodities increased sharply, showing that investors treated it more like a speculative risk asset rather than a hedge.

Moreover, in the post-pandemic period (subsample 2) when the economic global monetary expansion policy was rolled out, GEPU continued to have a strongly effect on the correlation (θ_{X2} = 0.7486*). This finding further reinforces Bitcoin's increasing financial integration according to Financial Network Theory, which leads to the intensified Bitcoin-Brent co-movement in response to hiking systematic risk.

Based on the above results, we can conclude that the correlation between Bitcoin and Brent oil price fluctuates under different levels of economic uncertainty. Moreover, the hedging effectiveness of Bitcoin against Brent oil is not static but varies with broader market forces as well as the degree of economic uncertainty prevailing at the time. Specifically, the positive impact of GEPU on the Bitcoin-Brent correlations indicates that Bitcoin can only be an effective hedging asset for Brent when GEPU is low and Bitcoin-Brent correlation is negative. These findings emphasize that the hedging ability of Bitcoin against oil is not absolute but contingent, relying on two determinants: (1) the level of global economic uncertainty (GEPU) and (2) the current correlation between the two assets. This implies that Bitcoin's effectiveness as a hedge depends heavily on broader market dynamics rather than being a consistent safe-haven asset.

4.4. The Hedging Performance of Bitcoin

This section quantifies the hedging effectiveness of Bitcoin against Brent oil. The covariance matrix is calculated first by applying the DCC-MIDAS-X in two cases, with and without structural break respectively. Then it is substituted into Equation (15) to calculate the optimal hedge ratio.

	Without structural break	**With structural break**
HE	0.0141	0.0277

Table 9: The hedging performance of Bitcoin over Brent oil

The findings indicate that even though the DCC-MIDAS-X with structural breaks model could slightly improve the HE ratio, Bitcoin's hedging ability against Brent is weak with the

HE values remaining below 3% in both cases. This minimal performance can be mostly credited to Bitcoin's persistently low correlation with oil, even across economic regimes, with realized correlation (RC) across the testing period is around 0.15. Break Theory (Pindyck and Rotemberg, 1990) makes the model extension understandable by including regime shifts, yet Bitcoin volatility and speculative position make it inconsistent as a hedge tool. While effective hedging requires strong inverse correlation, Bitcoin does not possess this characteristic compared to oil. These results align with Baur et al. (2018), Dutta et al. (2020) and Wang et al. (2024) that Bitcoin may provide some diversifications benefit rather than being a stable hedge of oil price risk.

5. Conclusion

The study explores the dynamic correlation and the hedging effectiveness of Bitcoin against Brent oil considering the role of the GEPU index. Using the DCC-MIDAS-X model with structural breaks, this research finds that GEPU significantly increases the long-run correlation between two assets, with estimated correlation rising through regime shifts across macroeconomic phases: pre-trade war, during the US-China trade war, and post-pandemic recovery. Precisely, the positive influence of GEPU on Bitcoin-Brent correlations suggests that Bitcoin functions most effectively as a hedging asset for Brent oil only when GEPU is low and the Bitcoin-Brent correlation is negative. Finally, the quantified hedging ability of Bitcoin remains weak with the hedging effectiveness index of below 3% and only 1.3% improvement after accounting for structural breaks. This suggests that Bitcoin may not be a consistent and stable hedge for oil fluctuation.

The findings support the Financial Network Theory (Allen and Gale, 2000) by showing that Bitcoin’s correlation with Brent oil strengthens over time, particularly during periods of economic uncertainty. It also contributes to MPT (Markowitz, 1952) by showing that Bitcoin has a weak and time-varying correlation with oil. This is good for diversification but challenging its role as an effective hedging asset against oil fluctuation. Furthermore, following the Structural Break Theory (Pindyck and Rotemberg, 1990), the findings emphasize the necessity of modifying financial models to account for macroeconomic regime shifts. In practical terms, the implications are that Bitcoin should merely be kept as a diversification tool but not as a direct hedge of oil market exposure. From a policy perspective, Bitcoin's growing infiltration of financial markets highlights the necessity for more stringent risk measurement frameworks due to its speculative nature and sensitivity to systemic economic shocks.

Notwithstanding its contribution, the study recognizes some limitations, such as model assumption and considerations about other exogenous factors impacting correlation, which can influence model accuracy. Possible future research can be to expand the analysis to other assets, formally test alternative risk management strategies beyond direct exposure hedge, and consider other potential correlation-driver factors beyond GEPU.

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Appendix

Assets' Price Charts during the Studied Period (January 2016 to September 2024)

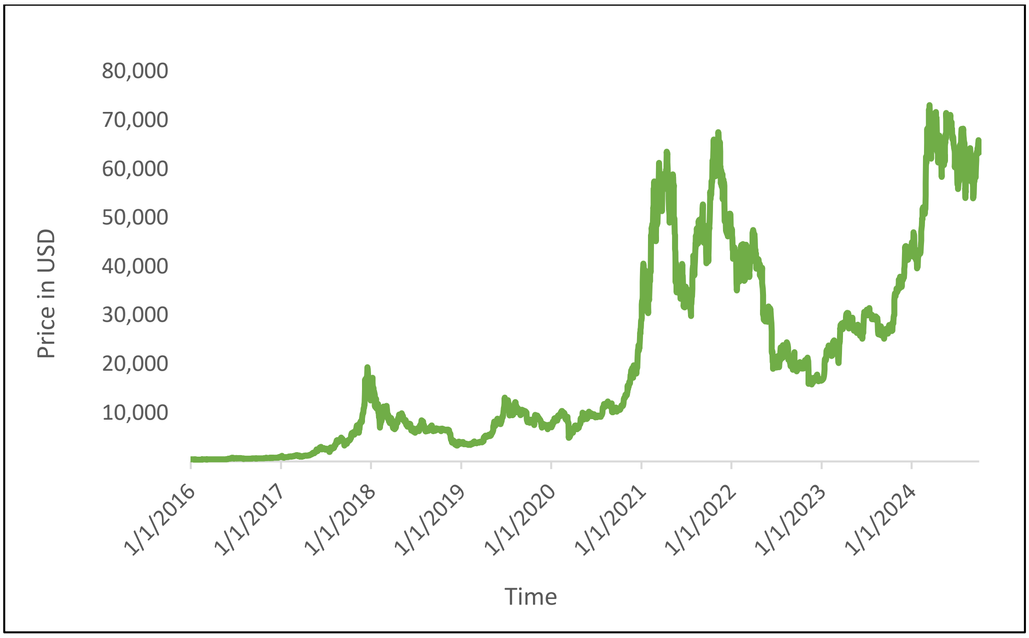

Figure 1. Bitcoin's daily prices

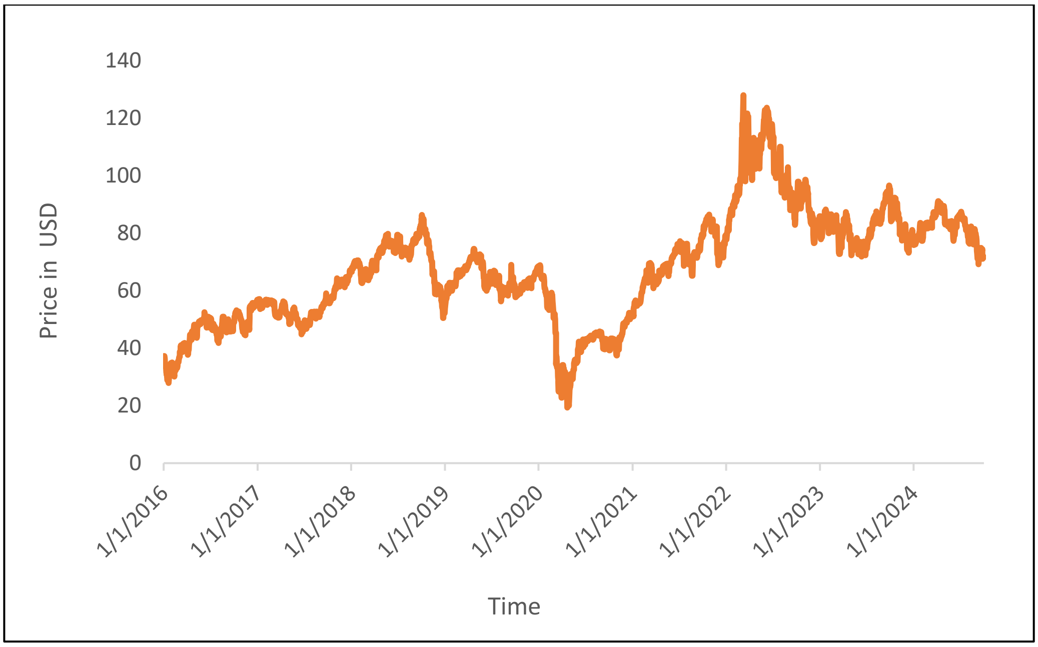

Figure 2. Brent oil's daily prices

Declaration of Authorship

I herewith declare that I have completed the work presented in this paper independently and without the use of any aid or resources except as indicated. All text passages in this paper that are quoted verbatim or paraphrased from published sources are identified as such. All other contents from other sources used in the paper are also identified as such. Neither the paper in full nor excerpts from it, nor other versions of it, have already been submitted for another examination or other graded course work at this or any other educational institution.

Additionally, I acknowledge the use of AI-based tools for proofreading and language refinement. However, these tools were employed solely for improving clarity and grammar without influencing the originality, integrity, or substantive content of the research.

Magdeburg, 18.03.2025 Ly Huong Pham