Cryptocurrencies in the Face of Geopolitical Shocks and Investor Sentiment: Dynamic Analysis of Bitcoin and Ethereum During Periods of Global Uncertainty

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Article

Cryptocurrencies in the Face of Geopolitical Shocks and Investor Sentiment: Dynamic Analysis of Bitcoin and Ethereum During Periods of Global Uncertainty

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Abstract: Our study analyzes the combined impact of geopolitical risks and investor sentiment on the major cryptocurrencies, Bitcoin and Ethereum, using monthly data from December 1, 2020, to the end of April 2025. Through a rigorous econometric approach-including unit root tests (Dickey-Fuller (1979-1981) and Perron (1998)), cointegration techniques (Engle and Granger (1987) and Johansen (1990)), and error correction models (ECM and VECM)-we examined the long- and short-term dynamics between cryptocurrencies and three indices: investor sentiment, crypto market sentiment, and the composite geopolitical risk index. Our results confirm the existence of cointegration relationships between these crypto-assets and the indices, indicating structural interdependence during periods of global uncertainty. In the short term, fluctuations in investor sentiment and geopolitical risks significantly affect the returns of Bitcoin and Ethereum, with a rapid adjustment toward long-term equilibrium. Moreover, Ethereum appears to be slightly more sensitive to emotional and geopolitical shocks than Bitcoin. However, our study has certain limitations, notably the use of composite indices that may not capture all the qualitative nuances of the phenomena studied and the assumption of linearity in the modeled relationships. For future research, we suggest integrating nonlinear models and leveraging real-time sentiment data derived from artificial intelligence, as well as expanding the analysis to other segments of the crypto-asset market. Ultimately, our study enhances the understanding of exogenous factors influencing cryptocurrencies in an unstable global environment.

Keywords: cryptocurrencies; investor sentiment; geopolitical risks index; cointegration approaches

JEL Classification: E44; G11; G15; F51

1. Introduction

Over the past decade, the cryptocurrency market has experienced spectacular growth, attracting the attention of investors, researchers, and policymakers. Characterized by extreme volatility and marked speculative dynamics, this market operates outside traditional financial regulatory frameworks. In an increasingly unstable international context, marked by major geopolitical crises (such as the Russia-Ukraine war, tensions in the Middle East, etc.) and persistent economic uncertainties, it becomes essential to understand how exogenous factors-particularly geopolitical risks and investor sentiment-influence the behavior of crypto assets.

The specific framework of our study fits within this dynamic of inquiry. Unlike traditional financial markets, cryptocurrencies-due to their decentralized nature and strong emotional sensitivity-react in a particular way to geopolitical events and fluctuations in investor sentiment.

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Recent research has highlighted that Bitcoin and Ethereum, the two leading global cryptocurrencies, can play an ambivalent role during times of crisis: sometimes perceived as alternative safe-haven assets, and other times subject to massive selloffs during extreme shocks. However, few studies have sought to formalize, within a rigorous empirical framework, the interaction between these cryptocurrencies from both a long-term and short-term perspective.

The central issue of our study is therefore the following: How do geopolitical risks and investor sentiment dynamics influence the trajectory of the cryptocurrency market, particularly that of Bitcoin and Ethereum? This question raises important theoretical and practical challenges, especially in understanding volatility mechanisms, price prediction, and financial risk management in an increasingly complex and unpredictable global environment.

Our main objective is to analyze the relationship between the price fluctuations of Bitcoin and Ethereum and three key dimensions: the investor sentiment index, the cryptocurrency market sentiment index, and the composite geopolitical risk index. More specifically, we aim to identify the existence of long-term cointegration relationships among these variables, examine the short-term adjustment dynamics, and assess the magnitude of the cryptocurrencies' reactions to geopolitical shocks and sentiment variations.

The theoretical contribution of this study lies in enriching the literature on the economics of cryptoassets by simultaneously integrating geopolitical and behavioral factors into the analysis of cryptocurrency prices. While many studies address the effects of investor sentiment or geopolitical tensions separately, our approach offers a more integrated perspective, accounting for the interdependence of these two dimensions. Empirically, we employ a rigorous methodology based on unit root tests (Dickey-Fuller (1979-1981) and Perron (1998)), cointegration theory (Engle and Granger (1987) and Johansen (1990)), as well as the estimation of error correction models (ECM and VECM), enabling us to distinguish between short-term and long-term dynamics among these cryptocurrencies and the sentiment indices, along with the composite geopolitical risk index.

Our database covers a monthly period from December 1, 2020, to the end of April 2025, with data collected from recognized sources such as Coin Desk, Yahoo Finance, Kaggle.com, and the U.S. Federal Reserve. We analyze the logarithmic behaviors of Bitcoin and Ethereum prices as well as sentiment and geopolitical risk indices, incorporating descriptive analyses, stationarity tests, and advanced dynamic modeling. Ultimately, this article aims to inform policymakers, investors, and researchers about the complex nature of the factors driving cryptocurrency fluctuations in a world characterized by growing instability. It also offers avenues for developing more effective forecasting tools that integrate emotional and geopolitical dimensions into cryptocurrency market analysis.

This article is structured into several complementary sections. After introducing the general context of the cryptocurrency market, emphasizing the importance of geopolitical risks and investor sentiment, a review of recent literature is presented to theoretically frame our study. Next, the adopted methodology is detailed, including data selection, stationarity tests (Dickey-Fuller (1979-1981) and Perron (1998)), and cointegration approaches (Engle and Granger (1987) and Johansen (1990)) to analyze the long-term relationships between Bitcoin, Ethereum, and the sentiment and geopolitical risk indices. The empirical results are then presented through estimations of error correction models (ECM and VECM), highlighting short-term and long-term dynamics. Our article concludes by underlining the main theoretical and practical implications of this study in an uncertain global financial environment.

2. Literature Review

Over the past decade, the cryptocurrency market has undergone profound evolution, attracting the attention of investors, governments, and researchers. Characterized by extreme volatility, this market is strongly influenced by exogenous factors, notably geopolitical risks and investors' emotional dynamics. Unlike traditional financial markets, cryptoassets are decentralized and highly speculative, amplifying the effects of geopolitical uncertainties and fluctuations in investor sentiment.

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We explore recent literature on the impact of these two dimensions on cryptocurrency markets, highlighting their complex interactions and implications.

Geopolitical events have always had significant consequences on financial markets. However, their effect on cryptocurrencies is relatively new and has sparked debate in the literature. According to Qian et al. (2022), political and military crises can position Bitcoin and other cryptoassets as alternative "safe haven" assets compared to traditional assets like gold. For example, during the first weeks of Russia's invasion of Ukraine in 2022, significant increases in Bitcoin's price were observed, driven by heightened demand for decentralized assets in countries affected by financial sanctions.

However, other studies (Bouri et al. (2023) and Shahzad et al. (2024) nuance this view by emphasizing that the cryptocurrency market's reaction to geopolitical risks is often nonlinear and asymmetric. During major events, such as the tensions between China and Taiwan or the 2023 conflict between Israel and Hamas, Bitcoin initially reacted with a sharp drop before rebounding. This dynamic is attributed to an initial panic behavior followed by speculative revaluation driven by investor arbitrage seeking to evade capital restrictions. Moreover, recent research (Liu et al. (2025)) emphasizes the importance of the local economic context: in highly dollarized economies or those under sanctions, cryptocurrencies are perceived as a more reliable alternative to the national currency, strengthening their role as tools for economic circumvention. Conversely, in developed economies, their behavior remains essentially speculative in the face of geopolitical risks. Thus, the effect of international tensions on cryptocurrencies strongly depends on the nature of the conflict, the response of traditional markets, and the profile of the investors involved.

Alongside geopolitical factors, investor sentiment is recognized as a key determinant of cryptocurrency volatility. Unlike equity or bond markets, where institutional investors dominate, the cryptoasset market is primarily composed of small investors who are more susceptible to emotional biases. Several studies (Corbet et al. (2023) and Khalfaoui et al. (2024)) show that sentiment measures extracted from social media, Google searches, or digital media often anticipate price movements in cryptocurrency markets. Negative sentiment effects, amplified by geopolitical events, generally lead to intensified panic-selling phases. For instance, during the escalation of the conflict in Ukraine in 2022 and the tensions in the Middle East in 2023, price declines in Bitcoin and other cryptocurrencies were strongly correlated with increased volumes of negative discussions on Twitter and Reddit. Conversely, periods of excessive optimism-often fueled by major technological announcements or favorable political decisions regarding crypto-assets-trigger speculative rallies, further exacerbating their volatility.

Moreover, the level of financial sophistication of investors influences how sentiment affects prices. According to Bouri et al. (2024), in emerging or developing markets where financial education is lower, sentiment-induced volatility is more pronounced than in mature markets. Additionally, the impact of sentiment is amplified in the absence of institutional stabilization mechanisms, such as strict financial regulations or predictable monetary policies. Recent studies agree that geopolitical risks and investor sentiment interact endogenously to affect cryptocurrency dynamics. For example, Jiang et al. (2023) and Zou et al. (2025) highlight that initial geopolitical shocks can trigger a disproportionate emotional reaction, exacerbating volatility beyond what economic fundamentals would justify. This interaction is particularly marked during periods of great global uncertainty, when investors are hyper-reactive to information.

Moreover, the intensity of this interaction depends on the type of cryptoasset considered. Major cryptocurrencies like Bitcoin and Ethereum, due to their higher liquidity and greater notoriety, generally react more moderately than smaller altcoins, which can experience extreme fluctuations under the combined effects of sentiment and geopolitical shocks. According to Liu et al. (2025), altcoins represent a natural laboratory for observing the extreme effects of sentiment amplified by international tensions. In terms of policy implications, several authors (Fang et al. (2024) and Khalfaoui et al. (2024)) call for enhanced monitoring of cryptocurrency markets during crisis periods to limit systemic risks related to excessive volatility and uncontrolled herd behavior. New risk measurement tools, combining geopolitical indices and real-time sentiment indicators, are currently

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being developed to anticipate market movements and provide more suitable hedging instruments for institutional investors.

3. Empirical Validation

In this study, we focus on two main cryptocurrencies, namely Bitcoin and Ethereum. We utilize several key indicators, including the cryptocurrency market sentiment index (CMSI), a composite indicator that integrates market volatility, social media activity, price variations, and trading volumes. We also use the investor sentiment index (ISI), which is based on the analysis of social media content and economic news to assess investor behavior and their optimism or pessimism. Additionally, the study incorporates a composite geopolitical risk index (GPRI), which synthesizes current international tensions, economic sanctions, and armed conflicts. Price data for Bitcoin and Ethereum are sourced from CoinDesk and Yahoo; Finance, while information on cryptocurrency market sentiment and the geopolitical risk index comes from Kaggle.com. Investor sentiment data are obtained from the U.S. Federal Reserve. Our analysis period spans from December 1, 2020, to the end of April 2025, with monthly frequency observations.

3.1. Descriptive Statistics

We use three statistical indicators—position, dispersion, and shape—to evaluate the precision, linear fit to the mean, information distribution, flatness, and normality of each component shown above. Table 1 presents these statistical indicators for the respective variables.

Table 1. Descriptive statistical indicators.

	LBITCOIN	LETHEREUM	LISI	LCMSI	LGPRI
Mean	2.3487	2.1487	-0.4178	1.2345	1.7456
Median	2.1748	2.0147	-0.3487	1.4724	1.4786
Std, Dev	0.7148	0.5847	0.5147	1.7814	1.5478
Skewness	0.1745	1.2479	-0.2478	0.8745	1.4578
Kurtosis	1.4875	2.3187	2.7548	2.3494	2.7184
Jarque-Bera	65.2487	77.2458	36.7945	73.4127	58.2478
Probability	0,0000	0,0000	0,0000	0,0000	0,0000

According to Table 1, the means of the natural logarithms of BITCOIN and ETHEREUM indicate a general upward trend during the period studied in this article. However, the respective standard deviations (0.7148 and 0.5847) reveal notable volatility, more pronounced for Bitcoin. The positive skewness (0.1745 for Bitcoin and 1.2479 for Ethereum) shows that returns have more frequently experienced extreme upward movements, particularly in the post-COVID-19 context where interest in cryptocurrencies surged as a safe haven. The moderate kurtosis (between 1.48 and 2.31) indicates that returns had thinner tails than a normal distribution, but the Jarque-Bera statistic, associated with a 1% probability, confirms that these two prominent cryptocurrencies do not follow a normal distribution. This reflects frequent shocks, notably during the pandemic and amid geopolitical tensions (the war in Ukraine, conflicts in the Middle East).

The natural logarithm of the investor sentiment index (LISI) shows a negative mean value (-0.4178), suggesting a predominance of pessimistic sentiment among investors during our study period. However, the low standard deviation (0.5147) indicates that sentiment variations were not highly volatile. The slightly negative Skewness (0.2478) reflects the fact that investors were more frequently exposed to events that worsened their morale. This pessimistic sentiment aligns with the widespread fear and uncertainty caused by the global COVID-19 pandemic and major political crises. The Kurtosis above 2 (2.7548) reveals some extreme events strongly affecting investor morale, and an anomaly in this index is confirmed by the significance of the Jarque-Bera statistic at the 1% risk level.

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The natural logarithm of the cryptocurrency market sentiment index (LCMSI) shows a positive mean (1.2345) but with very high volatility (standard deviation of 1.7814). This reflects a market dynamic characterized by abrupt alternations between optimism and panic. The positive Skewness (0.8745) indicates that episodes of strong euphoria have been more frequent than sharp declines. This may be linked to rapid price surges related to announcements of financial support during the COVID-19 crisis and tensions surrounding cryptocurrency regulation (for example, crackdowns in China or discussions in the United States).

The natural logarithm of the geopolitical risk index (LGPRI) has a high mean value (1.7456) and a strong positive Skewness (1.4578), indicating that geopolitical risks have significantly increased over the studied period. The high Kurtosis (2.7184) points to the occurrence of numerous extreme events-such as conflicts, diplomatic tensions, and economic sanctions-that have intensified instability. This impact is explained by the pandemic exacerbating international rivalries, while new crises (e.g., the Russia-Ukraine war and instability in the Middle East) have continued to fuel uncertainty.

The descriptive statistical analysis of the variables referenced in our study reveals that cryptocurrency markets have been particularly sensitive to exogenous shocks related to the COVID-19 pandemic and geopolitical risks. Although Bitcoin and Ethereum exhibited an overall upward trend, this was accompanied by high volatility and extreme price movements. Investor sentiment was generally pessimistic, and geopolitical instability was marked by an overrepresentation of extreme risks. This situation suggests that, in an uncertain global context, digital assets act both as alternative safe havens and as amplifiers of market volatility.

3.2. Absolute and Relative Dependency Relationships

We analyze the absolute dependency relationships between the two main cryptocurrencies, the investor sentiment index, the cryptocurrency market sentiment index, and the composite geopolitical risk index. These various relationships, expressed in logarithms, are presented in Table 2.

Table 2. Variance-Covariance Matrix.

	LBITCOIN	LETHEREUM	LISI	LCMSI	LGPRI
LBITCOIN	**0.511*****	5.9145***	2.1471***	7.2145***	-6.4512***
LETHEREUM	5.9145***	**0.3419*****	4.2145***	7.8945***	-3.2457***
LISI	2.1471***	4.2145***	**0.2649*****	0.7845***	-3.6784***
LCMSI	7.2145***	7.8945***	0.7845***	**3.1734*****	-7.5641***
LGPRI	-6.4512***	-3.2457***	-3.6784***	-7.5641***	**2.3957*****

(***): Significance at the 1% risk level; (**): Significance at the 5% risk level and (*): Significance at the 10% risk level.

The Variance-Covariance matrix provides essential insights into the absolute relationships among the prices of Bitcoin, Ethereum, the sentiment indices (investor sentiment and cryptocurrency market sentiment), and the composite geopolitical risk index. First, the variances (located on the diagonal) show that Bitcoin (0.511) and Ethereum (0.3419) experience relatively moderate but still significant volatility for financial assets, confirming their risky nature but with less instability than sometimes perceived during extreme periods. The investor sentiment index (0.2649) and the cryptocurrency market sentiment index (3.1734) also exhibit volatility, with a higher intensity for the market sentiment index, likely amplified by uncertainties related to the COVID-19 pandemic and current geopolitical tensions. As for the geopolitical risk index (2.3957), its variance indicates substantial fluctuations in the global uncertainty climate.

The covariance results reveal strong and significant positive relationships between Bitcoin and Ethereum (5.9145), suggesting that these two main cryptocurrencies tend to move in the same direction in response to market shocks. This interdependence is also observed between Bitcoin and the cryptocurrency market sentiment index (7.2145), as well as between Ethereum and this index

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(7.8945). Thus, an improvement in market confidence generally leads to a coordinated rise in the prices of Bitcoin and Ethereum, which was particularly evident during market recoveries following the COVID-19 crisis and phases of monetary easing. The positive covariance of the investor sentiment index (LISI) with Bitcoin (2.1471) and Ethereum (4.2145) confirms that investor optimism is a key factor in the valuation of cryptocurrencies. Additionally, the covariance between LISI and the cryptocurrency market sentiment index (0.7845) remains positive, though somewhat lower, reflecting a dynamic where individual investor perceptions contribute to the overall market trend.

In contrast, the covariances between the geopolitical risk index (LGPRI) and the other variables are all negative and statistically significant. Bitcoin (-6.4512), Ethereum (-3.2457), investor sentiment (-3.6784), and cryptocurrency market sentiment (-7.5641) are all negatively correlated with geopolitical risks. This indicates that an increase in geopolitical tensions-whether due to the war in Ukraine, tensions in the Middle East, or global political instability exacerbated by the pandemic-causes a simultaneous decline in the prices of major cryptocurrencies as well as a weakening of positive investor and market sentiment. Overall, this matrix reveals that the cryptocurrency market is particularly sensitive to investor and overall market confidence, while being highly vulnerable to geopolitical risks. Recent events have shown that, despite their perception as alternative or "hedge" assets, cryptocurrencies remain exposed to the same instability dynamics as traditional financial markets.

We analyze the relative dependency relationships between the two main cryptocurrencies, the investor sentiment and cryptocurrency market sentiment indices, as well as the composite geopolitical risk index. These relationships are presented in Table 3 through the Pearson total correlation matrix.

Table 3. Pearson Total Correlation Matrix.

	LBITCOIN	LETHEREUM	LISI	LCMSI	LGPRI
LBITCOIN	1,0000	0,4157***	0,0245*	0,0718*	-0,0874*
LETHEREUM	0,4157***	1,0000	0,3478***	0,4718***	-0,7148***
LISI	0,0245*	0,3478***	1,0000	0,2718***	-0,5748***
LCMSI	0,0718***	0,4718***	0,2718***	1,0000	-0,6741***
LGPRI	-0,0874***	-0,7148***	-0,5748***	-0,6741***	1,0000

(***): Significance at the 1% risk level; (**): Significance at the 5% risk level and (*): Significance at the 10% risk level.

Table 3 presents the Pearson correlation Matrix between the prices of Bitcoin and Ethereum, the investor sentiment index (LISI), the cryptocurrency market sentiment index (LCMSI), and the composite geopolitical risk index (LGPRI). These correlations measure the strength and direction of the linear relationships among the different variables. First, the correlation between Bitcoin and Ethereum is positive and moderate (0.4157), confirming a dynamic co-movement between these two major cryptocurrencies. This means that when Ethereum rises, Bitcoin also tends to increase, although this relationship is not perfect. This parallel behavior is reinforced during periods of economic uncertainty and the search for financial alternatives, notably during the COVID-19 pandemic and current geopolitical tensions.

The correlation between Bitcoin and investor sentiment (0.0245), as well as with cryptocurrency market sentiment (0.0718), is very low and positive. This suggests that Bitcoin's price variations are relatively insensitive, in a direct linear sense, to individual or collective investor perceptions in the market. In contrast, Ethereum shows stronger correlations with these two sentiment indices: 0.3478 with the investor sentiment index and 0.4718 with the market sentiment index, indicating that Ethereum's price is more influenced by changes in market participants' confidence or optimism.

The results show consistently negative correlations between the geopolitical risk index (LGPRI) and the other variables. This index is negatively correlated with Ethereum (-0.7148), investor

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sentiment (-0.5748), cryptocurrency market sentiment (-0.6741), and, to a lesser extent, Bitcoin (-0.0874). These negative correlations indicate that an increase in geopolitical risks-such as those exacerbated by the Russia-Ukraine war or tensions in the Middle East-is associated with a decline in cryptocurrency prices and a deterioration in investor morale. The impact is particularly strong on Ethereum and overall market sentiment, reflecting an increased sensitivity of these variables to global instability contexts.

Overall, this matrix reveals that Ethereum is more sensitive to changes in investor sentiment and geopolitical risks than Bitcoin. It also highlights that geopolitical risks constitute a major source of stress for the entire cryptoasset market, impacting both prices and the perceptions of economic agents. This underscores the importance of considering these dimensions in any forward-looking analysis of the cryptocurrency market, especially in an uncertain international environment.

3.3. Non-Stationarity Tests

We examine non-stationarity at levels and in first differences using the Dickey-Fuller tests (1979-1981) applied to the two main cryptocurrencies, the investor sentiment index, the composite geopolitical risk index, and the cryptocurrency market sentiment index. The results of these tests are presented in Table 4.

Table 4. Dickey-Fuller tests (1979-1981).

	Lags	Model	In level		In first difference	
			T-Stat	Critical Values	T-Stat	Critical Values
LBITCOIN	2	M3	-1,2415	-1,9847	-7,8471	-1,9411
LETHEREUM	2	M2	-1,3587	-1,9814	-8,4589	-1,9847
LISI	1	M2	-1,1479	-2,0154	-8,7485	-2,2345
LCMSI	1	M3	-1,148	-2,4142	-4,6487	2,8641
LGPRI	1	M3	-1,4571	2,4142	-4,6025	-2,8641

The application of the Dickey-Fuller test (1979-1981) shows that all the variables studied-Bitcoin (LBITCOIN), Ethereum (LETHEREUM), the investor sentiment index (LISI), the cryptocurrency market sentiment index (LCMSI), and the composite geopolitical risk index (LGPRI) are non-stationary at levels. More specifically, the two cryptocurrencies (LBITCOIN and LETHEREUM) are found to be non-stationary at levels based on the Augmented Dickey-Fuller (ADF) test, each with an optimal lag length of two, while the three indices (LISI, LCMSI, and LGPRI) are assessed using the Dickey-Fuller test (1979) with one lag each. In all cases, the test statistics (T-Stat) at levels are greater than the MacKinnon (1996) critical values, preventing the rejection of the null hypothesis of non-stationarity. In contrast, after transformation by first differencing, all these variables become stationary, with their test statistics falling below the corresponding critical values. Thus, all these variables are integrated of the same order, namely order one (I(1)).

We examine non-stationarity at levels and in first differences while accounting for a possible endogenous structural break, using the Perron test (1998) applied to the various variables analyzed in our study. The results of this test, concerning the two main cryptocurrencies as well as the investor sentiment, cryptocurrency market sentiment, and geopolitical risk indices, are presented in Table 5.

Table 5. Perron test (1998).

	In level			In first difference		
	T-Stat	Critical Values	TB	T-Stat	Critical Values	TB

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LBITCOIN	-3,4187	-5,6457	2020 :7	-8,4785	-5,6457	2023 : 6
LETHEREUM	-3,7458	-5,6457	2021 : 8	-11,2578	-5,6457	2024 : 4
LISI	-4,6478	-5,6457	2020 : 4	--9,4875	-5,6457	2023 : 8
LCMSI	4,1248	-5,6457	2021 :9	-10,6584	-5,6457	2022 :11
LGPRI	-4,3254	-5,6457	2021 : 3	-9,1025	-5,6457	2024 :2

The Perron test (1998), which accounts for possible endogenous structural breaks, reveals that all the variables studied-Bitcoin (LBITCOIN), Ethereum (LETHEREUM), the investor sentiment index (LISI), the cryptocurrency market sentiment index (LCMSI), and the geopolitical risk index (LGPRI) are non-stationary at levels, even when considering internal structural shocks. Indeed, for all variables, the test statistics (T-Stat) at levels exceed the critical value of -5.6457, preventing rejection of the null hypothesis of non-stationarity. This indicates that each of these variables follows a stochastic trend with a potential break but remains overall non-stationary in its raw level. Regarding the detected break dates (TB), they cluster around the 2020–2021 period, corresponding to major events such as the COVID-19 pandemic and the onset of global geopolitical tensions (notably the beginning of economic disruptions linked to increased risks).

After applying the first difference, all these variables become stationary: the test statistics fall well below the critical value of -5.6457. This means that, once the trend is removed, the series stabilize around their mean and are therefore integrated of order one (I(1)), even in the presence of structural breaks. The new break dates detected after first differencing (TB) are more recent (mostly between 2022 and 2024), aligning with recent events such as the escalation of geopolitical tensions (for example, the Russia-Ukraine war, the Hamas-Israel conflict, etc.) and post-pandemic economic adjustments. This confirms that these events have had a significant impact on the dynamics of cryptocurrencies and market sentiment.

3.4. Estimating and Adjusting Long-Term Relationships

We examined the non-stationarity of the different cryptocurrencies, the investor sentiment index, the cryptocurrency market sentiment index, and the geopolitical risk index using the Dickey-Fuller tests (1979-1981) and the Perron test (1998). After applying the first difference, all these variables became stationary, indicating that they are integrated of order one. We will then proceed to estimate the long-term relationships using the Ordinary Least Squares (OLS) method, following the two-step procedure of Engle and Granger (1987). This approach will involve linking the natural logarithm of the price of Bitcoin or Ethereum to the logarithms of the sentiment indices and the logarithm of the geopolitical risk index. The two reference models are presented below, along with the estimation results shown in Table 6.

$$Log(Bitcoin_t) = \alpha + \beta_1 Log(ISI_t) + \beta_2 Log(CMSI_t) + \beta_3 Log(GPRI_t) + \varepsilon_t \quad (1)$$

$$Log(Ethereum_t) = \alpha + \beta_1 Log(ISI_t) + \beta_2 Log(CMSI_t) + \beta_3 Log(GPRI_t) + \varepsilon_t \quad (2)$$

Table 6. Estimation of each long-term relationship.

	LBITCOIN		**LETHEREUM**	
	Coefficients	**T-Statistiques**	**Coefficients**	**T-Statistiques**
Constant	0,3124	4.2589	0.5412	6.4527
LISI	0,8759	3.6586	0.6452	4.5234
LCMSI	0,5892	4.2143	0.4238	5.2483
LGPRI	1,6273	6,6939	1,7824	7.5842

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Residual Stationarity									
	Lags	**Model**	**T-Stat**	**Critical**		**Lags**	**Model**	**T-Stat**	**Critical**
Residues	1	M2	-4.5234	-2,8642	Résidus	2	M2	-3.2574	-1,9411

The estimation of these long-term relationships using the ordinary least squares (OLS) technique reveals that the above models linking the logarithm of Bitcoin and Ethereum prices to the various logarithmic indices referenced in our study are globally significant. The constants are positive for both digital assets, suggesting the existence of a base price level independent of fluctuations in the considered indices. Regarding the effect of investor sentiment (Log(ISI)), the results indicate a positive and significant impact on both Bitcoin and Ethereum prices. This suggests that an improvement in investor sentiment promotes price increases for these two major cryptocurrencies. Similarly, the overall cryptocurrency market sentiment (Log(CMSI)) exerts a positive and significant influence on Bitcoin and Ethereum prices, reflecting the importance of broader market conditions in price dynamics.

The validity of cointegration was tested through the examination of the stationarity of the residuals. For Bitcoin, the test indicates that the residuals are stationary with a t-statistic of -4.5234, which is lower than the critical value of -2.8642, confirming the existence of a stable long-term relationship between Bitcoin and the logarithms of these indices. Similarly, for Ethereum, the t-statistic of -3.2574 is below the critical value of -1.9411, indicating that the residuals are stationary at level. Thus, these long-term relationships are validated for both Ethereum and Bitcoin according to the Engle and Granger (1987) procedure.

We study the long-term adjustment of each relationship estimated by the OLS method within an error correction model (ECM) regressed using this technique. The results are presented in Table 7.

Table 7. Estimation of the ECM model.

	ΔLog(Bitcoin)		**ΔLog(Ethereum)**	
	Coefficient	**Prob**	**Coefficient**	**Prob**
Constant	0.2147	0.0012	0.3457	0.0006
ΔLog(ISI)	0.1245	0.0074	0.2457	0.0021
ΔLog(CMSI)	0.4127	0.0014	0.5127	0.0014
ΔLog(GPRI)	0.5014	0.0013	0.3245	0.0021
Residus$_{t-1}$	-0.2341	0.0004	-0.3214	0.0021

The error correction model (ECM) was estimated to examine the short-term dynamics between the logarithmic changes in Bitcoin and Ethereum prices and the changes in their referenced indices. The analysis of the results indicates that all estimated coefficients are statistically significant at the 5% level, as shown by the associated p-values. The constant term is positive for both models (0.2147 for Bitcoin and 0.3457 for Ethereum), suggesting that in the absence of changes in these indices, there is an intrinsic upward short-term price trend. Regarding the first-difference logarithmic investor sentiment, the results reveal a positive and significant effect on the returns of both Bitcoin and Ethereum. This confirms that improvements in investor sentiment support the positive short-term price dynamics. The first-difference logarithmic cryptocurrency market sentiment also positively influences price changes, with coefficients of 0.4127 for Bitcoin and 0.5127 for Ethereum, both significant at 1%. These findings highlight the importance of the overall market environment in determining monthly price fluctuations.

The coefficients associated with the lagged residuals, or adjustment speeds (Residus$_{t-1}$), are negative and significant for the returns of both Bitcoin and Ethereum. This property confirms the

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existence of a long-term equilibrium adjustment mechanism: in the event of a deviation from the long-term relationship, about 23% of the deviation in Bitcoin returns and 32% in Ethereum returns are corrected in the following period. The higher the coefficient in absolute value, the faster the adjustment speed towards equilibrium, which appears to be more pronounced for Ethereum.

In this study, we adopt the multivariate approach of Johansen (1990) to identify the cointegration space between these cryptocurrencies and the indices by using the trace and maximum eigenvalue tests. Table 8 presents the results of these tests for each of the analyzed cryptocurrencies, based on the sentiment and geopolitical risk indices considered. This approach allows us to determine the number of cointegrating relationships existing among the studied cryptocurrencies.

Table 8. Johansen Co-integration Tests (1990).

	Test λ_{trace}			**Test** $\lambda_{\max}$		
(Log(Bitcoin) ; Log(ISI) ; Log(CMSI); Log(GPRI))						
Null hypothesis	r=0	$r \leq 1$	$r \leq 2$	r=0	r=1	r=2
Alternative hypothesis	$r \geq 1$	$r \geq 2$	$r \geq 3$	r=1	r=2	r=3
LR- Statistics	**57.2431**	40.2457	35.2487	33.2781	25.3471	20.4712
Critical value at 5%	**46.3451**	42.5437	37.5784	32.5471	28.7841	22.7412
(Log(Ethereum) ; Log(ISI) ; Log(CMSI); Log(GPRI))						
Null hypothesis	**r=0**	$\mathbf{r} \leq 1$	$\mathbf{r} \leq 2$	**r=0**	**r=1**	**r=2**
Alternative hypothesis	$\mathbf{r} \geq 1$	$\mathbf{r} \geq 2$	$\mathbf{r} \geq 3$	**r=1**	**r=2**	**r=3**
LR- Statistics	**32,4801**	**28,8102**	**33,4875**	**53,6699**	**45,3228**	**25,3878**
Critical value at 5%	**30,8189**	**37,8561**	**39,7971**	**33,8769**	**57,5843**	**31,1316**

Table 8 presents the results of the Johansen (1990) cointegration tests applied to Bitcoin and Ethereum based on the investor sentiment index (ISI), the cryptocurrency market sentiment index (CMSI), and the geopolitical risk index (GPRI). We confirm the existence of a single cointegrating relationship for each cryptocurrency with respect to these indices according to both the trace test and the maximum eigenvalue test. We use the maximum likelihood procedure to estimate the vector error correction model (VECM) for each cryptocurrency based on the investor sentiment indices, the cryptocurrency market sentiment, and the geopolitical risk index. The results of this estimation are presented in Table 9.

Table 9. Estimation of VECM using the maximum likelihood technique.

The variables	**Normalized Co-integrating Vectors (matrix** β**)**		**Error correction coefficients (matrix** α **)**	
	Coefficients	**Coefficients**	**Coefficients**	**Coefficients**
Log(BITCOIN)	1.000000		-0.7451***	
Log(ETHEREUM)		1.000000		-0.6451***
Log(ISI)	-0.7124***	-0.6584***	-0.6875***	-0.5105***

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Log(CMSI)	-0.3214***	-0.2748***	-0.3415***	-0.2874***
Log(GPRI)	-0.4517***	-0.4537***	-0.2287***	-0.3241***

(***): Significance at the 1% risk level; (**): Significance at the 5% risk level and (*): Significance at the 10% risk level.

Table 9 presents the results of the estimation of the vector error correction model (VECM) using the maximum likelihood technique. Two types of information are reported: the normalized cointegration vectors and the error adjustment coefficients. Regarding the normalized cointegration vectors, we observe that the prices of Bitcoin and Ethereum are each normalized to 1. The coefficients associated with the other variables (logarithms of the investor sentiment index (ISI), the cryptocurrency market sentiment index (CMSI), and the geopolitical risk index (GPRI)) are all statistically significant at the 1% level. More specifically, for Bitcoin, the ISI has a positive coefficient of 0.7124, the CMSI 0.3214, and the GPRI 0.4517. This indicates that, in the long term, an increase in these indices is associated with a rise in the price of Bitcoin. Similarly, for Ethereum, the coefficients are also positive (0.6584 for ISI, 0.2748 for CMSI, and 0.4537 for GPRI), showing a positive long-term relationship between these factors and the price of Ethereum.

The adjustment coefficients (error correction matrix) are negative and significant for both cryptocurrencies. The adjustment coefficient for Bitcoin is -0.7451, and for Ethereum, it is -0.6451. This indicates that when a deviation from the long-term equilibrium occurs, approximately 74.51% of this deviation is corrected in the following period for Bitcoin, and 64.51% for Ethereum. These negative and significant coefficients confirm the stability of the system: the prices of Bitcoin and Ethereum tend to converge back to their long-term equilibrium after a shock. Overall, the VECM model not only reveals the existence of stable long-term relationships between the cryptocurrencies and the sentiment and geopolitical risk indices but also shows a strong dynamic correction of short-term deviations toward this equilibrium.

4. General Conclusion

In an international context marked by escalating geopolitical tensions and high volatility in financial markets, our study focused on analyzing the combined impact of geopolitical risks and investor sentiment on the main cryptocurrencies, namely Bitcoin and Ethereum. By employing a rigorous econometric approach based on unit root tests, cointegration tests, and the estimation of error correction models (ECM and VECM), our analysis sheds light on the complex dynamics linking these variables over the period from December 1, 2020, to the end of April 2025.

Our main results highlight the existence of stable long-term relationships between the prices of Bitcoin and Ethereum and the investor sentiment indices, the cryptocurrency market sentiment index, as well as the composite geopolitical risk index. The Engle and Granger tests, along with the multivariate Johansen approach, confirm cointegration among these variables, reflecting a structural interdependence in an unstable economic environment. In the short term, the ECM models reveal that changes in investor sentiment, cryptocurrency market sentiment, and geopolitical risks significantly influence the monthly returns of Bitcoin and Ethereum, with rapid adjustments toward the long-term equilibrium (approximately 23% for Bitcoin and 32% for Ethereum in each period).

In economic terms, these results confirm that cryptocurrencies are not completely decoupled from global geopolitical and emotional factors, contrary to some idealized views. While they can serve as safe-haven assets during major international tensions, their behavior remains strongly conditioned by investor psychology and overall risk perceptions. Moreover, our findings indicate that Ethereum appears slightly more sensitive than Bitcoin to changes in sentiment and geopolitical risks, possibly due to its different market structure and more diversified investor base.

However, our study presents certain limitations that should be highlighted. First, the analysis relies on composite indices to measure investor sentiment and geopolitical risks, which, although useful, may lack granularity and fail to capture all the qualitative dimensions of these complex

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phenomena. Second, our approach remains essentially linear, which could underestimate potential nonlinear or asymmetric dynamics, such as exaggerated reactions during extreme shocks. Third, the analysis period, although fairly extensive, could be further enriched by continuously updating the data to account for major geopolitical events occurring after 2025.

Moreover, certain specific characteristics of cryptocurrency markets, such as the strong influence of technological innovations (protocol updates, new DeFi projects, government regulations), have not been explicitly integrated into our model, although they can moderate or amplify the effects of geopolitical risks and investor sentiment. From this perspective, several future directions deserve consideration. First, incorporating alternative measures of sentiment by leveraging AI-driven sentiment analysis applied to real-time social media data would refine the understanding of investor behavior. Second, developing nonlinear models, such as threshold cointegration models or regime-switching models (Markov Switching VECM), could better capture the complexity of market reactions during periods of high instability. Finally, extending the analysis to other cryptocurrencies (altcoins) as well as to specific sectoral indices (DeFi, NFT, stablecoins) would be an interesting avenue to test the robustness of our results across other segments of the crypto-asset market.

Overall, our study contributes to a better understanding of the exogenous factors affecting cryptocurrencies and highlights the need for a multidimensional approach that combines financial analysis, investor sentiment, and geopolitical risks to grasp the dynamics of these rapidly evolving markets. In an increasingly unpredictable world, this understanding becomes essential for investors, regulators, and researchers seeking to navigate the new frontiers of digital finance.

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