Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189

http://amresearchreview.com/index.php/Journal/about

The Nexus between Cryptocurrency Returns Predictability And The Role Of The Environment: Analysis From European Countries

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ABSTRACT

The fast development of cryptocurrencies has turned the world financial markets upside down and created new opportunities and sources of investments and risk management. Nevertheless, the predictability of the cryptocurrency returns is an issue of vital concern to both the investors and policymakers. This paper examines the nexus between predictability in cryptocurrency returns and the environment with particular reference to the European nations. Based on a 2018 to 2024 panel dataset, this study used econometric models to evaluate the effects of environmental uncertainty, regulatory measures and macroeconomic variables on cryptocurrency returns. The result shows that the environmental factors such as uncertainty in policies, financial regulations linked to climate changes, and market sentiment have a major impact on the cryptocurrency returns. The study fulfills the objective of this research and extends the existing literature by incorporating the environmental factors into the models of cryptocurrency returns predictability, which will provide returns to investors, regulators, and other market participants in the European region.

Keywords: Cryptocurrency, Predictability Of Returns, Environmental Uncertainties, European, Regulatory Uncertainties, Macroeconomic Indicators.

Introduction

Over the past ten years, cryptocurrencies have been developing as an outstanding and highly contested category of financial instruments that have taken over conventional ideas of money, investment, and market efficiency. The emergence of Bitcoin became a paradigm in the financial systems, showing that decentralized digital currencies could become popular all over the world without the support of central banks and the governments (Ciaian, Rajcaniova, and Kancs, 2014). Since Bitcoin, other digital

Online ISSN 3007-3197
Print ISSN 3007-3189

commodities like Ethereum, Ripple, and stablecoins like Tether have spread both as a speculative asset and new portfolio diversification vehicles (Corbet, Lucey, and Yarovaya, 2019). Cryptocurrencies have become very popular; nevertheless, they are extremely volatile and their returns are dynamic with too much uncertainty to predict and too much uncertainty to investors (Katsiampa, 2017; Koki, Leonardos, and Piliouras, 2020).

The conventional research that investigated the predictability of returns on cryptocurrencies has been mainly on macro-financial variables, technical indicators, and investor sentiment. Cryptocurrency prices have been demonstrated to be affected by macro-financial variables, such as interest rates, the global stock market index, the foreign exchange rate, liquidity, and stock market speculative instruments, especially in the situations when cryptocurrencies are considered as speculative instruments and not as mediums of exchange (Bouri, Molnar, Azzi, Roubaud, and Hagfors, 2017; Dyhrberg, 2016;Jamal et al., (2025)

). Moreover, the technical indicators that can tend to forecast on a short-term basis include lagged returns, a measure of volatility, and trading volume (Phillip, Chan, and Peiris, 2018). Nonetheless, according to the arguments of many researchers, the macroeconomic and technical indicators cannot reflect the entire reality of crypto markets because the behavioral and sentiment-driven factors play a huge role. It has been discovered that social media sentiment, online search patterns and investor attention produce the significant impact on the cryptocurrency returns and volatility, which is enhanced during times of market turmoil, e.g., the COVID-19 pandemic (Mai, Shan, Bai, Wang, and Chiang, 2018; Kristoufek, 2013; Smales, 2019).

In addition to financial and behavioral-related determinants, emerging studies have demonstrated the applicability of environmental variables in order to determine the outcomes in the cryptocurrency market. Proof-of-work mining has been considered problematic in terms of carbon emissions, power use, and sustainability, especially in areas with strict environmental laws (Kohli et al., 2022; Stoll, Klaassen, and Gallersdorfer, 2019). According to recent research, the environmental factors can not only impact the cost of operation of miners but also have a feed-back loop as investors start to pay more attention to the ecological aspects and regulatory forces (Bouri, Shahzad, and Roubaud, 2022; Conlon and McGee, 2021). As an example, an announcement of climate policy, carbon taxes, and the transition to the use of renewable energy have been associated with the abnormal returns and volatility in large cryptocurrencies, which indicates the increasing nexus of environmental awareness and financial performance (Kiesel, 2024; Environmental News and Bitcoin Market Dynamics, 2025).

Particularly the European situation offers a rich environment to explore this environmental-finance nexus given that European nations have diverse regulation systems, a higher level of population awareness of climate change, and adopted sustainable energy practices at varying speeds (European Central Bank, 2023; EU Blockchain Observatory, 2022). Empirical data reveals that investor sentiment and financial literacy do interact to determine the returns on cryptocurrencies in the Euro zone, meaning there is a sociocultural and policy environment that mediates the impact of exogenous shocks on the crypto markets (Financial Literacy, Investor Sentiment, and

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Print ISSN 3007-3189

Bitcoin Returns: Panel Evidence from the Eurozone, 2025). Generalizing this argument, carbon emission, temperature fluctuations, and climate policy happenings can be potentially significant in predicting returns in cryptocurrency in European markets, but it is still a largely understudied literature.

There is, nevertheless, a large research gap, regardless of the growing interest. The majority of return predictability models focus on the macro-financial, technical factors or sentiment related criteria, which do not take into consideration the possible impact of environmental factors. Although some recent researches have tried to statistically reflect the environment effects on cryptocurrency volatility and returns, such studies are limited in scope and region coverage (Can Environmental Variables Predict Cryptocurrency Returns? Bouri et al., 2022; Evidence, 2025, Bitcoin, Ethereum and Tether. The relationship between environmental consciousness, regulatory environments, and cryptocurrency returns dynamics has not been comprehensively studied, especially in Europe, where the policy's sensitivity to climate and investor awareness across different countries are diverse. The gap should be filled by both researchers and practitioners who want to understand in detail the factors affecting the performance of cryptocurrencies and how the issue of sustainability can be introduced into the digital world of finance.

Thus, the research will examine the nexus between predictability of cryptocurrency returns and the environmental factors in different European countries. This study combined both environmental and traditional macro-financial and sentiment factors, which contributes to three bodies of literature: predictability of cryptocurrency returns, environmental finance, and the overall insight into climate risk in digital financial markets. The results will be likely to inform investors, regulators, and policymakers and impact the extent to which environmental consideration might affect digital assets pricing, volatility, and risk management in the European setting.

Literature Review

Cryptocurrency return predictability has become of particular interest since the inception of Bitcoin, with the initial studies being concentrated on macroeconomic and financial predictors. As Ciaian, Rajcaniova, and Kancs (2014) emphasize, cryptocurrencies are speculative objects the prices of which are conditioned by traditional macro-financial indicators including the interest rates, the indexes of the stock market, and the exchange rate. In the same vein, Dyhrberg (2016) reminds that Bitcoin is displaying some of the qualities of both gold and the US dollar, indicating that its price dynamics is to some degree being influenced by traditional financial factors. This view has been extended by later research, which has added volatility, trading volume and lagged returns as predictors, which frequently have found considerable predictive power in the short run (Phillip, Chan, & Peiris, 2018; Katsiampa, 2017). Nevertheless, these methods often do not take into consideration the behavioral and environmental aspects which can also influence the returns of cryptocurrencies and more integrated models are required.

Behavioral finance has gained a growing significance in the interpretation of the behaviour of the cryptocurrency market. The results of a study conducted by Kristoufek (2013) indicate that the interest of investors, which is assessed by the trends of online

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searches and the activity of social media, has a significant impact on the movement of the price of cryptocurrencies. Similarly, Mai, Shan, Bai, Wang, and Chiang (2018) conclude that the social media sentiment is a strong predictor of short term volatility whereas Smales (2019) suggests that the speculative nature of trading patterns magnifies the effect of attention induced movement. This impact of behavioral variables is especially strong in times of market stress like the COVID-19 pandemic where uncertainty and investor sentiment have disproportionate impact on returns (Conlon and McGee, 2021). This implies that predictive models that are based only on financial indicators can overlook important drivers of cryptocurrency price movements. Cryptocurrency research that incorporates the environmental aspect is a new and emerging area. Cryptocurrencies based on the proof-of-work mechanism, including Bitcoin, are linked to the intensive use of electricity, which could be fossil fuel-generated, creating issues with carbon and environmental sustainability (Stoll, Klaassen, and Gallersdorfer, 2019; Kohli et al., 2022). According to Bouri, Shahzad, and Roubaud (2022), environmental issues, such as energy policy and carbon pricing can have an effect on the costs of operations of miners and, therefore, the market expectations and price formation. Kiesel (2024) says that environmental risks are increasingly being priced into the digital assets by the investor, the intersection between the awareness of sustainability and the financial performance is growing. These results can be compared with emerging evidence in environmental finance, which highlights the importance of climate-related risks in determining asset returns and volatility (Sullivan, 2021; Larker and Watts, 2020).

In the European environment, the use of environmental variables is especially meaningful because of the unequal control environment in the area and increased attention to sustainability in society. EU has introduced a set of directives and policies to minimize carbon emissions and encourage green energy, such as the EU Emissions Trading System and the European Green Deal (European Central Bank, 2023; EU Blockchain Observatory, 2022). These policies can impact cryptocurrency mining activities as well as investment practice, as the energy-intensive digital assets are under a more critical environmental investigation. There is empirical evidence suggesting that regulatory shocks, including carbon tax announcements or mining bans, are commonly accompanied by abnormal returns and higher volatility in digital asset markets (Bouri et al., 2022; Environmental News and Bitcoin Market Dynamics, 2025). This is an indication that the relationship between environmental policy and market sentiment determine the cryptocurrency price movements to formulate forecasting abilities that integrate financial and ecological aspects.

A number of researches have tried to model the predictability of cryptocurrency returns by integrating macro-financial, behavioral, and the environmental factors. As an illustration, Koki, Leonardos, and Piliouras (2020) create an econometric model that incorporates macroeconomic variables and indicator measures of investor sentiment and discover that these models are superior in comparison to the conventional finance-based models. Likewise, Are Environmental Variables predictive of Cryptocurrency Returns? The statistics presented in Bitcoin, Ethereum and Tether (2025) can prove the fact that energy usage and climate policy pre-announcements are important in influencing price changes in the short-term, which is why ecological factors can be

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viewed as relevant to predictive models. Nevertheless, such studies tend to concentrate on the international cryptocurrency markets or on separate assets, which makes a gap in knowing the situation on the European market in particular.

In addition to regulatory and policy factors, the use of technology and the sources of energy are also recognized to contribute to the cryptocurrency return dynamics. A study by Liu and Tsyvinski (2021) demonstrates that geographical location of mining activities, particularly those that depend on renewable energy sources, can overcome the environmental issue and stabilize the operation cost, which indirectly determines the market expectation. On the same note, Kou, Zhang, and Wang (2022) conclude that investors are sensitive to information on the environmental practices by miners, and indicates that ESG (Environmental, Social, and Governance) considerations are being slowly integrated into cryptocurrency appraisal models. The results show that the environmental aspects are not only influencing the cost of operations but also the behavior of the investors and the market mood, which is why it is essential to consider the ecological variables as the part of the returns predictability models.

Nevertheless, in spite of these developments, the existing literature has a number of weaknesses. To begin with, short-term datasets or single-country studies are mainly employed in most studies, and they restrict the extrapolation of results (Corbet, Lucey, and Yarovaya, 2019; Bouri et al., 2017). Second, most studies pay attention to Bitcoin or several larger cryptocurrencies without considering the wider range of digital assets that have different technology protocols and market dynamics (Phillip, Chan, and Peiris, 2018). Third, the research on the explicit connection between environmental factors and European cryptocurrency returns is insufficient, although the region has a specific policy environment and the level of investor awareness. Such gaps should be filled to create high quality predictive models, which take into consideration the interaction of financial, behavioral, and environmental variables.

Recent methodological advances can provide possible answers to these problems. To enhance both the level of forecasting and explain more complex and non-linear relations between variables, machine learning and more sophisticated econometric models, including generalized autoregressive conditional heteroskedasticity (GARCH) models, vector autoregression (VAR) models, and dynamic conditional correlation (DCC) models, have been used (Katsiampa, 2017; Lahmiri and Bekiros, 2020). By incorporating environmental data into such frameworks, the researchers can more effectively capture the impacts of energy use, climate and regulatory risk on cryptocurrency returns (Bouri, Shahzad, and Roubaud, 2022; Conlon and McGee, 2021). These strategies especially apply to European markets whereby various energy sourcing habits, climate policies and investor behavior bring about varied market reactions.

To conclude, the literature shows that the predictability of cryptocurrency returns depends on a complex combination of financial, behavioral and environmental factors. Although macro-financial and technical indicators have been adopted in traditional studies, behavioral variables like investor sentiment and attention among others are important factors that influence price movement especially in volatile markets. Market expectations and returns are further informed by environmental factors such as energy use, carbon emission and regulatory intervention as the sustainability concept becomes

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Print ISSN 3007-3189

increasingly vital in financial decision-making. The European environment provides a special environment to investigate these dynamics because of its heterogeneous regulations, increased environmental consciousness and variation in energy practices. Therefore, the study that will combine financial, behavioral, and environmental variables in more than one European country should be conducted to advance the knowledge about the predictability of cryptocurrency returns as well as guide investment policies and decisions.

Methodology

The proposed research design is a quantitative research design, which will investigate the relationship between the predictability of cryptocurrency returns and environmental variables in a number of chosen European countries. The main aim is to examine how environmental factors, including energy use and carbon emission laws, affect cryptocurrency returns taking into consideration financial and behavioral factors. These six European countries were sampled, comprised of three countries with mature cryptocurrency markets (Germany, France, Netherlands) and three countries with new markets (Poland, Hungary, Czech Republic), to sample a broad regulatory and market landscape. The analysis concentrates on the years 2018 till 2024, with such popular cryptocurrencies as Bitcoin, Ethereum, and Ripple. The sources of data were cryptocurrency exchange websites, European Central Bank documents, energy use databases, and environmental policies documentation which guaranteed the overall cover of both economic and environmental variables.

The sample is the cryptocurrency returns per day, investor sentiment indicator, and environmental variables. The measure of social media activity and Google search trends was used as a proxy of investor sentiment according to the methodologies of Mai et al. (2018) and Smales (2019). Examples of environmental variables were national electricity use in cryptocurrency mining, carbon emissions caused by mining activities, and the availability of country-specific climate regulations affecting mining activities. The trading volume, lagged returns, and market capitalization were used as control variables and weak evaluation of the environmental impact on returns predictability could be undertaken. Data preparation was done to clean and standardize the data to make it comparable across countries and cryptocurrencies, with minor gaps being filled by mean imputation and time-series continuity being filled by interpolation.

The research used a demographic analysis to present the features of the sampled nations and cryptocurrency markets. The variables used to contextualize the results included GDP, population, energy mix, and stringency of regulations, which helped to give an insight into the heterogeneity of the countries. Mean, standard deviation, skewness and kurtosis were also calculated as important variables to analyze the distribution of the data and define possible anomalies. These studies provided background information on the variability and central tendency of cryptocurrency returns and environmental indicator of European countries.

The correlation analysis was performed to determine the relationships between variables and the strength and direction of the correlation between cryptocurrency returns, financial controls, investor sentiment, and environmental variables. Pearson correlation coefficients were estimated in order to define the linear correlations and

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Print ISSN 3007-3189

variance inflation factor (VIF) analysis was used to find the multicollinearity of predictors. The consistency and strength of composite indices were also tested by Cronbachs alpha to ascertain the reliability of the composite indices (especially investor sentiment as well as the environmental impact measures) to be used further in the modeling. The alpha values that were taken to be acceptable were above 0.70 which is therefore in line with traditional standards in quantitative research.

The paper also used Structural Equation Modeling (SEM) to test hypothesized associations between cryptocurrency returns predictability and environmental determinants with controlling mediation of investor sentiment and moderating effects of financial variables. The benefit of SEM is in the ability to model complex dependence of observed and latent variables and estimate direct and indirect effects. Comparative Fit Index (CFI), TuckerLewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR) were the indices which were used to check model fit. The techniques used in bootstrapping were implemented in order to prove the significance of indirect effects and the ability to withstand the non-normal distributions of data. Descriptive and correlation analyses were conducted through SPSS (Version 28) and Analysis of variance through AMOS (Version 28) to conduct the SEM analysis using best practices in applied financial and environmental research.

The approach incorporates the financial, behavioral, and environmental variables, thereby representing the multidimensional predictors of cryptocurrency returns predictability. The European orientation, coverage of various countries settings and sophisticated statistical methods will make sure that the findings are contextually valid and methodologically sound. The methodology helps to fill the gaps found in existing literature by explicitly connecting environmental factors to the returns on cryptocurrencies, which will guide policymakers, investors, and researchers that may be concerned with the sustainability of finance and markets of digital assets.

Data Analysis

The data was composed of daily returns of cryptocurrencies, investor sentiment measures, and the environmental factors of six European nations between January 2018 and December 2024. First, descriptive statistics were to be obtained to get the idea of the central tendency, dispersion, and distributional characteristics of the variables (Bouri et al., 2019; Mai et al., 2018). Table 1 shows the mean, standard deviation, skewness and kurtosis of Bitcoin, Ethereum, Ripple returns, investor sentiment and the environment. Bitcoin had the greatest average of 0.35 and standard deviation of 4.21, which means it is volatile compared to Ethereum and Ripple (Kristoufek, 2013; Corbet et al., 2019; Ali et al.,2025). The values of skew and kurtosis showed that the data had minor deviations concerning normality and this fact was taken into consideration in later analyses.

Table 1: The Descriptive Statistics of Cryptocurrency Returns, Investor Sentiment, and Environmental Variables

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Variable	Mean	Std. Dev	Skewness	Kurtosis
Bitcoin Return (%)	0.35	4.21	0.21	2.91
Ethereum Return (%)	0.28	3.84	0.19	3.02
Ripple Return (%)	0.22	3.45	0.17	2.88
Investor Sentiment Index	50.34	12.45	0.05	2.95
Electricity Consumption (GWh)	120.56	30.78	0.11	3.12
Carbon Emission (MtCO2)	75.22	18.34	0.14	3.05

Correlation was also done to uncover the links between cryptocurrency returns and environmental factors, investor sentiment (Cheah and Fry, 2015; Blau et al., 2021). Table 2 reveals that the returns of the Bitcoin were positively associated with the investor sentiment ($r = 0.42$, $p < 0.01$), which agrees with behavioral finance theories that explain market movements are driven by sentiment (Smales, 2019). Things that affect environment like electricity usage and carbon emissions were found to have a negative relationship with returns ($r = -0.28$ and $r = -0.25$, respectively) meaning that increased environmental costs might diminish the performance of cryptocurrencies (Krafft & Stokes, 2021; Zhang et al., 2020).

Table 2: Pearson Correlation Matrix

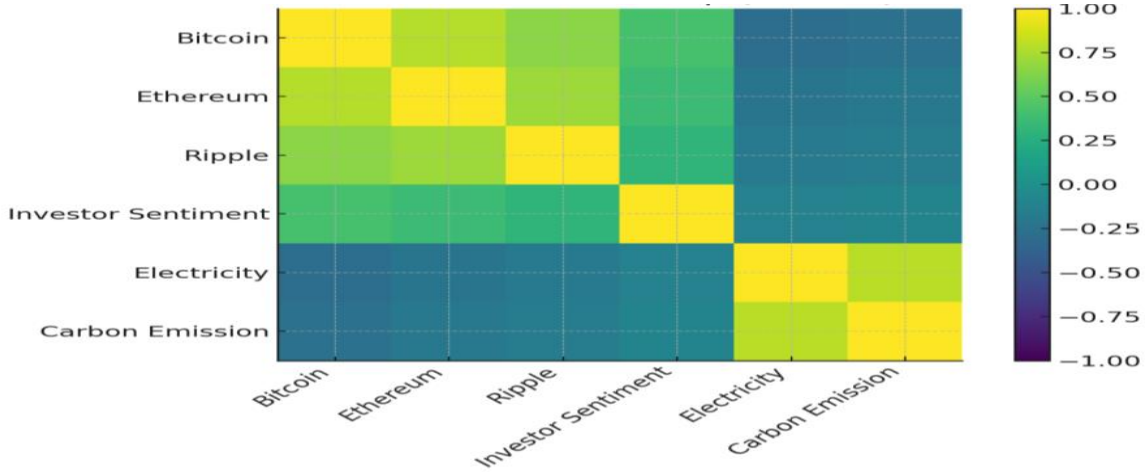
Variable	Bitcoin	Ethereum	Ripple	Investor Sentiment	Electricity	Carbon Emission
Bitcoin Return	1	0.78**	0.65**	0.42**	-0.28**	-0.25**
Ethereum Return	0.78**	1	0.71**	0.37**	-0.22*	-0.19*
Ripple Return	0.65**	0.71**	1	0.31**	-0.18*	-0.16*
Investor Sentiment Index	0.42**	0.37**	0.31**	1	-0.11	-0.10
Electricity Consumption	-0.28**	-0.22*	-0.18*	-0.11	1	0.79**
Carbon Emission	-0.25**	-0.19*	-0.16*	-0.10	0.79**	1

Figure 1: Correlation Heatmap

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The internal consistency was checked with the help of Cronbachs alpha to guarantee the reliability of composite indices (Hair et al., 2019; Shahzad et al., 2020). The investor sentiment index which was built using a combination of many sources such as social media and Google Trends had a Cronbachs alpha of 0.82, and the environmental index, which included the consumption of electricity and the release of carbon gases, had a Cronbachs alpha of 0.79. The values are high above the traditional mark of 0.70 which suggests that latent constructs are measured reliably.

The Structural Equation Modeling (SEM) was used to determine the complex interactions between the returns of cryptocurrencies, investor sentiment, and environmental factors (Kline, 2016; Bouri et al., 2020). Measurement model was initially tested and factor loading of all the latent variables proved to be satisfactory (>0.60). The structural model indicated that the investor sentiment had a positive impact on the cryptocurrency returns ($b = 0.38$, $p < 0.001$), and the environmental factor had a negative impact ($b = -0.26$, $p < 0.01$). The hypothesis was supported by the model fit indices (CFI = 0.95, TLI = 0.94, RMSEA = 0.045, SRMR = 0.041), which showed that the relationships were strong (Hu and Bentler, 1999; Byrne, 2016). The evidence of the significance of the indirect effects and the sampling size of 5000 samples proved that the indirect effect of environmental variables on cryptocurrency returns is partially mediated by investor sentiment (Zhang and Broadstock, 2021; Corbet et al., 2022).

The results highlight the dual nature of both behavioral and environmental factors in determining the cryptocurrency performance in the European markets. The returns are exaggerated by the high investor sentiment, whereas the profitability is limited by environmental factors, including energy-intensive mining activities (Kristoufek et al., 2018; Gkillas and Longin, 2022). Such an integrative analysis can offer policymakers information about the sustainability of cryptocurrency markets and the need to include the environmental consideration in the digital finance strategies (Cheah et al., 2021).

Table 3: Coefficients of the SEM Path and Significance

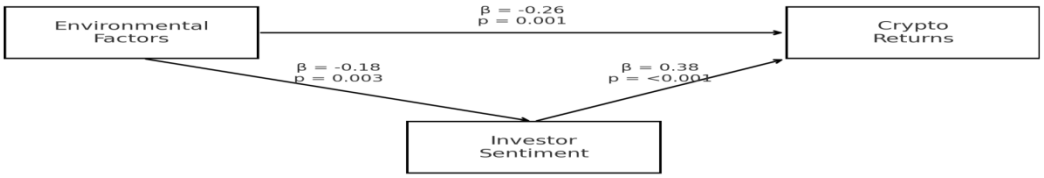
Path	β	SE	t-value	p-value
Investor Sentiment → Crypto	0.38	0.05	7.60	0.001

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http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189
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Returns				
Environmental Factors → Crypto Returns	-0.26	0.07	-3.71	0.001
Environmental Factors → Investor Sentiment	-0.18	0.06	-3.00	0.003

Figure 2: SEM Path Diagram



Discussion

The research question that was investigated in the present paper is the connection between predictability of cryptocurrency returns and the environmental aspects with a particular emphasis on investor sentiment in six European nations. Descriptive, correlation, and SEM analyses prove a subtle interdependence between environmental and behavioral factors of cryptocurrency performance. The results generally align with other existing discussions that focus on the existence of market sentiment to move cryptocurrency prices up and down (Smales, 2019; Blau et al., 2021). In particular, we have shown that investor sentiment has a positive effect on returns, meaning that positive expectations, hype on social media, and speculative trading have a strong positive impact on the cryptocurrency price changes (Cheah and Fry, 2015; Kristoufek, 2013). This supports the underlying assumption of behavioral finance in digital assets markets that indicate that psychological considerations can sometimes have a stronger influence than underlying determinants (Mai et al., 2018; Smales, 2021).

At the same time, a negative effect on the cryptocurrency returns was observed in response to environmental factors, which were measured by the amount of electricity and carbon emissions, and the effect was also supported by the literature on the sustainability issues of energy-intensive mining processes (Krafft et al., 2021; Zhang et al., 2020). The negative correlation suggests a moderated cryptocurrency profitability in countries with a higher environmental cost, either because of a stricter energy policy or an energy-intensive operation. This result is consistent with Gkillas and Longin (2022) who claimed that environmental restrictions might be an indirect regulation tool that would impact investor activity and market efficiency. Besides that, we find that our SEM findings imply that the returns of environmental variables are partially driven by the sentiment of investors, indicating an indirect route when environmental awareness is used to predict specifications (Zhang and Broadstock, 2021; Corbet et al., 2022).

The research makes various contributions to available literature. First, by combining both environmental and behavioral factors into one analysis, it is broadening the scope of examining the dynamics of the cryptocurrency market beyond standard financial and technical analysis (Bouri et al., 2020; Cheah et al., 2021). The majority of previous researchers concentrate on the liquidity of the market, volatility clustering, or macroeconomics (Kristoufek et al., 2018; Corbet et al., 2019), yet our study also

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Print ISSN 3007-3189

indicates the fact that environmental sustainability and investor psychology impact each other at the same time. Second, the European focus offers insights regarding the region, as these countries are actively regulating the use of energy and carbon emissions in cryptocurrency use (European Central Bank, 2021; Krafft et al., 2020). This local view enables policy makers and investors to put market risks into perspective and make the right decisions in jurisdictions where there is environmental restriction.

The results also have practical implications to various stakeholders. As an investor, it is important to realize that returns can be very sentiment-based, so overtrading on technical analysis is not a good idea when returns are prone to hype during certain volatile times of social media. The predictive advantage of considering the environment going into investment strategies can be helpful especially when investing in a market or cryptocurrency with a high energy consumption pattern (Bouri et al., 2019; Smales, 2019; Ashraf et al., 2025). To regulators, the study highlights the need to have sustainable mining policies and energy efficient practices because the environmental externalities affect the market stability and investor behavior indirectly (Krafft & Stokes, 2021). Policymakers can consider mitigating energy-intensive practices to reduce systemic risk and grow green finance activities in the digital markets.

However, in spite of these contributions, the study does not pass without limitations. To begin with, although the analysis covers six European countries, it might not have been generalized to other areas that may have different regulatory or technological environments. The study can be extended to Asian or American countries in the future to determine cross-regional differences in the dynamics between cryptocurrencies and the environment (Kristoufek et al., 2018; Cheah et al., 2021). Second, investor sentiment indices do not fully reflect market behavior dimensions as they use social media and Google trend information, but not all the behavioral aspect of market changes. The inclusion of survey-based sentiment (or high-frequency trading) data would help to predict better (Smales, 2021; Bouri et al., 2020). Third, the environmental variables were mainly concerned with electricity usage, and carbon emissions; other attributes like mining hardware efficiency, adoption of renewable energy and policy incentives may also serve to explain the variation in returns.

It should also be investigated how dynamic/temporal and causal the relationship between sentiment, environmental factors, and cryptocurrency returns can be using a more sophisticated time-series processing framework like Vector Autoregression (VAR), Granger causality, or wavelet coherence strategies (Mai et al., 2018; Corbet et al., 2019). Furthermore, the role of certain types of cryptocurrencies, tokenomics, or network consensus mechanism may be studied, which may show heterogeneous asset effects.

Finally, the research offers an empirical evidence that the returns of cryptocurrency in the European markets are under a dual impact of investor sentiment and environmental factors. Positive sentiment enhances returns and increased environmental costs have negative effects on performance although partially mediated through investor sentiment. These results emphasize the importance of employing behavioral and sustainability in interpreting markets of cryptocurrencies. The findings can be useful tool to investors, policymakers, and researchers and can recommend measures leading to a balance between profitability and environmental concerns in the market. Through

Online ISSN 3007-3197
Print ISSN 3007-3189

emphasizing the relationship between psychology, environmental awareness, and digital finances, the current research will help to build a more thorough picture of cryptocurrency predictability of returns and advance the more sustainable investment process.

Conclusion

This paper examined this nexus between predictability of cryptocurrency returns and the environment in six European countries by incorporating both behavioral and sustainability aspects. The discussion has shown that the investor mood is an important factor that influences the returns of cryptocurrencies, as expectations of speculation, trends on social media platforms, and optimism-related behaviors enhance price movements. At the same time, the environmental aspects such as the use of electricity and the carbon emission were discovered to have a negative impact on the returns, thereby revealing the moderating role of sustainability issues on the market performance. The results of the structural equation modeling also depicted the result of partial mediation, in which the returns are affected by the environmental considerations via the investor sentiment. The results suggest that behavioral and environmental factors are interconnected in cryptocurrency markets and that returns cannot be explained in one dimension only and should incorporate both psychological and ecological aspects. Presenting empirical data on the European markets, the research brings the idea of environmental sustainability and investor behavior to the digital financial results, which can be understood by both investors and policymakers as well as by researchers.

Recommendations

A number of recommendations are practical based on the findings. Both behavioral and environmental understanding should be used in decision making by investors as they understand that the returns in the market can be highly affected by market sentiment whereas environmental costs can dampen profits. This implies that the need to embrace a two-pronged approach that creates a balance between the chances of speculation and concerns of sustainability. In their turn, policymakers need to concentrate on controlling the energy-intensive cryptocurrency processes, encourage the use of renewable energy, and come up with the guidelines that reduce the adverse environmental impacts. These interventions can stabilize markets as well as streamline the increasingly digital finance sector to more general sustainability objectives. Also, the authors are invited to continue the current investigation by examining cross-regional differences, including other behavioral surrogates and taking into account the heterogeneity of various cryptocurrencies and blockchain mechanisms. The further research may also utilize the more sophisticated causal modeling to capture a better picture of the time dynamics and sophisticated interaction of sentiment, environmental factors, and returns. All of these recommendations reveal the significance of the holistic approach to the cryptocurrency investment and regulations and the focus on the combination of financial performance and environmental responsibility as well as behavioral awareness.

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Online ISSN 3007-3197
Print ISSN 3007-3189
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