THE IMPACT OF ENERGY CONSUMPTION IN CRYPTO ASSETS ON CRYPTO ASSET PRICES AND CARBON EMISSIONS: CASE OF BITCOIN AND ETHEREUM[1]

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Abstract

In this paper, it is aimed to evaluate the relationship between energy consumption in crypto assets and crypto asset prices. In this direction, the price, CO2 emission and energy consumption series of Bitcoin and Ethereum between March 17, 2021, and March 15, 2023, were examined weekly. In order to clarify the subject, Fourier Granger causality and Fourier ADL cointegration tests were applied to the series. In the findings, a bidirectional causality relationship was determined between Bitcoin price, Bitcoin energy consumption and Bitcoin CO2 emission series, and no causality relationship was detected between Ethereum price, Ethereum energy consumption and Ethereum CO2 emission series. On the cointegration side of the analyses, while there is a long-run nexus between Bitcoin Price and Bitcoin CO2 emission and Bitcoin energy consumption variables, it has been observed that there is no long-run nexus between the variables for Ethereum. At the end of the study, it was mentioned that it would be useful to examine the market values of these variables in future studies

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[1] *This study is based on Meltem BİLİRER's master's thesis titled "Decentralized Finance Applications and Electricity Consumption, Carbon Dioxide Emission, Price Relationship of Crypto Assets After Merge: An Application on Selected Coins and Tokens" which was carried out under the supervision of Prof. Dr. Feyyaz ZEREN at Graduate Education Institute, Department of International Trade and Finance, Yalova University, Yalova, Türkiye.*

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and that since the Merge event in Ethereum is an important development for crypto assets, it is possible to increase similar developments with the necessary incentives and policies in this direction.

Keywords: cryptocurrency, energy problem, merge, proof of stake, proof of work

JEL Classification: G15; Q43

1. Introduction

With the widespread use of the Internet, technological developments have taken place in all areas of our lives over time, and the impact of these developments on trade has been inevitable. And along with this, many attempts have been made to electronic money, which forms the basis of commercial transactions. Although the first attempts were not very successful, with Satoshi Nakamoto's announcement of the blockchain-based digital currency Bitcoin in 2008, rapid developments took place in this field and this process was followed by the emergence of various crypto assets (Charandabi and Kamyar, 2021; Yumuşaker, 2019).

Although crypto assets are not dependent on a central institution or any other authority, their values are determined according to the instant supply and demand in the market, and transactions are recorded in an encrypted form on a system called blockchain (Cengiz, 2018). Blockchain technology, which has become popular with Bitcoin and has the potential to facilitate human life in many areas, has a significant impact on the global carbon footprint due to its high energy consumption trend. Blockchain has been multiplied and diversified over time for different use cases. We can give an example of Ethereum, which leads this diversification, operates in a decentralised way and has smart contracts on it, unlike Bitcoin (Bada et al., 2021).

In addition to these, Nakamoto in his/her article describing the structure and working mechanism of blockchain technology, in other words, referred to the Proof of Work (PoW) mechanism, which represents the form of the Bitcoin production process. This mechanism, in which software developers, called miners, compete to solve heavy mathematical puzzles for which they will receive certain amounts of Bitcoin rewards in return for winning, requires a significant amount of energy consumption due to its incentive structure (Öztürk et al., 2018; Zhang and Chan, 2020).

In order to solve the problem of high energy consumption brought about by the increase in the use of Bitcoin, researchers have started to look for alternatives to Proof of Work. One of the main alternatives offered to solve the current energy demand problem, which poses similar risks in Ethereum, another blockchain-based crypto asset, as in Bitcoin, has been Proof of Stake (PoS) (Siim, 2017). In the Proof of Stake mechanism, the authority to update the blockchain is given to randomly selected validators instead of existing competing miners in Proof of Work. There is a monetary reward here as well, but to earn this reward, validators do not need to be in a competitive situation as miners do in Proof of Work (Saleh, 2021).

Initially based on the consensus mechanism Proof of Work (PoW), Ethereum left this mechanism, which causes intense energy consumption that requires competition between miners, and switched to the Proof of Stake (PoS) mechanism, which is more advantageous in terms of energy efficiency, in September 2022. After Merge, which expresses the structural updates in this transition period, the fact that those holding Ethereum on the chain in the last block before the Merge had the same number of assets in both the PoS chain and the PoW chain after the Merge gave rise to the expectation that there would be a sudden increase in the ETH liquidity of the Ethereum market (Heimbach et al., 2023).

In this study, the relationship between crypto-asset energy consumption and crypto-asset prices and carbon emissions will be examined, and changes in the market will be discussed after the transition of Ethereum crypto-asset to Proof-of-Stake protocol in line with the determination of the relationship between energy efficiency and asset price levels.

2. Literature review

In this part of the study, which aims to examine the relationship between energy consumption in crypto assets, crypto asset prices and carbon emissions by considering Ethereum's situation in the market after The Merge event, similar studies in the literature are mentioned in connection with the content of the research. Although there are not many similar studies in the literature on the relationship between energy consumption and the price of crypto-assets in terms of content, it can be said that there are studies on Bitcoin and Ethereum in general, and most of them have been examined in the context of operating protocols.

Ampel (2023) investigated how the existing mechanism affects the cryptocurrency price and transaction volume in cryptocurrencies based on the consensus mechanism for transaction verification and network security. As a result of Ampel's (2023) analysis of Ethereum, which has changed its consensus protocol, it has been determined that Ethereum's mechanism change has a positive effect on the price but has a non-significant negative effect on transaction volumes. The study stated that the transition from Proof-of-Work to Proof-of-Stake is promising because it has positive effects both environmentally and in terms of increasing investment opportunities.

In their study, Zheng et al., (2023) aimed to examine the causality relationship between cryptocurrency transactions and electricity consumption. As a result of the analysis, it was observed that the series of cryptocurrency transactions and electricity consumption, which were exposed to daily shocks, gradually returned to average convergence. It has been determined that prices trend with hash rates.

DiFebo et al. (2021), in their study examining the relationship between the energy market and Bitcoin prices with the multivariate-quantile conditional autoregressive (MVMQ-CAViaR) model and the Granger causality test, it was determined that Bitcoin spillovers have a stronger effect on carbon markets and that the carbon market is not a granger cause to Bitcoin. In addition, it has been concluded that Bitcoin affects the carbon market in sub-tranes.

Felek et al. (2023) in their study examining the relationship between Bitcoin and carbon emissions between the periods 2017M1-2022M1, they applied Kapetanios et al. (2006)'s Nonlinear Co-integration analysis and Granger causality test to the series. As a result of their studies, it has been concluded that there is a nonlinear cointegration relationship between Bitcoin and CO2 in the long run and a one-way causality relationship from Bitcoin to carbon emissions.

Huynh et al. (2022), in their study, which is the first empirical article examining the relationship between Bitcoin's energy consumption and the Bitcoin market, they determined the existence of a relationship between Bitcoin energy consumption and returns and volumes by using quasi-variances and variance decompositions on daily data. According to the study, the effect of Bitcoin from trading volumes to energy consumption is higher than returns in the long run.

In addition, according to the results of the study, the decline in the Bitcoin market not only prevents energy consumption, but also triggers the interconnectedness of energy consumption from now on.

In this study, Afjal and Sajeev (2022) examined the return volatility spread of crypto assets with increasing annual energy consumption and the effect of Bitcoin, Ethereum and three other crypto assets on four energy markets (Nifty Energy Index, S&P 500 Energy Index, S&P/TSX Canadian Energy Index, Shanghai Stock Exchange Energy Index) using the Granger Causality Test and DCC MGARCH model and considering the period between 2016-2021; As a result of their findings, they determined that the general correlation, which changes over time, between energy markets and crypto asset units is low and weak.

Pagnottoni (2023) applied the method to investigate the topology of shock transmission networks across cryptoassets, energy prices, CO2 emissions, in this study, which presented a topological framework proposal for variance decomposition analysis of multivariate time series in time and frequency domains. The results of the research show that the topologies of long and short-term shock transmission networks are completely different, and superhighways and roads have changed significantly over time, but it has been stated that there are no direct strong links between cryptoassets and carbon markets after the Covid-19 outbreak.

In this study, in which De Vries (2023) examines crypto assets in the context of sustainability, it is emphasized that a special way of limiting the environmental effects of crypto assets, such as intense energy demand, is to avoid the Proof of Work (PoW) mechanism. In this study, which evaluates the transition of Ethereum, the second largest crypto asset in terms of market value, from the Proof-of-Work PoW mechanism to the Proof-of-Stake (PoS) mechanism with The Merge in September 2022, the opportunities and difficulties of replicating The Merge event in other crypto asset units are discussed. Accordingly, it has been stated that this initiative of Ethereum is an important example despite the existing difficulties, and it is not impossible to realize this initiative among other crypto assets in line with this example and with the right incentives. It was emphasized that the research needed for Bitcoin and other crypto assets to switch to PoS should be focused on, especially considering that the decreases in Bitcoin's energy demand are likely to be reflected globally.

Symitsi and Chalvatzis. (2018), in their study aiming to examine the interaction between Bitcoin and energy and technology companies with the VAR-GARCH model, determined that there are significant return spreads from energy and technology stocks to Bitcoin and that Bitcoin has long-term volatility effects on energy companies.

Corbet et al. (2021), in their study of Bitcoin and energy markets, discussed the underlying dynamics of Bitcoin's price fluctuations and crypto-asset mining and investigated their effects on utilities companies and basic energy markets. As a result of their research, it was stated that crypto-asset energy consumption has a continuous and significant effect on the performance of some companies in the energy sector, emphasizing the importance of considering and further evaluating the environmental effects of growth in crypto-assets in this direction.

Das and Dutta (2020) examined the relationship between miner revenues and energy consumption in Bitcoin, using the quantile regression method and the Markov regime change model, based on the question ‘Is energy consumption the Achilles heel of miner income?’. As a result of their analysis, they determined a negative relationship between the variables and stated that the negative effect is important in cases where miner incomes are low and variable. Therefore, considering the increase in energy costs, they emphasized that cheap energy sources and efficient mining equipment are important in terms of sustainability.

Badea and Mungiu-Pupăzan (2021) aimed to provide an overview of the subject by examining the economic and environmental impact of Bitcoin through a systematic literature review. The research provided an opportunity to evaluate the level of knowledge regarding the environmental impact of the mining process in terms of energy consumption and CO2 emissions to identify potential solutions in terms of analysis of Bitcoin regulation and mitigation of the current negative impact. In their research findings, they observed that despite the negative environmental impact caused by Bitcoin, it continues to be used as a tool for various economic purposes, and the current regulatory trends in countries show that its use has begun to gain legitimacy, despite the criticisms against Bitcoin.

Yılmaz and Kaplan (2022) examined the effects of crypto-asset mining operations on environmental sustainability, including climate change and global warming. As a result of their research, they stated that the energy consumed by mining has important environmental effects in the context of carbon emissions, global warming, climate change, and air pollution. In addition, in order to prevent these negative effects, the importance of innovative steps to be taken in this area, new legal regulations to be introduced, and the use of various evidence protocols and renewable energy sources that can be used specific to the system are emphasised in terms of crypto-asset markets and environmental sustainability.

When the existing studies in the literature are examined within the scope of the subject of this study, it can be said that the studies were made especially on Bitcoin and Ethereum. It can be said that the reason for this is that Bitcoin works with the Proof-of-Work protocol, while Ethereum starts with the Proof-of-Work protocol like Bitcoin and then moves to the Proof-of-Stake protocol by eliminating the mining process that causes intense energy consumption in the Proof-of-Work. In this context, it has been suggested that in order to avoid this environmental risk caused by crypto-asset investments in general, it would be beneficial to focus on the transition of other crypto assets to the Proof-of-Stake protocol or whether different protocol types can be developed that do not technically cause intense energy consumption.

3. Data and method

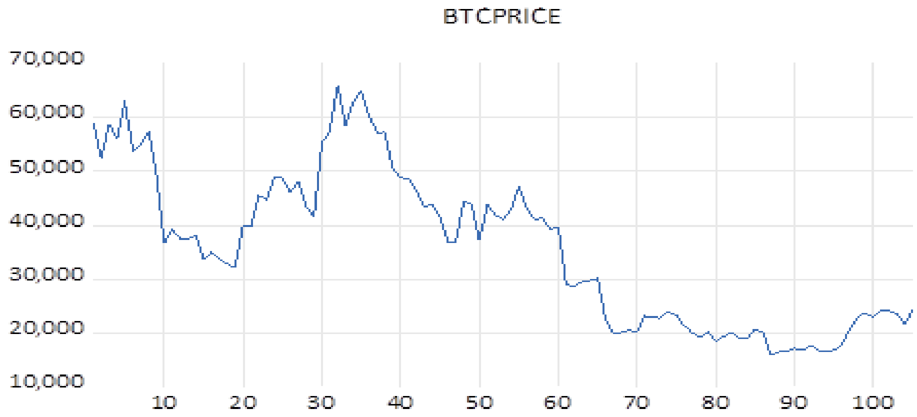
3.1. Data

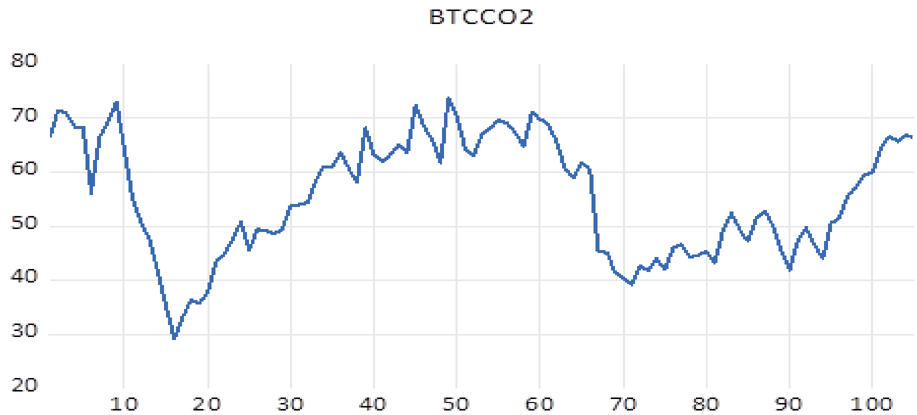
In this study, in order to examine the relationship between the energy consumption of crypto assets and the prices of crypto assets and CO2 emissions, the price, CO2 emission, energy consumption series of Bitcoin and Ethereum for the period 17 March 2021 – 15 March 2023 were examined, and the data of the series were discussed on a weekly basis.

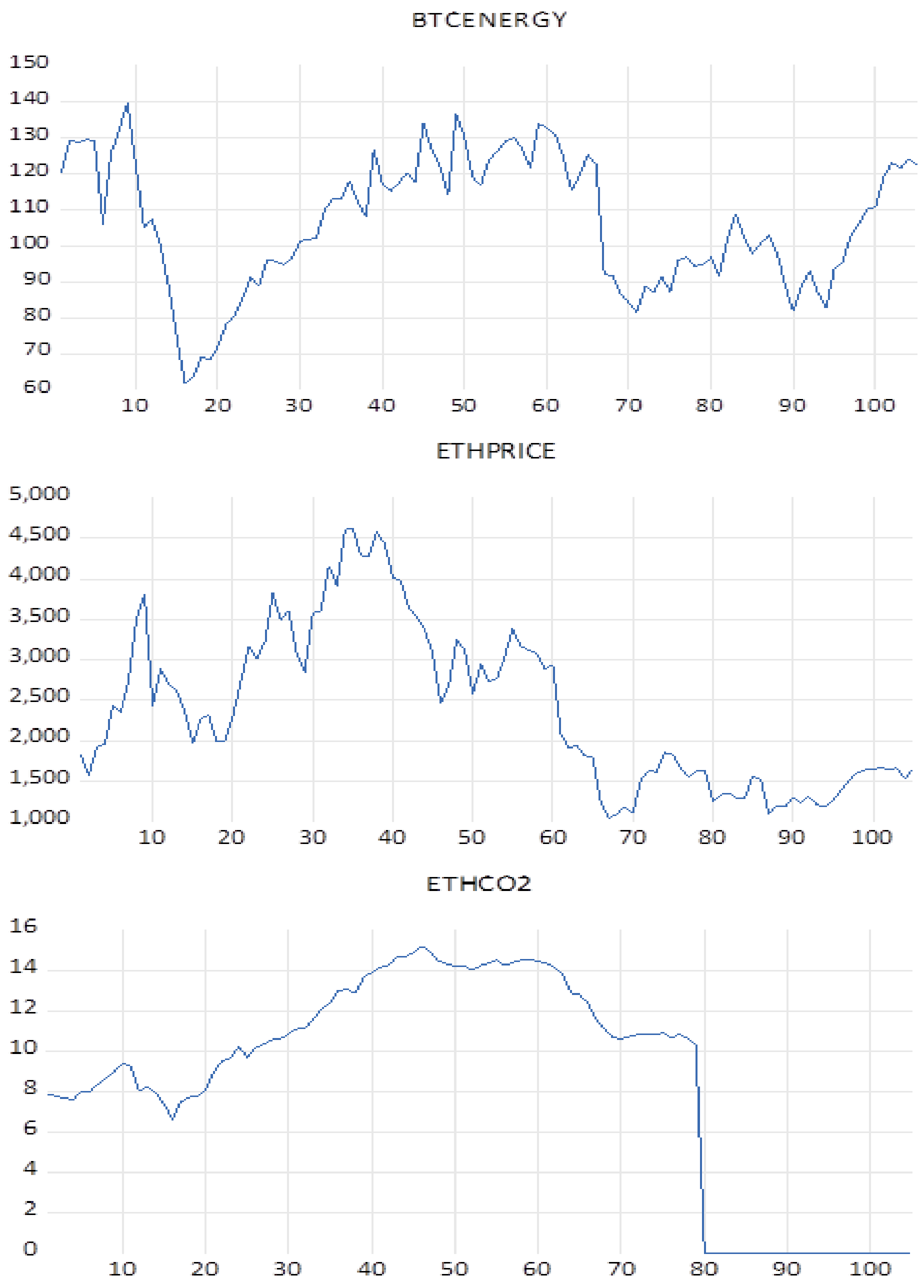
In the study, Bitcoin's energy consumption data from March 17, 2021 to March 1, 2023 is from Cambridge University of Cambridge Alternative Finance Center (CCAF), 8 and 15 March data from Crypto Carbon Ratings Institute (CCRI); March 17, 2021 – March 15, 2023 historical price data taken from investing.com. Ethereum 17 March 2021 – 15 March 2023 energy consumption data from Crypto Carbon Ratings Institute (CCRI), historical price data from investing.com. CO2 emissions data for both cryptoassets are from the Crypto Carbon Ratings Institute (CCRI). The time series charts for these series are presented below.

Graphs 1-6

Time Series Charts of Variables






BTCENERGY
150
140
130
120
110
100
90
80
70
60
10 20 30 40 50 60 70 80 90 100
ETHPRICE
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
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ETHCO2
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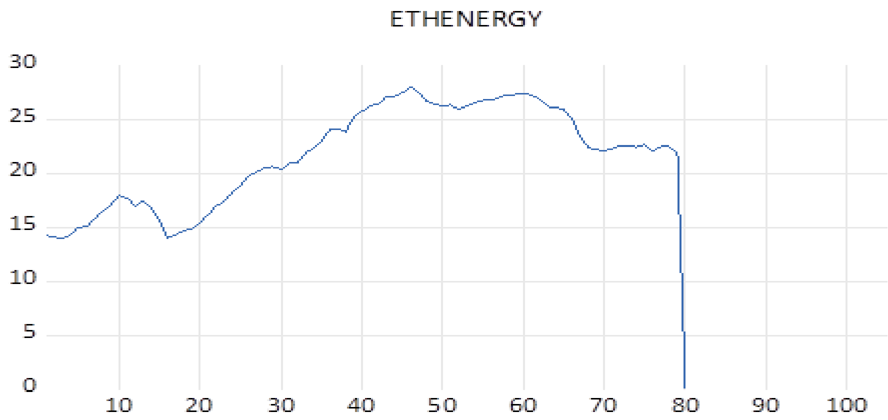
10 20 30 40 50 60 70 80 90 100



Source: authors'

When the graphs are examined, it is understood that Bitcoin price, energy consumption, and CO2 emission variables show a similar course. On the other hand, with the effect of the merge, there was a serious break in Ethereum's CO2 emission and energy consumption data on September 21, 2022. It is clear from the graphs that this situation is not fully reflected in Ethereum prices. The aim of this study is to confirm these interpretations with empirical analysis.

3.2. Methodology and Empirical Findings

3.2.1. Fourier ADF Unit Root Test

The Dickey-Fuller Unit Root Test was first developed in 1979 by D. A. Dickey and W. A. Fuller (İzolluoğlu, 2019). Unit root tests are divided into linear and nonlinear unit root tests. If the trends of the series of variables considered in a study are linear over time, the stationarity condition of these series is determined by linear unit root tests. However, if the trend in the time series of the variables is not linear, the stationarity condition is determined by nonlinear unit root tests (Yücesan, 2021). This test, which is used to test the stationarity of the time series, is the basis of the unit root tests developed by making additions over time. In this study, the Fourier Augmented Dickey-Fuller Unit Root Test (FADF) developed by Walter Enders and Junsoo Lee in 2012 was used. The FADF test is seen as an alternative to the Perron (1990), Zivot and Andrews (1992), and Bai and Perron (2003) tests since it also includes asymmetric relationships in the analysis. The biggest advantage of this test, which also takes into account the structural breaks in the existing variables by adding some trigonometric terms to the equation of the ADF unit root test, is that it is not necessary to predetermine the number and form of the existing break points in the series (İzolluoğlu, 2019; Mike and Alper, 2020; İnal et al., 2023).

The Fourier ADF Unit Root Test model is as follows:

$$y_t = y_0 + y_1 \sin\left(\frac{2\pi kt}{T}\right) + y_2 \cos\left(\frac{2\pi kt}{T}\right) + v_1 \quad (1)$$

The terms shown on the present equation and the values they represent are as follows: t=trend, T=sample size, π=3.1416, frequency is an integer between 1 and 5 as a value.

The test results are as in the table given below:

Table 1

Fourier ADF Unit Root Test Results

	Level	First Difference
Bitcoin CO_2 Emission	-3.1873 (2)	-8.1883 (2) ***
Bitcoin Energy Consumption	-3.1371 (2)	-8.6372 (4) ***
Bitcoin Price	-1.9801 (4)	-8.0106 (4) ***
Ethereum CO_2 Emission	-2.9449 (1)	-10.0616 (1) ***
Ethereum Energy Consumption	-2.9302 (1)	-9.9496 (3) ***
Ethereum Price	-3.3625 (1)	-8.2290 (4) ***

*Note: *** Indicates significance with 99% confidence. Values in parentheses indicate optimal Fourier values.*

In the first test results, no stationarity was observed in any of the variables of Bitcoin CO2 Emission, Bitcoin Energy Consumption, Bitcoin Price, Ethereum CO2 Emission, Ethereum Energy Consumption, Ethereum Price, and the hypothesis that there is a unit root was accepted. For this reason, the difference of all available variables was taken and as a result, stationarity was determined in all variables with 99% confidence.

3.2.2. Fourier Granger Causality Test

Since Granger causality analysis ignores structural breaks when performed with the Vector Autoregression (VAR) model, Enders and Jones (2016) added Gallant's (1981) Fourier functions to the VAR model and developed a new test that takes into account the structural breaks without knowing the date and number. This new test developed by Enders and Jones (2016) is the Fourier Granger causality test and the model is as in equation 2. The null hypothesis of the test was established as no causal relationship (Pata and Ela, 2020).

$$\alpha(t) = \alpha_0 + \sum_{k=1}^{p} \alpha_k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{p} \beta_k \cos\left(\frac{2\pi kt}{T}\right) \quad (2)$$

$$y_t = \theta + \phi_1 y_{t-1} + \cdots + \phi_u y_{t-i} + u_t \quad (3)$$

$$y_t = \theta_0 + \varphi_{1k}\sin\left(\frac{2\pi kt}{T}\right) + \varphi_{2k}\cos\left(\frac{2\pi kt}{T}\right) + \phi_1 y_{t-1} + \cdots + \phi_i y_{t-i} + u_t \quad (4)$$

T in the equation represents the number of observations, the smallest value of the k residual sum of squares, and the value of π is 3.1416. Equation 2 represents the Fourier trigonometric functions, equation 3 represents the VAR model, and equation 4, which is obtained by adding the Fourier trigonometric functions to the VAR model, represents the Fourier-Granger causality test model (Yurtkuran, 2021).

The results of the Fourier-Granger Causality test are given in Table 2.

Table 2

Fourier Granger Causality Test Results

	Fourier Number	Test Statistics	Asymptotic Probability Value	Bootstrap Probability Value
BP → BEC	2	7.022***	0.006	0.020
BP → BCE	2	3.853**	0.050	0.050
BCE → BP	2	7.830***	0.005	0.004
BEC → BP	2	5.184**	0.023	0.020
EP → EEC	1	0.000	0.991	0.996
EP → ECE	1	0.000	0.994	0.993
EEC → EP	1	0.556	0.456	0.435
ECE → EP	1	0.425	0.429	0.393

*Note: In Table 2; * means with 90% reliability, ** with 95% reliability, *** with 99% reliability. BP=Bitcoin Price, BEC= Bitcoin Energy Consumption, BCE= Bitcoin CO2 Emission, EP=Ethereum Price, EEC= Ethereum Energy Consumption, ECE= Ethereum CO2 Emission, → indicates the direction of causality.*

As a result of the Fourier Granger Causality Test of the variables examined bilaterally in Table 2, a bidirectional causality relationship was determined between Bitcoin Price, Bitcoin Energy consumption and Bitcoin CO2 Emission data. For BF→BET and BCE→BF with 99% confidence, and for BF→BCE and BET→BF 95% confidence significance was determined. On the Ethereum side, no directional causality relationship was detected between the variables.

3.2.3. Fourier ADL Cointegration Test

The cointegration models introduced to the literature by Granger (1981) and Engle and Granger (1987) have been criticized for establishing the null hypothesis as no cointegration (Gazel, 2018). The Fourier ADL Cointegration Test was used in this study to determine whether the variables act together in the long run (Barut and Kaya, 2020). The Fourier ADL Cointegration Test, which was created by adding trigonometric functions to the ADL cointegration model by Banerjee et al. (2017), differs from other cointegration tests because the single frequency component can capture unknown multiple structural breaks (Aztimur et al., 2023:778; Barut and Kaya, 2020). In this model, in which the test statistic is compared with the critical values suggested by Banerjee et al. (2017), if the test statistic value is greater than the critical values, the H0 basic hypothesis, which represents the result of cointegration, is accepted. With this test, in cases where the frequency numbers are low, very different types of refraction can be detected, thus increasing the power of the test and preventing the use of more dummy variables (Barut and Kaya, 2020).

The model of the test is as follows:

$$\Delta y_{1t} = d(t) + \delta_1 y_{1,t-1} + \gamma' y_{2,t-1} + \varphi' \Delta y_{2t} + e_t \qquad (5)$$

In Equation 5, y_{1t} represents the dependent variable, and the symbols δ, γ and φ are the independent variables. The current $d(t)$ deterministic component in the Fourier approach is defined as in Equation 6.

$$d(t) = \gamma_0 + \sum_{k=1}^{q} \gamma_{1,k} \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{q} \gamma_{2,k} \cos\left(\frac{2\pi kt}{T}\right),\ q \leq T/2 \qquad (6)$$

The hypotheses of the test are as shown below:

$H_0 : \delta_1 = 0 \qquad H_1 : \delta_1 < 0$

The statistic test is calculated as in Equation 7.

$$t_{ADL}^{F} = \frac{\hat{\delta}_1}{se(\hat{\delta}_1)} \qquad (7)$$

Here, $\hat{\delta}_1$ is the PLS (Partial Least Squares) estimator, and $se(\hat{\delta}_1)$ represents the standard error of $\hat{\delta}_1$ obtained from the PLS estimation (Aztimur et al., 2023).

Fourier ADL Cointegration test results are given in Table 3.

Table 3

Fourier ADL Cointegration Test Results

	Test Statistics	Frequency	Min AIC
BP − BEC	-4.473069**	2	6.782503
BP − BCE	-5.082497***	2	5.519302
EP − EEC	-3.003339	1	4.443543
EP − ECE	-2.989543	1	2.969159

*Note: In Table 3; ** Represents significance with 95% confidence, and *** Represents with 99% confidence. BP=Bitcoin Price, BEC= Bitcoin Energy Consumption, BCE= Bitcoin CO2 Emission, EP=Ethereum Price, EEC= Ethereum Energy Consumption, and ECE= Ethereum CO2 Emission.*

According to Fourier ADL Cointegration test results, for Bitcoin Price variable; It is accepted that Bitcoin CO2 Emission and Bitcoin Energy Consumption variables are above the critical values calculated for 1%, 5% and 10% significance levels, respectively, and that there is a cointegration relationship between them. In this direction, Bitcoin Price and Bitcoin CO2 Emission and Bitcoin Energy Consumption variables have cointegrated in the long run. On the Ethereum side of the tests, since no cointegration relationship was detected between the variables, there is no relationship in the long run.

4. Concluding remarks

Bitcoin, which has become widespread today, and crypto assets with similar working principles have caused intense energy consumption and emission problems brought by the mining process; These problems have also led to the emergence of criticism on crypto assets. In addition, alternatives have been sought to develop environmentally friendly steps to reduce intense energy consumption and carbon emissions in order to reduce these risks in the transactions of crypto assets, which offer various advantages to the user such as fast and low-cost transactions. The Proof of Stake mechanism is one of the main alternatives offered in this context. Ethereum, a crypto asset with a high market value like Bitcoin, switched from the Proof of Work mechanism, which requires intense energy consumption, to the

Proof of Stake mechanism, which is seen as more advantageous in terms of energy efficiency, in September 2022. With this development, it is aimed to prevent intense energy consumption by giving the blockchain update authority to randomly selected validators instead of competing miners in Proof of Work.

In this study, it is aimed to examine the relationship between energy consumption, carbon emission and prices of crypto assets by considering the price, CO2 emission, energy consumption series of Bitcoin and Ethereum for the period 17 March 2021-15 March 2023 on a weekly basis. First, the stationarity of the series was examined by using the Fourier ADF Unit Root Test with the available data, and then the causality between variables was investigated with the Fourier Granger Causality Test. Considering the causality test results; it can be said that since the price increase on the Bitcoin side directly affects the demand for this asset, the energy consumption caused by Bitcoin mining operations has increased with this demand. In addition, the causality relationship from the detected Bitcoin price to Bitcoin carbon emission can be explained by the fact that the price increases in this asset cause negative environmental effects. The lack of causality between the variables on the Ethereum side can be explained by the breaking of causality as a result of the significant decrease in energy consumption and carbon emissions after the transition to the Proof-of-Stake mechanism of the data obtained after September 21, 2022 in the series discussed. Fourier ADL Cointegration Test was applied to the series in order to examine the relationship between the variables. In the results, the long-term cointegration relationship of Bitcoin Price and Bitcoin CO2 Emission and Bitcoin Energy Consumption variables were determined. In Ethereum, however, no relationship was detected among the variables. The reason for this situation can be explained similarly to the situation in causality.

When comparing the findings with the studies in the literature, it can be said that the cointegration tests between Bitcoin and CO2 emissions gave similar results with Felek et al. (2023). On the other hand, in their paper where Zheng et al., (2023) aimed to examine the causality relationship between cryptocurrency transactions and electricity consumption, it was concluded that transactions are important determinants of electricity consumption due to the computing power distributed wherever there is high profit. Ampel (2023), another study examining the repercussions of Ethereum's protocol change, found that Ethereum's mechanism change had a positive effect on the price as a result of its analysis. The study stated that the transition from Proof of Work to Proof of Stake has positive effects both environmentally and in terms of increasing investment opportunities. These findings are similar to the results obtained in our study.

In future studies, research on this subject can be expanded with different econometric methods and studies can be increased to contribute to the literature on the relationships between variables and their effects on each other. Energy and carbon market values are not discussed in this study. In this sense, it is anticipated that it may be useful to examine the market values of these variables in future studies. In this study, the reflections of Ethereum's consensus protocol change, which is an important step in preventing high energy consumption resulting from transaction processes in crypto assets, were examined by considering crypto asset prices, carbon emission and energy consumption variables. Considering the results of the analysis, it was observed that Ethereum's transition to the Proof of Stake protocol had positive effects. In this regard, it is aimed to contribute to the literature through econometric results that will clarify the current situation with the data obtained and to guide future studies. In this sense, in order to prevent the negative environmental effects of crypto assets, whose use has become widespread, research can be conducted to determine whether a protocol change will be appropriate for other crypto assets, similar to Ethereum. If possible, environmental damage can be prevented by taking steps towards this change. Finally, technology companies or companies open to innovation can also contribute to this field through initiatives and support for different research on preventing intense energy consumption, and governments can implement policies to support initiatives in this field and even provide incentives for these research and practices with state-supported projects.

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