The Impact of Environmental Consciousness and Policy Uncertainty on Cryptocurrency Market Fluctuations

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Abstract: - Cryptocurrencies represent a major financial innovation, offering an alternative to traditional monetary systems, but they spark debate due to their environmental impact and regulatory challenges. This groundbreaking study explores the intricate dynamics shaping the cryptocurrency market, employing an ARDL model to examine the Nasdaq Cryptocurrency Index from April 2021 to January 2023. By integrating novel variables based on media data analysis like the Uncertainty Cryptocurrency Policy Index and the Cryptocurrency Environmental Attention Index, our analysis offers a unique perspective on this evolving market. Our findings reveal captivating dynamics such as the short-term self-reinforcing nature of the market, the immediate impact of policy uncertainty, and the enduring influence of environmental concerns. This pioneering research paves new ways to understand and anticipate the future of cryptocurrencies, at the crossroads of financial innovation and sustainability challenges. This research illuminates the interplay between financial innovation and sustainability challenges, providing crucial insights for understanding and anticipating the future of cryptocurrencies.

Key-Words: - Political uncertainty, Environmental attention, Cryptocurrency Index, Autoregressive Distributed Lag model, Short-term effect, Long-term effect

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1 Introduction and Research Framework

Every day, our world uses a vast amount of energy that powers our lives but leaves a lasting impact on our planet. This energy usage fundamentally alters the Earth's atmosphere. With rising global temperatures and increasing extreme weather events, the relationship with energy is central to an unprecedented challenge in how to satisfy the demands of a growing global population while maintaining the delicate balance of the ecosystem. In light of the effects of global warming and the increase in extreme weather like the increase in the world average temperature to 2 °C, climate change presents a significant obstacle to the sustainable development of the global economy and society, [1]. Consequently, countries have implemented climate policies to mitigate global warming by reducing carbon emissions, [2], [3].

A long-term unidirectional relationship between energy consumption and greenhouse gas emissions from 1975 to 2011 was identified and showing that energy consumption drives emissions and influences GDP, supporting the energy-led growth hypothesis, [3]. However, reducing energy consumption could harm GDP. Climate change is a global issue, and China aims to peak carbon emissions by 2030 and reach carbon neutrality by 2060 as part of its "dual carbon" strategy. Economic disparities and government intervention impact energy carbon emission efficiency in Chinese cities, while science and education levels have a negative effect, [4]. Fossil fuels worsen climate change, while renewable energy mitigates it. They recommend prioritizing renewable energy, enhancing efficiency, and implementing carbon pricing to achieve sustainable development, [5].

Thus, adapting to climate change, while achieving sustainable growth, is a global concern. However, a new area of research is emerging with the development of the concept of cryptocurrency which represents a major financial innovation, offering an alternative to traditional monetary systems. This innovative model appeals to many investors and users who see it as a means to break free from the control of traditional financial institutions. Cryptocurrencies have generated a lot of discussion because of their impacts on environmental sustainability and regulatory frameworks. The environmental discourse focuses on their energy use and carbon emissions, particularly in mining activities. This aspect is a cause of concern in terms of the environment, the sustainability of the sector in the long run, and the practices of sustainability within the industry. From the regulatory perspective, cryptocurrencies are threatening the conventional financial infrastructure and policies, which, in turn, has reignited the discourse on the protection of investors, the stability of financial systems, and the need to have new regulations for digital assets, [6]. These debates are significant as they highlight the multifaceted role of cryptocurrencies in the current global economy that is undergoing constant change and therefore requires a balanced consideration of the various effects that these digital assets may have. Cryptocurrencies which are currencies based on cryptography within the global economy are growing at an exponential rate. Blockchain is considered to have the potential to increase the energy consumption of cryptocurrencies mining, [7]. The effects of cryptocurrencies and blockchain technology on energy conservation and sustainable development need to be well understood. The mining efficiency of different cryptocurrencies is related to use algorithms, [8]. The results show that the algorithm selection is crucial to the mining efficiency. Also, they calculate the global electricity consumption and carbon emissions from Monero mining and the numbers are quite staggering for the year 2018. There are great variations in the energy consumption of different cryptocurrencies based on their consensus mechanisms, with Proof of Work being the most energy-demanding, [5]. Some cryptocurrencies with more efficient algorithms have energy consumption levels that are comparable to those of traditional payment systems such as Visa and Mastercard. The findings underline that most projects are already producing a lot less CO2 than Bitcoin. Through widening consensus algorithms and encouraging mining to occur using renewable energy, cryptocurrencies' ecological footprint can significantly decrease. Based on hardware efficiency evaluation, transitioning to Proof-of-Stake (POS) algorithms and using renewable energy can lower energy consumption, improve mining processes, and increase profitability, [7].

This thematic evolution is validated by a bibliometric analysis from the Scopus database, focusing on English research articles while excluding non-English papers, reviews, and conference materials, [9]. The analysis highlights the rise of cryptocurrency in global finance, emphasizing its decentralized nature and lack of centralized oversight. However, concerns about the environmental impact of the energy-intensive process of crypto mining are raised. In fact, an additional environmental debate has been added to the discussion on cryptocurrencies. The ecological impact of cryptocurrencies, particularly concerning energy consumption and carbon emissions related to the mining process, is increasingly being scrutinized, [10]. The emergence of cryptocurrencies, particularly Bitcoin, has sparked growing interest in their environmental impact, mainly due to the high energy consumption associated with the "mining" process, especially for cryptocurrencies using the proof-of-work (PoW) consensus mechanism. , CO_2 emissions from Bitcoin alone could lead to a 2°C increase in global warming within less than thirty years, [11], [12]. Although this study has been criticized for its assumptions, it highlighted the potential magnitude of the problem. [13] examine how cryptocurrency volume, GDP, and energy consumption affect environmental sustainability in the top 20 countries actively involved in the cryptocurrency sector, using CO_2 emissions as a key indicator. The findings confirm a bidirectional causal link between environmental degradation and cryptocurrency volume, as well as a unidirectional relationship with GDP and energy consumption. Crypto-trading, energy consumption, and GDP are causally linked to electronic waste production, widening environmental challenges and social inequalities. To mitigate these impacts, the study advises the substitution of high-consuming-energy blockchain technology with green technology and the implementation of green fiscal policies to abate CO2 emissions. To address these issues, the industry is seeking greener alternatives. In the context of these issues, several solutions have been proposed. such us introducing some carbon taxes on cryptocurrency as a means of promoting more environmentally friendly methods, [14]. Others suggest tighter controls on mining operations in areas that are fossil fuel-reliant, [12].

Cryptocurrency's environmental impact is a priority and changing concern. As high energy usage and electronic waste produced by mining are sharp concerns in cryptocurrencies, research and innovation offer the promise of greener alternatives. Migration to low-energy consumption consensus protocols such as Proof of Stake (PoS) and regulation policy enforcement can transform cryptocurrencies' ecological future significantly. Along with industry expansion, the balancing act between innovation and sustainability will prove to be necessary to attain sustainable digital currency,

[15]. Increased environmental awareness has been evident from social media reports on the impact of cryptocurrencies on the environment. With this raised awareness, a Cryptocurrency Environment Attention Index (ICEA) was introduced, which is an improved measure for digital asset market analysis, [2]. By quantifying market attention and sentiment, it provides investors, researchers, and policymakers with insightful information in the very complex cryptocurrency universe, [16]. As the market continues to evolve, tools like the ICEA will increasingly be utilized to comprehend and forecast cryptocurrency market behavior further. It was conceived to meet the growing need for robust market sentiment indicators in the highly volatile cryptocurrency space, as traditional financial metrics often fail to capture the nuances of this digital asset class, [17]. The ICEA incorporates key components such as social media analytics, search engine trends, news sentiment analysis, trading volumes and significant regulatory events, using advanced natural language processing and machine learning algorithms to process and analyze data in real-time, [2], [18], [19]].

The cryptocurrency policy continues to be the subject of serious discussion. Since the introduction of Bitcoin in 2009, the cryptocurrency market has been characterized by high volatility and uncertainty. This literature review synthesizes current research on the sources and implications of uncertainty in this rapidly evolving market. Among the major expressions of uncertainty is price volatility. prices of Bitcoin are prone to jumps typical of volatile emerging markets, which contributes to their unpredictable nature [20] and [21] observed regime shifts in Bitcoin volatility, with different levels of uncertainty over time. Market uncertainty is also sourced from regulatory uncertainty. [22] depicted how cryptocurrency prices react sensitively to news regarding regulatory actions and elaborated on how regulatory uncertainty affects investor moods and market dynamics . Technological risk adds an element of uncertainty as susceptible weaknesses attacks and divergence risk in blockchain-based currencies, [23].

This assumption was discredited by Conlon and McGee (2020) during the COVID-19 pandemic with regard to Bitcoin volatility during periods of global crises. Investor sentiment and speculations further drive uncertainty into the markets, [24]. Bitcoin returns are attributed to a series of uncertainty metrics such as the VIX index and economic policy uncertainty and studied how investor attention affects Bitcoin returns and volatility, [25]. There is also market manipulation. [26] present evidence for manipulative trading activity and [27] examine the effect of Tether issuance on Bitcoin price and raise question about price formation integrity testing. Moreover, the new interactions between traditional financial markets and cryptocurrencies are uncertain. [28] presented some evidence of cryptocurrencies' relative distance from conventional financial systems, whereas more recent findings with an increasing correlation in crisis periods between cryptocurrency and conventional markets . In fact, [29] have established evidence of a dominant trend inthe behavior of cryptocurrencies in financial crises. Their study, in this case, during the COVID-19 pandemic, showed a sharp rise in correlations among cryptocurrencies, notably Bitcoin, and strained conventional financial markets. This contrasts with the typical expectation that cryptocurrencies are havens in times of crisis. Rather, it shows the presence of an influence of contagion of finance where volatility in conventional markets overflows into cryptocurrencies. Such a relationship is of significance to material portfolio diversification and risk management and conceivably represents the maturity of the crypto market increasingly integrated into the world financial system. Such evidence raises testing questions of financial stability and regulatory issues, and possible directions for future research on the long-run evolution of such relationships in various economic settings.

This literature review indicates that cryptocurrency uncertainty is a result of a compound interaction between inherent market volatility, regulatory uncertainty, technology risk, investor sentiment, and new relationships with conventional financial markets. a new cryptocurrency uncertainty index was developed using recent media coverage analysis, [30]. The new index provides new insights into cryptocurrency market dynamics and investor sentiment. It has two distinct sub-indices, each of which measures a distinct class of uncertainty: cryptocurrency uncertainty price, which is a measure of price uncertainty, a measure of price volatility, and market value uncertainty and thereby receiving a glimpse of investor and market sentiment expectations, and Uncertainty Cryptocurrency Policy (UCPI), which measures uncertainty related to cryptocurrency policy and regulation, measures concern with regards to the likelihood of regulatory direction change, government interference, and changing bases of society law. The authors show that the uncertainty index follows closely and positively movement based on significant events in the life of cryptocurrencies. Movement may be of the type of spikes in uncertainty following major regulation releases, hacking of exchanges, or the initial emergence of new blockchain breakthroughs. The new approach is a helpful measure and tool for studying uncertainty in the crypto domain for researchers, investors, and policy-makers at large. The uncertainty index can be employed as a leading indicator that can predict market movements, measure policy impacts, and learn more about the complex behavior of the cryptocurrency with the growth of the crypto market, it is important to learn more about such dynamics and their impact on investors, regulators, and the entire financial system. [31] indicate issues with choosing specific cryptocurrencies because of decentralization, irrational valuation, and extreme price fluctuations. They suggest crafting an appropriate cryptocurrency index in order to identify overall market patterns. The Nasdaq Cryptocurrency Index (NCI) is an important milestone toward the inclusion of cryptocurrencies within the wider financial system. In offering a standardized measure of digital asset performance, it is an important tool for investors, researchers, and market participants alike. As the market of cryptocurrency continues to mature, the NCI will increasingly be at the center of our analysis and interaction with this rapidly evolving space. The launch of the Nasdaq Cryptocurrency Index (NCI) is a significant milestone toward the development of the cryptocurrency market. It performs a significant role as a market benchmark, the NCI provides a standardized way of measuring the general performance of the cryptocurrency market [32], and much like the S&P 500 does for the stock market, [33]. As an investment tool, the index can serve as a basis for products, potentially making cryptocurrency investments more accessible to a wider class of investors. For risk management, the NCI provides a comprehensive view of the market, allowing for risk assessment and portfolio management by investors and institutions that trade in cryptocurrencies.

In addition, the backing of a well-known institution like Nasdaq lends credibility to the cryptocurrency market, which may encourage additional mainstream investment and adoption. However, the NCI is subject to challenges common in the crypto market, including an undue degree of volatility, whose composition and value can change quickly [34], regulatory uncertainty, whose changing regulation can affect constituents and calculation of the index [22] and fear brought about by market manipulation, as it has been found that the crypto market is vulnerable to manipulation, [26]. The highly unstable and quick-moving character of the cryptocurrency market [35], [36] has created indexes such as the Nasdaq Cryptocurrency Index (NCI), the Cryptocurrency Environmental Attention Index (ICEA), and uncertainty indices, each of which reflects the unique character of market dynamics.

The ICEA reflects the sentiment and attention of the public; it often serving as a prediction of upcoming price action for the NCI, which graphs prominent cryptocurrencies. Attention periods that are reflected through the use of the ICEA tend to precede cryptocurrency price action, and this explains the impact that public sentiment exerts on cryptocurrency pricing. Market uncertainty, measured by the Uncertainty Cryptocurrency Policy Index (UCPI) [30], is related to higher public interest and higher volatility of the cryptocurrency, a sign of feedback. News about regulations, one of the most influential elements of the ICEA, has a major impact on market uncertainty and the performance of the cryptocurrency as captured through the NCI. The NCI, by market capitalization and liquidity, correlates with trading volume, commonly currying during heightened environmental attention periods as gauged by the ICEA. While the NCI is an indicator of long-term market behavior, the ICEA and uncertainty indicators are measures of short-term volatility and show the extent to which sentiment is being translated into price trends. The relationships between these indices also cast suspicion upon the efficiency of markets, in light of the ICEA's explanatory power of the NCI movement, implying the cryptocurrency market still is inefficient. The newness of the market of cryptocurrencies provides an explanation for this inefficiency, as attested to by demands for integrated models to describe market behavior from a more comprehensive perspective. Composite analysis of such indices helps investors and risk managers make informed choices as it highlights the need to quantify public perception rather than market performance and perceived risk in the new crypto landscape. A composite study of the cryptocurrency markets, environmental focus, and policies regarding cryptocurrency issues is suggested in this article.

By using a dynamic approach, we seek to investigate how policy debates and environmental concerns in the media affect the heterogeneity of the market price of cryptocurrencies. This study also seeks to identify how public and government concerns about the environmental aspect of cryptocurrency mining and transactions affects market behavior. Analysis would take into consideration several variables such as media attention reflecting the state of awareness by the public as well as the policy uncertainty index, to understand the interactions amongst these factors, in a generalized manner. Such analysis in its proposed ARDL model form presents a detailed and comprehensive insight regarding the complicated interaction amongst the state of environment focus, uncertainty, and price fluctuation within the cryptocurrency market. The results may contribute to theoretical insight and common practice in cryptocurrency market analysis, investment, and policy formation. Our paper's organization is the following: we start with a literature review, and then come a detailed presentation of theory and methodology. Afterward, an analysis and discussion of the results are given. Finally, an overview of our results and implications is presented.

2 Theoretical Framework and Methodology

The ARDL model is an excellent advancement over econometric modeling, with a full methodology to handle short-run deviations and long-run equilibrium relationships. The model is extremely useful and insensitive, hence a darling in contemporary economic research and policy-making. The fact that the ARDL model can handle multiple structural breaks has made it fashionable in energy economics [37], financial economics [38], and environmental economics [39]. Its ability to handle complicated dynamics and cointegration relationships makes it a useful tool for policymakers and researchers alike.

Autoregressive Distributed Lag (ARDL) is a highly intricate dynamic model where the dependent variable is defined as a function of its own past values, along with current and previous values of other explanatory variables, [40]. It overcomes severe benefits of less complex non-dynamic models with the inclusion of time dynamics and thus helps to provide higher accuracy for predictions as well as better decision effectiveness. The most desirable attribute of the ARDL model is that it can analyze both short-run and long-run relationships between the variables as well as cointegration. This is especially beneficial in economics since economic variables are likely to hypothesize long-run equilibrium relationships with short-run deviations, [41].

The ARDL model can be estimated for series integrated at different orders (orders I(0) and I(1)), [42]. The model is not for series integrated to more than order 1, again stressing unit root testing must be done beforehand. The Bounds test, initially developed in [42], is the pillar of the ARDL methodology determining the cointegration relationship among a series of differing orders of integration. It provides two critical values: the lower bound for strictly I(0) and the upper bound for strictly I(1). The error-correction term of the ARDL model investigates the presence of a cointegration relationship. A value, less than one in absolute value, verifies such a relationship, linking short-run behavior to long-run equilibrium.

The ARDL model subsequently combines the merits of two models, i.e., the Distributed Lag model and the autoregressive model.

To its credit, the AR model allows the dependent variable to be defined in terms of its delayed values, the rationale for which there is a title "autoregressive", to be a regression of a variable on its lagged values. The DL model, on the other hand, is based on the fact that the endogenous variable is a function of the explanatory variable and its lags. The "Delayed Lag" nomenclature explains that the immediate short-run effect of the explanation variable on the explained variable varies from its long-run effect. This combination provides the entire theoretical framework to test sophisticated economic relationships. Practically speaking, the best number of lags has to be estimated. This is most commonly done through the use of information criteria, i.e., the Akaike Information Criterion (AIC) or Schwarz Information Criterion (SIC), [41]. These criteria ensure the most efficient model specification. The ARDL model allows expression the dependent variable y as a function of the independent explanatory variable X and lagged dependent variable and lagged independent variables thus the general equation:

$$\Delta y_t = \alpha + \sum_{i=1}^{p} \beta_{1i} \Delta y_{t-i} + \sum_{i=1}^{q} \beta_{2i} \Delta X_{t-i} + \gamma_1 y_{t-1} + \gamma_2 X_{t-1} + \varepsilon_t \quad (1)$$

where:

- Δ : the first difference operator
- α : the intercept
- β_1, β_2 : the short-term impacts of the variables y and X , respectively
- γ_1, γ_2 : the long-term dynamics of the variables y and X, respectively
- ε : independent and identically distributed error term (white noise)
- p : number of delays of the dependent variable y.

- q : the number of delays to be specified for the explanatory variable.

The research aims to contribute extensively to the understanding of the effect of social media on cryptocurrency market dynamics through use of the Autoregressive Distributed Lag (ARDL) to examine the dynamic interaction among the Cryptocurrency Environmental Attention Index (ICEA), Nasdaq Crypturrency Index (NCI) and Uncertainty Cryptocurrency Index. Conception of the interplay between such indexes can guide regulatory policy so that policymakers can predict how changes in sentiment and uncertainty in the market will affect the prices of cryptocurrencies. This research can reveal how attention from investors as seen on social media is converted into market uncertainty and ultimately into prices, offering insightful information on investor behavior in cryptocurrency markets, [38]. Such an approach provides some new insights.

In actuality, utilizing the ARDL model on such specified cryptocurrency indices, the current research presents a novel framework of methodology for crypto-asset analysis that can be supplemented by higher-order econometric analyses in the future. The ARDL model facilitates an investigation of both the short-run dynamics and long-run equilibrium relationship between these indices, [42]. This approach is imperative in the fast-changing world of cryptocurrency, where short-term trends can vastly diverge from long-term directions. This study will be a priceless contribution to existing knowledge about the dynamics of cryptocurrency markets because it uses the ARDL model to analyze the relationship between the Nasdaq Cryptocurrency Index (NCI), the Cryptocurrency Environmental Attention Index (ICEA), and the Uncertainty Cryptocurrency Policy Index. This relationship can be written as follows:

$$\Delta NCI_t = \alpha + \sum_{i=1}^{p} \beta_{1i}\, \Delta NCI_{t-i} + \sum_{i=1}^{q} \beta_{2i}\, \Delta ICEA_{t-i} + \sum_{i=1}^{r} \beta_{3i}\, \Delta UCPI_{t-i} + \gamma_1 NCI_{t-1} + \gamma_2 ICEA_{t-1} + \gamma_3 UCPI_{t-1} + \varepsilon_t \quad (2)$$

- Δ : the first difference operator
- α : the intercept
- β_1, β_2 ,β_3 : short-run impacts of the variables NCI, ICEA and UCPI , respectively
- γ_1, γ_2, γ_3 : long-term adjustments of the variables NCI, ICEA and UCPI, respectively
- ε : independent and identically distributed error term (white noise)
- p : number of lags of the dependent variable NCI.
- q, r : number of lags for the explanatory variables ICEA and UCPI, respectively.

This model utilizes April 18, 2021, to January 15, 2023, spanning a period of 92 weekly observations.

All variables are available online using the below links:

- ICEA, UCPI, [43]
- NCI, [44]

The above sources furnish the full data required for considering market movement, policy uncertainty, and environmental challenges in the given time period.

3 Empirical Analysis and Finding

Table 1 reports that the status of stationarity has been rigorously confirmed for all three datasets at the level, ensuring each series remains stable over time. This test is pivotal in ensuring the validity and reliability of further analysis as it ensures that the mean and variance properties of the series are a function of time and therefore constant over time. This enables proper modelling and forecasting using data.

Table 1. ADF test for stationarity at level (Lag Length=0)

	t-Statistic	Prob. (p-value)
NCI	-9.134607	0.0000
UCPI	-3.788253	0.0043
ICEA	-63.68436	0.0001
Test critical values:	1% level	-3.503879
	5% level	-2.893589
	10% level	-2.583931

In addition, The F-Bounds test result (Table 2) indicates that the variables are co-integrated, meaning they have a significant long-term relationship. This is important to econometric modelings, it allows testing for long-run relations between variables even though they could move in the short run. Also, the CointEq(-1) coefficient of -0.960677 in the most suitable ARDL(1, 1, 4) model based on the Akaike Information Criterion (AIC) has some serious implications on the cryptocurrency market dynamics. Its negative sign and apparent statistical significance indicate a long-run equilibrium relationship between the Nasdaq Cryptocurrency Index (NCI) and explanatory variables Uncertainty Cryptocurrency Policy Index (UCPI) and Cryptocurrency Environmental Attention Index (ICEA) (Table 2). This coefficient indicates that the system is rapidly correcting deviations from equilibrium, with some 96.07% of any imbalance in the previous period being corrected in the current period. Such rapid adjustment underscores the market's resilience and efficiency in incorporating new information, particularly regarding shifts in political uncertainty and environmental concerns. For investors, this implies that opportunities for short-term arbitrage based on market imbalances may be fleeting, as the market quickly adjusts.

Table 2. Optimal Model Description

Selected Model: ARDL(1, 1, 4) Model selectionmethod:Akaike info criterion (AIC)					
The existenceo f a run long-term relationshi p	F-Bounds Test				
	Test Statistic	Value	Signif.	I(0)	I(1)
	F-statistic	22.07372	10%	2.63	3.35
	K	2	5%	3.1	3.87
			2.5%	3.55	4.38
			1%	4.13	5
ARDL Long Run Form	EC = NCI - (-0.1872*UCPI + 0.7676*ICEA - 61.7601)				
Vector Error Correctio n Models (VECM) : long-term equilibriu m	CointEq(-1)	-0.960677 (0.0000)			
Test of the Model's Robustnes s	Ramsey RESET Test	1.038458 (0.3023)			
	HeteroskedasticityTest:Breus ch-Pagan-Godfrey	1.128721 (0.3535)			
	Breusch-Godfrey Serial Correlation LM Test	0.098631 (0.9062)			

P-values are given in .parentheses

These results align with established theories of cointegration and error correction model and identify the response of the cryptocurrency market to external influences while recognizing some possible complexity in the role of lagged variables in influencing NCI dynamic sthrough individual stock beta spread testing and dynamic method application in the cryptocurrency market, there were firm and sustained herding activities that existed regardless of market status, [45]. Recently, cryptocurrency trading has gained worldwide attention due to its high activity levels and insufficient regulatory frameworks. The analysis of the trading patterns of 21 leading cryptocurrencies from 2016 to May 2023 reveals significant herding behavior from 2016 until March 12, 2020, after which it diminishes. This represents a critical moment where market forces changed, especially the shift from individual to institutional investors that resulted in cryptocurrency trading, [30].

The use of the ARDL (1, 1, 4) model on the cryptocurrency market provides a definitive perspective of the multi-dimensional forces at play in the Nasdaq Cryptocurrency Index (NCI). The model with significant factors like the Uncertainty Cryptocurrency Policy Index (UCPI) and the Cryptocurrency Environmental Attention Index (ICEA) provides an analysis of the multi-dimensional interaction in the new financial arena (Table 2). In fact, the lagged one-step-ahead autoregressive version of the NCI reflects the role of the short memory of the market. The temporal self-effect of NCI, i.e., the autoregressive nature of the crypto market, is an established fact, which, has been validated by studies of individual impact risk factors on crypto assets, [8]. The dynamics of cryptocurrency prices are comparatively largely dependent on the movement of historical market trends, [28]. This is one of the characteristics that highlight the very high level of speculation and volatility of the cryptocurrency market and how prevailing trends can affect quickly behaviors of investors. Other than that, adding UCPI with delay across a horizon captures short-run and acute policy uncertainty effects on the cryptocurrency market. [4] found evidence that cryptocurrency volatility has a direct association with economic policy uncertainty. The immediacy of NCI to react to UCPI motions implies that crypto market investors tend to react toward regulatory and political problems. Additionally, ICEA with four-period lags offers an interesting explanation of how long green problems continue to function in the cryptocurrency market. Its higher lag requirement indicates findings, with the rising salience of green issues in cryptocurrency adoption and pricing, [46]. The longer-term effect of ICEA on NCI would reflect in the shift in sentiment about the sustainability of cryptocurrency, and the likely effect of green policies on the industry. The effect of long-term environmental concern (ICEA) on NCI, as an indicator of the increasing importance of Environmental Social Governance (ESG) issues for crypto valuation, is an aspect that was investigated in carbon footprints of blockchain, [47].

This finding was in line with those who found that news sentiment is one of the determinants of cryptocurrency returns: positive or bullish sentiment often induces herd mentality and price appreciation. The investor sentiment, conveyed through cryptocurrency news headlines, affects both the overall Cryptocurrency Market Index and the individual performance of cryptocurrencies, [48].

The results of the tests of validity presented in Table 2 are highly favorable for the ARDL model. The model appears to be correctly specified (Ramsey RESET test, which examines non-linear specification errors), there is no evidence of heteroscedasticity (Breusch-Pagan-Godfrey test for heteroscedasticity) and there is no indication of serial correlation in the residuals (Breusch-Godfrey LM test for serial correlation). These findings significantly enhance the validity and reliability of the ARDL model for analyzing relationships among NCI, UCPI and ICEA. They suggest that the estimates are likely unbiased and efficient and that statistical inferences based on this model are reliable. In the context of cryptocurrency market analysis, where volatility and complex dynamics are common, having a model that passes these tests successfully is particularly noteworthy. It indicates that the proposed approach effectively captures relationships between political uncertainty, environmental attention and cryptocurrency indices, thereby providing a solid foundation for more extensive analysis and forecasts.

Table 3 (Appendix) provides a detailed summary of the estimation results, highlighting the key parameters and statistical significance of the model variables.

The ARDL model estimation result showed in Table 3 (Appendix) highlights the complexity of determinants driving the cryptocurrency market, with lag and possibly nonlinear impacts. They suggest that environmental concerns may have longer-term impacts on the market, while political uncertainty could have more immediate effects. Our ARDL model results for the NCI reveal intricate dynamics within the cryptocurrency market. While the model explains a modest portion of NCI variation (adjusted R-squared equal to 11%), it highlights significant relationships. Political uncertainty (UCPI) shows a potentially negative short-term impact, emphasizing the market's sensitivity to regulatory factors. In contrast, environmental attention (ICEA) exhibits a significant positive effect but with a notable delay of four periods, suggesting a progressive influence of ecological concerns on cryptocurrency valuation. This observation aligns with the findings regarding the increasing importance of environmental considerations in this sector [46] and especially with these that reveal a positive impact of the environmental awareness index on the prices of Bitcoin, Ethereum and the uncertainty indices, [2].

The low autocorrelation and overall model significance ($p = 0.027$) reinforce its validity despite limited explanatory power. These results underscore the multifaceted nature of the cryptocurrency market, where political and environmental factors play distinct yet significant roles, with effects manifesting over different time scales. This analysis provides valuable insights for investors and regulators, highlighting the need to explore other potentially influential variables for a more comprehensive understanding of the dynamics in this rapidly evolving market.

4 Conclusion and Implications

Our ARDL analysis provides significant insights into the cryptocurrency market and carries important implications for researchers, investors, and policymakers alike. The study highlights the complex and time-delayed media discussion dynamics influencing the market. The evolution of the cryptocurrency market interacts with the growing awareness of environmental and regulatory challenges expressed inthe media. It emphasizes that market participants are increasingly aware of the environmental impacts and use media as a public power to progress toward greater environmental sustainability in the cryptocurrency sector, [10]. Specifically, the significant delayed effect of the Environmental Attention Index (ICEA) over four periods contributes to existing literature, underscoring the growing importance of Environmental Social Governance (ESG) factors in this sector, [47].

Regarding implications, our findings suggest that cryptocurrency investment strategies should consider not only immediate factors like political uncertainty but also longer-term trends related to environmental concerns. This necessitates a more sophisticated, long-term investment approach. Moreover, the significant impact of the Uncertainty Cryptocurrency Policy Index (UCPI) underscores the importance of clear and consistent communication of regulatory policies. Regulators must be aware that their actions and statements can have rapid and substantial effects on the cryptocurrency market. Furthermore, the long-term positive effect of ICEA implies that cryptocurrency projects would benefit from integrating and proactively communicating their environmental sustainability initiatives, potentially as a differentiation and long-term value factor. The moderate explanatory power of our model suggests that there are other important variables not included, prompting future research avenues to determine and include these additional variables, perhaps through the utilization of nonlinear models or machine learning models. Lastly, the sensitivity of NCI to political and environmental variables suggests the increasing incorporation of the cryptocurrency market into the broader financial system. This implies that policymakers must give extra attention to how their policy affects this sector while making macroeconomic considerations.

This research demonstrates that political uncertainty (UCPI) has an immediate on NCI, demonstrating the responsiveness of the adverse market to regulation shocks. Environmental attention (ICEA), conversely, imposes a positive effect with a delay, demonstrating the increasing impact of ESG concerns onthe price of cryptocurrencies with time. All these findings are of major implication to stakeholders of cryptocurrencies. Investors can gain from adopting approaches that counteract short-run regulatory ambiguity and long-run sustainability trends. Regulatory policymakers must make regulatory policies clear and consistent, appreciating their immediate influence on market forces. Cryptocurrency projects can become more appealing by marketing environmental sustainability programs to attract ESG-aware investors. Increased sensitization of the environmental price of cryptocurrencies is bound to increase their market value volatility. Due to their emergence and global proliferation, regulatory authorities are compelled to respond. There is a requirement to launch a high-level debate on the sustainability issues this revolutionary innovation has introduced. Evaluation of the possible effects of this new technology on climate change, and the development of strategies for adapting to these effects, must be incorporated into global sustainable development agendas. Though the ARDL model accounts for a moderate percentage of NCI variation, it does provide some crude insights into the intricate workings of the cryptocurrency market. The paper encourages further examination of other left-out variables that could be substantial and provides some avenues for further research through nonlinear or machine learning methods.

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During the preparation of this work the author used ChatGPT in order to improve the readability and language of the manuscript. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Conflict of Interest

The authors have no conflicts of interest to declare.

APPENDIX

Table 3. Estimation of ARDL (1, 1, 4) Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
NCI(-1)	0.039323	0.102906	0.382129	0.7034
UCPI	0.789848	0.519830	1.519436	0.1326
UCPI(-1)	-0.969649	0.521626	-1.858897	0.0668
ICEA	-0.608264	0.777437	-0.782396	0.4363
ICEA(-1)	0.707075	0.877330	0.805940	0.4227
ICEA(-2)	-0.404180	0.899861	-0.449158	0.6545
ICEA(-3)	0.743955	0.745308	0.998185	0.3212
ICEA(-4)	0.298849	0.089508	3.338805	0.0013
C	-59.33147	95.84016	-0.619067	0.5377

R-squared	0.190268	Meandependent var	-0.514545
Adjusted R-squared	0.108270	S.D. dependent var	9.503475
S.E. of regression	8.974268	Akaike info criterion	7.323256
Sumsquaredresid	6362.462	Schwarz criterion	7.576620
Log-likelihood	-313.2233	Hannan-Quinn criteria.	7.425330
F-statistic	2.320400	Durbin-Watson stat	1.964050
Prob(F-statistic)	0.027239		