Investigation of the effects of digital money Bitcoin and Electronic Funds Transfers on electric energy consumption

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Abstract

The dizzying developments in information and communication technologies have affected many areas such as economy, education, health, tourism, travel, and defense. These developments in technology have made digitalization an inevitable part of our lives today. In this context, this study aims to examine the effect of electronic fund transfers and Bitcoin on electrical energy consumption between the years 2016M4-2021M11 in Turkey. Econometric time series analysis methods were used as a method in the study. In this direction, firstly, Augmented Dickey-Fuller and Phillips-Perron unit root tests were applied to the variables in the analysis. Then, based on the results of the unit root tests, the autoregressive distributed lag bound test was applied to the variables. As a result of this application, it has been observed that there is a cointegration relationship between the electronic fund transfers, Bitcoin, and electrical energy consumption between the years 2016M4-2021M11 in Turkey. Then, the long-and short-term relationship between the variables was analyzed. According to the findings, a positive but statistically insignificant relationship was found between the electronic fund transfers and electrical energy consumption in both the short and long term. It has been found that there is a positive and statistically significant relationship between Bitcoin and electrical energy consumption in both the short and long term. At the last stage of the analysis, the Toda-Yamamoto causality test was applied to the variables and it was found that there is a one-way causality relationship from electronic fund transfers to electrical energy consumption.

Keywords: Bitcoin, digital, fund, transfer, electricity, consumption

Jel Codes: C32, E00, G19

1. Introduction

Information and communication technologies, which developed rapidly with the first Industrial Revolution, started to experience their golden age from the second half of the 20th century. In this process, especially the invention of computers, the internet, and smart devices is a revolution for technological developments.

While these developments in information and communication technologies eliminated the borders of the country in a short time, they turned the world into a global virtual village and affected many fields such as politics, science, art, culture, education, and many similar areas locally and globally, especially economy and production. In particular, the Covid-19 epidemic, which emerged in December 2019 and is still in effect, has now shown that technology is an inseparable and important part of our lives.

Undoubtedly, the economic sector is one of the sectors most affected by these developments in technology. In this context, the invention of computers, the internet, and smart devices enables technology not only in industry and mass production but also in the economic activities and transactions of human beings in daily life, only a click away. Thanks to technological developments, this digital transformation in the economy now allows people to perform almost all banking transactions without going to banks. In addition, digitalization offers the opportunity to buy, sell and use digital money, which has had an important place in the economic agenda recently. In this way, such transactions, which can be done in the digital environment, save people time and significantly reduce transaction costs.

Based on these developments in technology, the main purpose of this study is to examine the value of digital money Bitcoin and the effects of electronic fund transfers on electrical energy consumption in Turkey between the years 2016:M4-2021:M11. Autoregressive Distributed Lag (ARDL) bounds test and the Toda-Yamamoto causality test, which are econometric analysis methods, were used to examine these relationships.

2. Literature Review

In the literature review, no studies were found that deal with the digital currency Bitcoin, electronic fund transfers, and electricity consumption variables together. Studies in the literature are mainly on energy consumption with Bitcoin. Therefore, this study is of great importance in terms of filling the gap in the literature. The results obtained in this study support the results of most studies in the literature. The studies conducted in the literature on this subject and the detailed summary of the results obtained in these studies are given in Table 1 below.

Table 1. Literature Summary

Authors (Publication Year)	Countries (Period)	Method	Conclusion and Findings
Vries (2018)	General (2009-2018)	Data Analysis	Bitcoin is an extremely energy-hungry design. For this reason, it has been concluded that the Bitcoin network consumes a significant amount of electricity and this consumption will continue to increase.
Greenberga, & Bugden (2019)	Washington (2014-2018)	Data Analysis	Long-term projections for crypto mining, blockchain technology general data storage, and processing could lead to new energy consumption explosions in the US and around the world.
Li et al., (2019)	China (2018)	Data Analysis, Experimentation	The energy consumption from cryptocurrency mining is increasing day by day.
Gallersdorfer et al., (2020)	General (-)	Algorithm	Hundreds of mined crypto and coins, especially Bitcoin, increase energy consumption.
Das & Dutta (2020)	General (2017-2019)	Regression Analysis	In Bitcoin and data mining, revenues are low and very volatile, while energy consumption is increasing. This situation increases the energy costs and negatively affects the income of data miners.
Sedlmeir et al., (2020)	General (2019-2020)	Data Analysis	Although the energy consumption of Bitcoin and similar blockchains is very large, it has been observed that they do not pose a major threat to the climate, especially when compared to the number of transactions they can handle.
Vries (2020)	General (2017-2019)	Data Analysis	Estimates of Bitcoin network electricity consumption show that it will consume 87.1 Terawatts (TW) of electricity annually in September 2019, when the profitability of data mining peaked. This figure is approximately equal to one year's electrical energy consumption in a country like Belgium.
Kılıç et al., (2021)	Selected Countries (2017-2021)	CCC-GARCH	It has been determined that there is bidirectional volatility spread between the Cambridge Bitcoin Electricity Consumption Index (CBECI) and the MOEX energy index, and one-way volatility spread between the S&P 500 and SSE energy indices and CBECI. In addition, it has been determined that shocks from the S&P 500 energy index increase the CBECI index, but shocks that occur in the MOEX energy index decrease the CBECI index.
Huynh et al., (2021)	General (2017-2019)	Variance Decomposition	A bidirectional effect was found between energy consumption and Bitcoin returns. It has also been observed that the liquidity represented by Bitcoin trading volumes is an important indicator for energy consumption.
Corbet et al., (2021)	China, Japan and Russian (2010-2019)	DCC-GARCH	The dimensions of the energy used in cryptocurrency transactions have a decisive role in the prices of the electrical energy market.

3. Data Set and Method

In the econometric analysis of this study, monthly data from Turkey between the years 2016:M4-2021:M11 were used. The reason why the analysis period was preferred between these years is the common data restriction caused by electricity consumption. The data were obtained from the database of the Central Bank of the Republic of Turkey and the database of investing.org. The natural logarithm of the variables used in the analysis was taken, and these variables are given in Table 2, shown below.

Table 2. Variables and Description

Variables	Variable Short Name	Variable Description
Bitcoin	LNBTC	Monthly value
Electronic Funds Transfers	LNEFT	Amount of monthly EFT output from the Central Bank of the Republic of Turkey (Million TL)
Electric Energy Consumption	LNEEC	Turkey's total monthly electricity energy consumption (megawatts)

In the first stage of econometric analysis, statistical summaries of the variables were created. Then, the stationarity structures of the variables were examined with The Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) unit root tests. In the third stage of the analysis, The Autoregressive Distributed Lag (ARDL) bounds test was applied to the variables in line with the results of the unit root tests. At the last stage of the analysis, the analysis was completed by applying the Toda-Yamamoto causality test to the variables.

4. Empirical Findings

Statistical summaries of the variables that constitute the first stage of the analysis performed in this study are given in Table 3 below.

Table 3. Descriptive Statistics

Variable	Observation	Minimum Value	Maximum Value	Mean	Standard Deviation
LNEEC	68	13.359	13.855	13.596	0.088
LNEFT	68	27.239	28.961	27.978	0.391
LNBTC	68	6.105	11.023	8.768	1.315

When the statistical summaries given in Table 3 are examined, it shows that the number of observations, minimum-maximum values, averages, and standard deviations of the variables is suitable for the analysis. In line with these results, unit root tests, which are the next stage of the analysis, were started.

4.1. Unit Root Tests

For time-series analyses to be performed properly, the variables included in the analysis must have a stationary (without unit root) structure (Aytekin, 2021). One of the important tests used to determine whether the variables have a stationary structure is the unit root test (Aytekin & Bozkaya, 2021). Therefore, in this study, ADF and PP unit root tests were used to determine whether the variables have a stationary structure. The obtained results are given in Table 4 shown below.

Table 4. ADF and PP Unit Root Test Findings

Level	Variable Name	ADF		PP	
		With Constant	With Constant & Trend	With Constant	With Constant & Trend
		t-Statistic (Probability)	t-Statistic (Probability)	t-Statistic (Probability)	t-Statistic (Probability)
At Level	LNEEC	-1.805 (0.375)	-6.779 (0.000)*	-3.615 (0.008)*	-3.811 (0.022)**
	LNEFT	-0.2854 (0.921)	-1.353 (0.865)	-4.459 (0.892)	-1.945 (0.621)
	LNBTC	-1.205 (0.667)	-1.807 (0.690)	-1.246 (0.650)	-2.110 (0.530)
At First Difference	LNEFT	-11.097 (0.000)*	-11.074 (0.000)*	-11.0777 0.0000	-11.074 (0.000)*
	LNBTC	-6.9616 (0.000)*	-6.921 (0.000)*	-7.012 (0.000)*	-6.9727 (0.000)*

* and ** denote statistical significance at 1% and 5% significance levels, respectively, while Δ denotes difference operator.

When the results of the ADF and PP unit root tests given in Table 4 are examined, it is understood that the electrical energy consumption is stationary at the level of I(0) according to the constant-trend model of the ADF unit root test, and the PP unit root test according to both the constant and the constant-trend model. With the electronic fund transfer given in Table 4, it has been understood that Bitcoin is stationary, that is, I(1), at the first difference according to both the fixed and fixed-trend models of the ADF and PP unit root tests.

The fact that the variables are stationary at different levels indicates that it would be healthier to use the ARDL bound test in cointegration analysis (Pesaran et al., 2001). For this reason, the cointegration test of this study was preferred as the ARDL bound test based on the results of unit root tests.

4.2. ARDL Bound Test

ARDL bounds test is an important cointegration test developed by Pesaran et al (2001). The most important advantage of this test is that it can be applied even if the variables are stationary in different orders (some of the variables are I(0), some of them are I(1)). Pesaran et al. (2001) calculated two limit values for this test, one being the lower limit, I(0), and the other being the upper limit, I(1). After applying this limit test to the variables, if the calculated F statistical value is below the lower limit value I(0), it is decided that there is no cointegration relationship between the variables. If the calculated F statistical value is above the upper limit value I(1), it is decided that there is a cointegration relationship between the variables. Finally, Pesaran et al. (2001) stated that if the F statistical value calculated in their study takes a value between the lower limit value I(0) and the upper limit value I(1), no decision can be made for cointegration this time (Pesaran et al., 2001).

In this study, ARDL(2.2.0) model was estimated based on the results of unit root tests. This model was estimated based on the Akaike (AIC) information criterion and two automatically selected lags. The diagnostic test results of this predicted model are given in Table 5. These results show that the predicted ARDL(2.2.0) model does not have autocorrelation, varying variance, and specification error, and the residuals of the model are normally distributed.

Table 5. ARDL Bound Test Results

F-statistic Value	**Critical Value**	
20.176	**I(0) Bound**	**I(1) Bound**
%1	5.15	6.36
%5	3.79	4.85
%10	3.17	4.14
Diagnostic Challenge Test Results		
R-squared		0.647
Adjusted R-squared		0.611
F-statistic (Probability)		0.000
Breusch-Godfrey Serial Correlation LM Test (Probability)		0.327
Heteroskedasticity Test (Probability)		0.578
Ramsey Reset Test (Probability)		0.554
Jarque Bera (Probability)		0.606

When the results of the ARDL limit test given in Table 5 are examined, it is seen that the F statistical value is calculated as 20.176. It has been understood that this calculated F statistical value is higher than the upper limit values of 6.36 and 4.85, which are the 1% and 5% significance levels given in Table 5. This result shows that there is a cointegration relationship, that is, a long-term relationship, between Bitcoin, electricity consumption, and electronic fund transfers in Turkey.

Table 6. Error Correction Model (ECM) and Short-Term Test Results

Variable	Coefficient	Std. Error	t-Statistic	Probability
D(LNEEC(-1))	0.580	0.101	5.713	0.000
D(LNEFT)	0.031	0.050	0.613	0.542
D(LNEFT(-1))	-0.132	0.051	-2.567	0.013
D(LNBTC)	0.022	0.010	2.102	0.039
CointEq(-1)	-0.778	0.099	-7.826	0.000

According to the results given in Table 6, the error correction coefficient of the analysis was calculated as -0.778. This calculated coefficient indicates that the deviations in the short-term balance will reach the long-term balance again in approximately 1/(|-0.778|)=1.2 months. In addition, the t statistical value of this coefficient and the probability value given in Table 6 show that this coefficient is statistically significant.

Another result given in Table 6 is the short-term results. In this context, a statistically significant and positive relationship was found between electrical energy consumption and Bitcoin in the short term, while a positive but statistically insignificant relationship was found between electrical energy consumption and electronic fund transfers.

Table 7. Long Term Test Results

Variable	Coefficient	Std. Error	t-Statistic	Probability
LNEFT	0.022	0.044	0.508	0.613
LNBTC	0.028	0.012	2.233	0.029
C	12.724	1.141	11.151	0.000

Estimated long run equation;

$$\mathrm{LNEEC}_t = \beta_0 + \beta_1 \mathrm{LNEFT} + \beta_2 \mathrm{LNBTC} + \varepsilon_t$$

LNEEC= +0.022*LNEFT + 0.028*LNBTC + 12.724

When the long-term results given in Table 7 are examined, a statistically significant and positive relationship was found between electrical energy consumption and Bitcoin in the long term, while a positive but statistically insignificant relationship was found between electrical energy consumption and electronic fund transfers. Based on these results, it is possible to say that the volatility seen in Bitcoin's value in both the short and long term increases the electricity consumption in Turkey. This result creates a cost-increasing effect for Turkey, which is a foreign-dependent country in energy.

4.3. Toda-Yamamoto Causality Test

The Toda-Yamamoto causality test was developed by Toda and Yamamoto in 1995 to determine the causal relationship between variables and the direction of this relationship. This test is applied to the variables over the VAR model with increased delay. The Toda-Yamamoto causality test has two advantages over other causality tests. The first of these is that this test is applicable even if the variables used in the analysis are stationary at different levels. The second is that there is no need for the precondition of determining the cointegration relationship between the variables. Therefore, in the first stage of this test, the level at which the variables are stationary at the highest level, which is expressed as d_{max}, is determined. Then, the appropriate lag length for the variables is determined and this lag length, expressed as k, is added to d_{max} and the VAR model with increased lag length is estimated. In the last stage, the Toda-Yamamoto causality test is applied to the variables over this estimated VAR model. The Toda-Yamamoto causality test for two variables such as X and Y is modeled as in equation 1 and equation 2 given below (Toda & Yamamoto, 1995);

$$X_t = \mu + \sum_{i=1}^{k+dmax} a_1 X_{t-i} + \sum_{i=1}^{k+dmax} a_2 Y_{t-i} + \varepsilon_t \quad (1)$$

$$Y_t = \mu + \sum_{i=1}^{k+dmax} \beta_1 Y_{t-i} + \sum_{i=1}^{k+dmax} \beta_2 X_{t-i} + \varepsilon_t \quad (2)$$

In this study, for the Toda-Yamamoto causality test, the d_{max} number was determined as 1 (d_{max}=1) using unit root tests at the first stage. In the second stage, k, which indicates the most appropriate number of lag lengths, was determined as 2 (k=2). Thus, by summing the dmax determined as 1 and the k numbers determined as 2 (d_{max}+k=1+2=3), the VAR model with increased lag length was estimated. Then, the Toda-Yamamoto causality test was applied to the variables over this model and the results are given in Table 7 shown below. In addition, the Toda-Yamamoto causality equations created for the variables used in the study are as shown below.

$$\mathrm{LNEEC}_t = \mu + \sum_{i=1}^{k+dmax} a_1\, LNEEC_{t-i} + \sum_{i=1}^{k+dmax} a_2\, LNEFT_{t-i} + \sum_{i=1}^{k+dmax} a_3\, LNBTC_{t-i} + \varepsilon_t \tag{3}$$

$$\mathrm{LNEFT}_t = \mu + \sum_{i=1}^{k+dmax} \beta_1\, LNEFT_{t-i} + \sum_{i=1}^{k+dmax} \beta_2\, LNEEC_{t-i} + \sum_{i=1}^{k+dmax} \beta_3\, LNBTC_{t-i} + \varepsilon_t \tag{4}$$

$$\mathrm{LNBTC}_t = \mu + \sum_{i=1}^{k+dmax} \lambda_1\, LNBTC_{t-i} + \sum_{i=1}^{k+dmax} \lambda_2\, LNEEC_{t-i} + \sum_{i=1}^{k+dmax} \lambda_3\, LNEFT_{t-i} + \varepsilon_t \tag{5}$$

Table 7. Toda-Yamamoto Casuality Test Results

Independent Variables	**Dependent Variable: LNEEC**				
	d_{max}+k=3	**χ^2-Value**	***P* Value**	**Decision**	**Conclusion**
LNEFT	3	7.106	0.028	H_0: Rejection	LNEFT => LNEEC
LNBTC	3	4.135	0.126	H_0: Acceptance	LNBTC ≠>LNEEC
ALL	3	9.850	0.043	H_0: Rejection	ALL => LNEEC
Independent Variables	**Dependent Variable: LNEFT**				
	d_{max}+k=3	**χ^2-Value**	***P* Value**	**Decision**	**Conclusion**
LNEEC	3	0.110	0.946	H_0: Acceptance	LNEEC ≠> LNEFT
LNBTC	3	3.537	0.170	H_0: Acceptance	LNBTC ≠> LNEFT
ALL	3	3.678	0.451	H_0: Acceptance	ALL ≠> LNEFT
Independent Variables	**Dependent Variable: LNBTC**				
	d_{max}+k=3	**χ^2-Value**	***P* Value**	**Decision**	**Conclusion**
LNEEC	3	1.454	0.483	H_0:Acceptance	LNEEC ≠>LNBTC
LNEFT	3	1.707	0.426	H_0:Acceptance	LNEFT ≠>LNBTC
ALL	3	3.017	0.554	H_0:Acceptance	ALL ≠> LNBTC

=>: Granger-causes. ≠> : no Granger-causes.

When the results of the Toda-Yamamoto causality test given in Table 7 were examined, a causal relationship was found only from electronic fund transfers to electrical energy. When both Bitcoin and electronic fund transfers are considered together, it is understood that both independent variables are the cause of cumulative electrical energy consumption.

5. Conclusion and Discussion

As a result of this study; It has been concluded that there is a long-term relationship between fund transfers, Bitcoin, and electrical energy consumption in Turkey between the years 2016M4-2021M11. In addition, in the Toda-Yamamoto causality test, a causality relationship was found from electronic fund transfers to electrical energy consumption.

Based on these results, it has been observed that the volatility seen in the value of Bitcoin in the short and long term in Turkey increases the electricity consumption in Turkey. The main reasons for Bitcoin to increase electricity consumption are; it can be listed as the volatility in Bitcoin causing an increase in the number of Bitcoin transactions and transaction volume, the fact that transactions can be made in the Bitcoin market twenty-four hours a day, and Bitcoin has an important data mining, storage, and backup infrastructure.

The results of the Toda-Yamamoto causality test showed that electronic fund transfers are the cause of electrical energy consumption in the short term in Turkey. The main reasons why electronic fund transfers increase electrical energy consumption in the short term are; these transfers can be made only at certain times of the day, there is a daily transaction limit in these transfers, the transfers are not continuous, and the fund transfer transaction volumes are less than Bitcoin.

To summarize, in this study, it was concluded that Turkey's electrical energy consumption increased during the transactions of electronic fund transfers with Bitcoin in the period included in the analysis.

Finally, these results reached in this study are in the literature; Vries (2018), Greenberga & Bugden (2019), Li et al. (2019), Gallersdorfer et al. (2020), Das & Dutta (2020), Sedlmeir et al. (2020), Vries (2020), Kılıç et al. (2021), Huynh et al. (2021), and Corbet et al. (2021) supports the results of the studies conducted by.

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