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POSSIBLE EFFECTS OF UNCERTAINTY FACTORS ON GREEN BOND RETURNS

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Abstract

This study aims to determine the short and long-run relationship between green bond returns and uncertainty factors. For this purpose, study uses S&P Green Bond Index as green bond indicator and Economic Policy Uncertainty Index and Climate Policy Uncertainty Index as uncertainty factors. In addition, VIX and CDS variables, which are thought to affect the green bond market, are used as control variables in the study. In this context, the period range of the study is determined as 09/2014 - 09/2024 and the study is conducted on the S&P Green Bond Index. As a result of the study using the ARDL bounds test approach, it is found that all of the explanatory and control variables are statistically significant in the long run. The results show that the green bond market is sensitive to uncertainty and risk factors.

Keywords: *Green Bonds, Uncertainty Factors, ARDL Bounds Test.*

BELİRSİZLİK FAKTÖRLERİNİN YEŞİL TAHVİL GETİRİLERİNE OLASI ETKİLERİ

Öz

Bu çalışmada yeşil tahvil getirisi ile belirsizlik faktörleri arasındaki kısa ve uzun dönemli ilişkinin tespit edilmesi amaçlanmaktadır. Bu amaç doğrultusunda çalışmada yeşil tahvil göstergesi olarak S&P Yeşil Tahvil Endeksi baz alınırken, belirsizlik faktörleri olarak Ekonomi Politikası Belirsizlik Endeksi ve İklim Politikası Belirsizlik Endeksi baz alınmıştır. Bununla birlikte yeşil tahvil piyasasını etkilediği düşünülen VIX ve CDS değişkenleri ise çalışmada kontrol değişkenlerini olarak kullanılmıştır. Bu kapsamda çalışmanın dönem aralığı 09/2014 – 09/2024 olarak belirlenmiş ve çalışma S&P Yeşil Tahvil Endeksi özelinde gerçekleştirilmiştir. ARDL sınır testi yaklaşımının kullanıldığı çalışma sonucunda açıklayıcı ve kontrol değişkenlerinin tamamının uzun dönemde istatistiki olarak anlamlı sonuçlar verdiği tespit edilmiştir. Elde edilen sonuçlar, yeşil tahvil piyasasının belirsizlik ve risk faktörlerine karşı duyarlı olduğunu göstermektedir.

Anahtar kelimeler: *Yeşil Tahvil, Belirsizlik Faktörleri, ARDL Sınır Testi.*

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1. INTRODUCTION

Financial markets can react very quickly to economic developments. The direction and scale of this reaction are closely linked to the developments. Long positions (buying) in financial markets are expected to increase in a period when the economy is growing efficiently, monetary easing has begun, or there is consensus about the future (Neukirchen et al., 2022; Zakhidov, 2024), while short positions (selling) in financial markets are expected to increase in a period of economic stagnation, rising interest rates, or increased uncertainty (Lin and Su, 2020; Hung et al., 2021; Yuan et al., 2022). In this context, it can be stated that financial markets are dynamic and sensitive to developments. In addition, it is considered important to determine the impact of new index data calculated in line with recent global developments on financial markets. Considering that with globalization, financial markets are sensitive to external factors as well as internal factors and that all global markets are affected by possible risk factors, the importance of the new index data, in other words, the new uncertainty and risk indicators, will be better understood. In particular, economic policy indicators, climate risk uncertainty indices, and risk and fear indicators that are closely related to investors are considered to be leading indicators in this context.

Recent global developments have not only led to the calculation of new risk indicators, but also provided the basis for the development of new financial assets that will appeal to investors in the new era in financial markets. Therefore, it can be concluded that global developments have an impact on the calculation of new risk indicators and the development of financial assets in accordance with the period and time. In this regard, the green bond investment instrument, which has recently attracted the attention of researchers and investors, can be given as an example. A green bond is an investment instrument that has the characteristics of a traditional bond but commits to using the financing obtained for sustainable and environmentally sensitive investments (Maltais and Nykvist, 2020; Bhutta et al., 2022). The returns on green bonds issued are measured by the S&P Green Bond Index. This index is a green bond indicator and is frequently used by researchers in the literature (Dong et al., 2023; Tiwari et al., 2023; Baltas and Mann, 2024). Historical values of the index are presented in Figure 1 below;

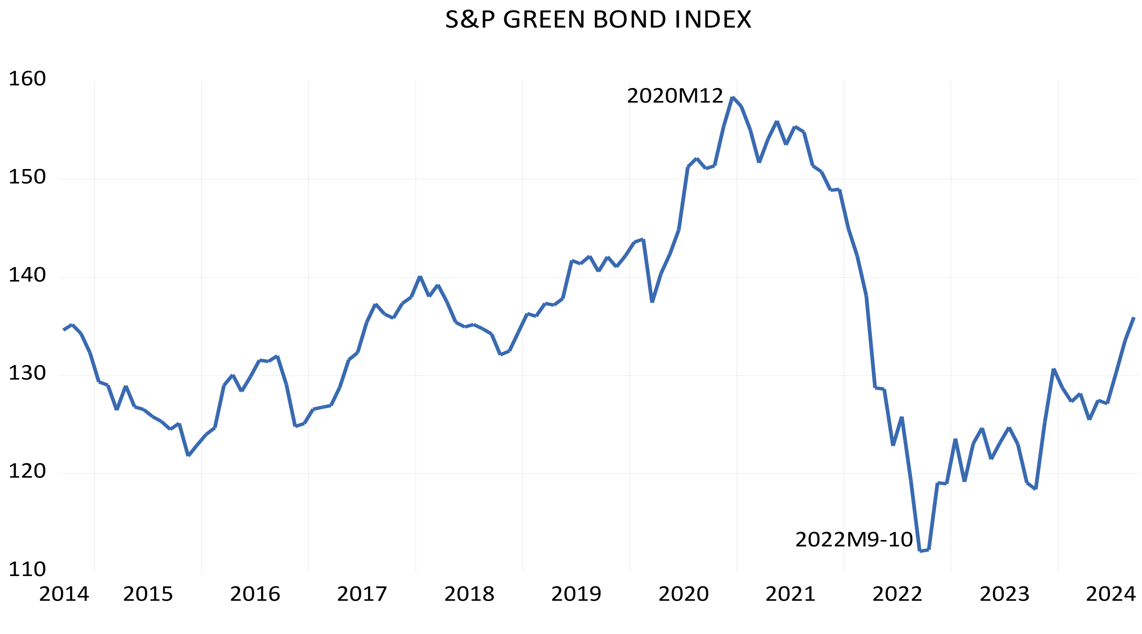

Figure 1: Green bond total return

The S&P Green Bond Index calculates total green bond returns in US dollars on an index basis, based only on green bond issues in the US (S&P Green Bond Indices, 2024). Although the index is calculated for the US, it is seen that it is used together with different variables in the literature (Kanamura, 2020; Reboredo et al., 2020; Chatziantoniou et al., 2022). As can be seen from the table, the index started to be calculated as of the last quarter of 2014. However, it is observed that the highest value was in December 2020 and the lowest value was in September and October 2022. Remembering that the US withdrew from the Paris Agreement in November

2020, it is thought that this situation reflected negatively on the green bond market. However, it is observed that an upward trend has started in the index recently. In light of the information provided above, it is considered important to investigate the relationship between green bond returns, which are a relatively new investment instrument introduced in response to global developments, and uncertainty indices, which have recently started to be calculated in response to global developments. Thus, it will be possible to obtain detailed information about green bonds, a relatively new financial asset, new risk indicators that have recently been introduced to the literature, and the relationship between these two variables. Therefore, the current study addresses the problem of how developments in economic uncertainty and climate uncertainty, which have been introduced to the literature as new risk factors, affect green bond returns. Therefore, the study seeks to answer the questions 'how and in what direction does economic uncertainty affect green bond returns' and 'how and in what direction does climate uncertainty affect green bond returns'. However, since the variables used in the study are relatively new, it is observed that there is a deficiency in the literature studies on this subject. As a result, green bond investors may obtain inconsistent results in risk and return calculations and expected returns at maturity, and policymakers may make decisions on the depth and development of green bond markets with incomplete findings. Therefore, the current study is expected to contribute to the literature, provide useful information to green bond investors, and provide policymakers with reference indicators. In addition, to the best of our knowledge, this is the first time that the relationship between green bonds and uncertainty factors is investigated by including investor fear and country risk premium factors in the analysis. This aspect of the study reveals its unique value.

Based on the information provided above, this study examines the possible effects of uncertainty factors on green bond returns. Economic Policy Uncertainty (EPU) and Climate Policy Uncertainty (CPU) are taken into account as uncertainty factors, while the S&P Green Bond Index is used as the green bond indicator. In addition, the country risk premium (CDS) and the investor fear indicator (VIX), which are thought to affect green bond returns, are used as control variables in the study. Since the green bond investment instrument is a new investment instrument compared to traditional investment instruments, continuous data is only available for the US country, and the EPU and CPU variables are calculated for very few countries including the US, the current study is performed for the US country. The scope of the study is based on the period between 09/2014, when the S&P green bond index first calculated, and 09/2024, when the current study prepared. In addition, the ARDL bounds test approach, which is used in short and long-run relationship analysis, is applied to determine the possible effects of uncertainty factors on green bond returns. The study consists of five sections including introduction, conclusion and recommendations.

2. LITERATURE REVIEW

In this section of the study, the studies in the literature on the current issue are included. In this context, looking at the studies in the literature, it can be stated that the issue of green bonds is addressed in many different studies and thus attracts the attention of researchers. The fact that it is a new investment instrument, especially compared to traditional investment instruments, as well as the fact that companies consider it within the framework of social responsibility and investors consider it as a long-term investment instrument for the future, increases the interest in green bonds. In addition, the fact that climate change is gaining more and more prominence and resonance in today's world and that climate-based events are felt more and more clearly every day is thought to keep the interest in the green bond investment instrument alive.

In this context, Antoniuk and Leirvik (2021), who examine the relationship between green bonds and climate transition risk, use a combination of many variables, including the S&P Green Bond Index, CO_2, Brent, Clean Energy, and VIX. As a result of the study, it is determined that there is a relationship between green bonds and climate change, but the 2016 US presidential election and the US withdrawal from the Paris Agreement had a negative impact on green bonds. In another study evaluating green bonds in the context of economic and climate factors, Hung (2021) used causality analysis in his study, based on the period between 2013:01 and 2019:03. The study concluded that a unidirectional causality relationship was detected between green bonds and CO_2 emissions. In another study in the literature, Tsagkanos et al. (2022) examined the relationship between green bond investment instruments and financial stress. The study is based on monthly data for the period between 2014:01 and 2022:01. The study concludes that there is a causality relationship from green bonds to financial stress. In another study with the same starting point as the current study, Long et al. (2022) examined the volatility spillovers between green bonds and uncertainty factors. The study was conducted for the US, Europe, and China, and EPU (Economic Policy Uncertainty Index), OVX (CBOE Crude Oil ETF Volatility Index), VIX (the CBOE Volatility Index), GPR (Geopolitical Risk Index), and TEU (Twitter-based Economic Uncertainty Index) were used as uncertainty indicators. In line with the findings of the study, OVX and VIX indicators have a significant impact on green bonds. However, it is concluded that the US markets are more dominant than the European and Chinese markets. Similarly, in another study published in the same year, Pham and Nguyen (2022) investigated how EPU, OVX, and VIX indicators affect the green bond market. The study was conducted for the US country and for the period 2014-2020. The study finds that the relationship between green bonds and uncertainty indicators varies over time.

In another study, Wang et al. (2023) investigated the relationship between green bonds with energy prices, CPU (Climate Policy Uncertainty Index) and carbon emissions. The study, which uses monthly data, is based on the period between 2012:09 and 2022:08. The study concluded that the Ukraine-Russia wars, the US withdrawal from the Paris Agreement and the Covid-19 period increased the strength of the relationship between the variables. Tang et al. (2023), who analyze the green bond market under geopolitical risk and uncertainty factors, use a combination of several indicators, including the EPU variable, in their study, based on the period between 2012:09 and 2022:08. As a result of the study using the ARDL method, it is found that the EPU variable has a negative impact on the green bond market both in the short run and in the long run. Similarly, Gök (2023), who analyzes the relationship between the green bond market, geopolitical risk, and the EPU index, bases his study on the Russian-Ukrainian war period. In line with the findings, it is concluded that there is a causality relationship between the EPU index and the green bond market, but the EPU index is more effective in predicting the green bond market than the geopolitical risk. In the same year, Ren et al. (2023) investigated the short- and long-run relationship between the green bond market and the CPU index based on the period between 2011:10 and 2021:03. As a result of the study, it is stated that there is no relationship between green bond returns and CPU in the short run, but there is a positive relationship between the two variables in the long run.

In another recent study, Raza et al. (2024) investigated the relationship between green bonds, clean energy, sustainable market indicators, and the CPU index. In the study where two different period intervals are created, the full period covers the period between 12/2008 - 09/2022, while the Covid-19 period covers the period between 01/2020 - 09/2022. In the study, the S&P Green Bond Index is used as a green bond, the S&P Global Clean Energy Index as clean energy, and the Dow Jones Sustainability Index as a sustainable market indicator. The study finds that rises in the CPU index lead to volatility in green bonds, clean energy, and sustainable market indicators. Similarly, Ozkan et al. (2024) investigated the relationship between green bonds, clean energy, sustainable market indicators, and the CPU index and found that the CPU index positively affects green bonds, clean energy, and sustainable market indicators. In another study investigating the relationship between green finance indicators and uncertainty indices, Wang et al. (2024) examined the relationship between five different green finance indicators, including the S&P Green Bond Index with EPU, CPU, and MPU (Monetary Policy Uncertainty) uncertainty indices. As a result of the analysis, it is found that EPU and MPU uncertainty indices have a significant effect on green finance indicators, while the effect of the CPU uncertainty index is limited. Kim et al. (2024), who investigated the relationship between uncertainty indicators with green bonds and carbon emissions by bringing a different perspective to the literature, determined the period range as 12/2008 - 08/2022 using monthly data in their study. Using GARCH models, the study finds that temporary uncertainties (geopolitical risk, disease risk) weaken the relationship between green bonds and carbon emissions, while climate and economic uncertainties strengthen it.

As can be seen from the field studies given above, there are different studies on the S&P Green Bond Index as a green bond indicator. However, to the best of our knowledge, no study is found in which investor fear and country risk are included in the analysis of the relationship between the S&P green bond index and uncertainty factors. The inclusion of the investor fear indicator and the risk profile of the investee country in the analysis of financial asset investments allows for more comprehensive, consistent, and robust findings. In this context, the present study fills the gap identified in the literature and is one of the pioneering studies in the field in terms of the variables used and in terms of addressing the problem. However, it is seen that different findings are obtained in literature studies. The main reason for this is thought to be due to the variables used, the period range, and different study methods. Therefore, it is concluded that a clear finding could not be obtained, and field studies are ongoing.

3. METHODOLOGY

This study aims to determine the short- and long-run relationship between green bond returns and uncertainty factors. In the study, the S&P Green Bond Index variable is taken as the green bond return, while the EPU and CPU variables are taken as uncertainty factors. In addition, the VIX index and CDS premiums, which are thought to affect green bond returns, constitute the control variables of the study. In light of this information, detailed information on the explained, explanatory and control variables used in the study is shown in Table 1 below;

Table 1: Variables of the study

Explained Variable	Symbol	Calculation Method	Source
S&P Green Bond Index	GREEN		S&P Global
Explanatory Variables			
Economic Policy Uncertainty	EPU	Logarithm	Economic Policy Uncertainty
Climate Policy Uncertainty	CPU		
Control Variables			
Volatility Index	VIX		Investing
Credit Default Swap	CDS		

The table above shows the names, abbreviations, calculation methods, and the source of the variables used in the study. In addition, September 2014, the date of the first calculation of the S&P Green Bond index, which is the explained variable of the study, is the beginning of the study period, and September 2024, the date when the study started to be prepared, is the end of the study period. In other words, the data set of the study consists of monthly data and the period 09/2014 - 09/2024. In addition, since the S&P Green Bond index is calculated for the US, care has been taken to ensure that the explanatory and control variables used in the study are also US-specific. In this context, it can be stated that the data on EPU and CDS variables used in the current study are prepared for the US. However, considering that the CPU and VIX variables used in the current study are calculated for the US markets, it can be stated that the variables form a whole as such.

The EPU index is a main index composed of a composite of three types of sub-indices. The first component of the index is based on the coverage of economic and policy uncertainty in ten major newspapers. The second component of the index is based on reports published by the Congressional Budget Office. The third and final component of the index is based on the Survey of Professional Forecasters published by the Federal Reserve Bank of Philadelphia (www.policyuncertainty.com). However, the CPU index, another explanatory variable of the current study, was first introduced by Gavriilidis (2021). The index calculation is based on news on climate policy in US newspapers. Therefore, it can be stated that the index is calculated for the US. As a result of the study, it is concluded that the CPU index, which is introduced to the literature as a new uncertainty index, negatively affects CO_2 emissions. Finally, in terms of control variables, the VIX variable measures investor fear. The CDS variable shows the risk premium of countries. Since these two variables are risk indicators, they may have an impact on green bond investments. However, the fact that these two variables are frequently used in the literature and modeled with different variables shows that these variables are taken into consideration by researchers and attract the attention of researchers.

Based on the information given above, in order to determine the short- and long-term relationship between green bond returns and uncertainty factors, descriptive statistics information is given first to see the structure of the data set. Then, correlation analysis and VIF (Variance Inflation Factors) tests are performed to determine whether the explanatory and control variables cause multicollinearity problems in the study. Subsequently, unit root tests are performed with ADF unit root tests without structural breaks and Fourier ADF unit root tests taking into account structural breaks. Since the S&P Green Bond index, which is the explained variable of the study, contains a unit root at the level, and since the other variables used in the study are found to be stationary at different levels, the ARDL bounds test approach is applied in the next stage of the econometric process of the study. Accordingly, the most appropriate ARDL model is determined first, and the F bounds test is performed over this model. After determining the existence of a long-run cointegration relationship with the F bounds test, long-run and error correction coefficient estimates are performed, respectively. In the next step of the methodological process, residual tests are tested. In this context, Breusch-Pagan-Godfrey's test for heteroscedasticity, Breusch-Godfrey's LM test for autocorrelation, and the Jarque-Bera coefficient for normal distribution are analyzed. In the last stage of the econometric analysis process of the study, CUSUM and CUSUM-Q graphs are analyzed to determine whether the coefficients obtained are stable or not. A graphical representation of the econometric process described in detail above is shown in Figure 2 below;

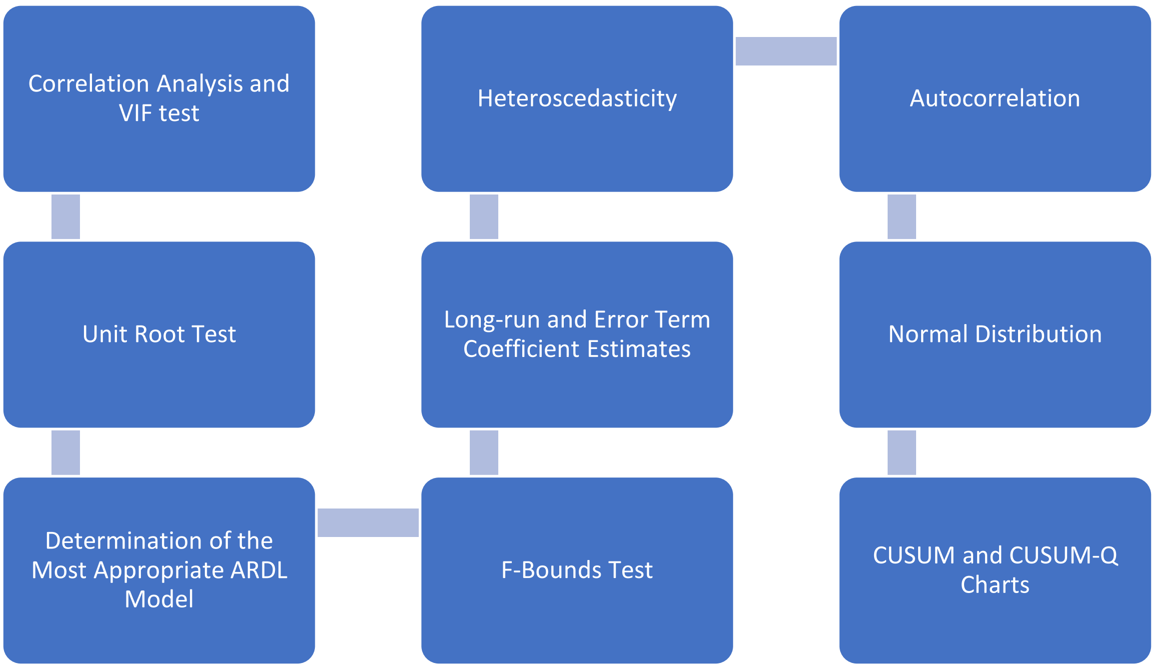

Figure 2: Methodological process

When Figure 2 above is analyzed, it can be stated that the econometric analysis process of the study starts with correlation analysis and the VIF test and ends with CUSUM and CUSUM-Q graphs. In this context, the regression representation of the ARDL model developed in line with the econometric process explained in detail above and presented graphically is presented in equation 1 following:

$$\Delta GREEN_t = \beta_0 + \delta_1 GREEN_{t-1} + \delta_2 EPU_{t-1} + \delta_3 CPU_{t-1} + \delta_4 VIX_{t-1} + \delta_5 CDS_{t-1} + \sum^{m}_{i=1} \beta_{1i} \Delta GREEN_{t-i} + \sum^{n}_{i=0} \beta_{2i} \Delta EPU_{t-i} + \sum^{n}_{i=0} \beta_{3i} \Delta CPU_{t-i} + \sum^{n}_{i=0} \beta_{4i} \Delta VIX_{t-i} + \sum^{n}_{i=0} \beta_{5i} \Delta CDS_{t-i} + \varepsilon_i \quad (1)$$

Equation 1 above shows the ARDL model developed for this study. The term represents the constant coefficient, Δ the first difference operator, $\beta_{1,2+\cdots+5}$ the short-run dynamic relationship, $\delta_{1,2+\cdots+5}$ the long-run dynamic relationship, and ε_i the model error term. With the help of this model, the short- and long-run findings between green bond returns and uncertainty factors are presented in the next section of the study.

4. FINDINGS

This section of the study presents the analysis findings obtained in line with the econometric process described above. First, in order to have detailed information on the variables used in the study, descriptive statistical information obtained from the raw data is presented. The results are shown in Table 2 below;

Table 2: Descriptive statistics

	GREEN	EPU	CPU	CDS	VIX
Mean	134.2972	137.3954	176.3815	16.77380	18.37884
Median	132.5000	124.1095	173.1963	13.66000	16.26000
Max.	158.4100	350.4598	411.2888	63.38000	53.54000
Min.	112.1000	79.80896	49.12534	5.490000	9.510000
Skew	0.475561	1.900221	0.418540	1.793177	1.825735
Kurt.	2.597924	7.289896	3.025471	6.544709	7.769025
J-B	5.375926*	165.6015***	3.535973	128.1939***	181.8873***
Obser.	121	121	121	121	121

Note: ***, and * indicate respectively statistical significance at the 1, and 10 percent levels.

As can be seen from the analysis results in the table above, the mean of the GREEN variable is 134.29, while the EPU mean is 137.39, the CPU mean is 176.38, the CDS mean is 16.77, and the VIX mean is 18.37. However, the variable with the highest value in the data set is CPU (411.28), while the variable with the lowest value is CDS (5.49). The Jarque-Bera probability values obtained for the variables indicate that the CPU variable does not give statistically significant results and the H_0 hypothesis cannot be rejected, while all other variables give statistically significant results and the H_0 hypothesis is rejected. In other words, it is determined that the CPU variable exhibits a normal distribution feature, while the other variables do not exhibit a normal distribution feature. It can be stated that the skewness value of the CPU variable is at the level of 0 and the kurtosis value is at the level of 3, which supports the Jarque-Bera results obtained. Lastly, due to the continuity of the variables, it can be said that the study data set consists of 121 observations.

In the next stage of the study, correlation analysis is conducted to see the strength and direction of the relationship between the variables. The findings are presented in Table 3 below;

Table 3: Correlation analysis

	GREEN	EPU	CPU	CDS	VIX
GREEN	1.0000				

EPU	0.2947	1.0000			
	3.3648	-----			
	0.0010	-----			
CPU	0.0907	0.5637	1.0000		
	0.9941	7.4463	-----		
	0.3222	0.0000	-----		
CDS	-0.7610	-0.3178	0.0653	1.0000	
	-12.7961	-3.6566	0.7140	-----	
	0.0000	0.0004	0.4766	-----	
VIX	0.1544	0.6321	0.2185	-0.3050	1.0000
	1.7056	8.9000	2.4437	-3.4945	-----
	0.0907	0.0000	0.0160	0.0007	-----

The table above, which shows the correlation relationship between the variables, shows the correlation coefficient, t-stat. and probability values, respectively. When the results obtained are analyzed, it is seen that the highest correlation relationship is between EPU and VIX with a positive coefficient value of 0.6321. Therefore, it can be interpreted that EPU and VIX variables move in the same direction 63% of the time. As economic uncertainty increases, it is expected that the VIX variable, which measures investor fear, will be negatively affected and increase. The correlation relationship between the variables between 0.30 and 0.64 is interpreted as a medium relationship (Ural and Kılıç, 2013: 244). In light of this information, it can be stated that the variables used in the study have a medium correlation relationship and do not pose a problem.

In the next stage of the study, VIF analysis is performed to detect multicollinearity. The findings are presented in Table 4 following:

Table 4: Results of VIF test

Variables	Coefficient Variance	Uncentered VIF	Centered VIF
EPU	0.000637	682.2018	2.457840
CPU	0.000172	200.7003	1.462531
CDS	9.91E-05	33.01969	1.208926
VIX	0.000382	141.3787	1.860618
C	0.008757	393.3376	NA

The VIF test is widely used in the literature to detect multicollinearity (Bayman and Dexter, 2021; Chan et al., 2022; Kyriazos and Poga, 2023). The Centered VIF value above 10 in the test results can be stated to indicate a multicollinearity problem in the study (Sarianti et al., 2024: 113). When the results obtained in the current study are examined, it is seen that the Centered VIF value is below 10, and therefore, it can be interpreted that there is no multicollinearity problem in the study. This result is similar to the correlation analysis results.

After determining that the variables used in the study did not cause any problems in the preliminary tests, unit root analysis is performed. The results are presented in Table 5 below;

Table 5: Results of unit root analysis

Variable	ADF				Fourier ADF			
	Level		1st difference		Level		1st difference	
	Constat	Trend	Constat	Trend	Constat	Trend	Constat	Trend
GREEN	-1.48	-1.48	-9.60***	-9.56***	-1.64	-1.62	-10.16***	-10.14***
EPU	-3.10**	-3.15*	-	-	-6.09***	-6.13***	-	-
CPU	-5.02***	-6.86***	-	-	-5.07***	-7.46***	-	-
CDS	-1.90	-2.25	-11.71***	-11.69***	-2.08	-3.58*	-9.25***	-9.37***
VIX	-4.41***	-4.56***			-5.66***	-6.06***	-	-
Critical Value	Constat: 1%(-3.48), 5%(-2.88), 10%(-2.57) Trend: 1%(-4.03), 5%(-3.44), 10%(-3.14)				Constant: 1%(-3.77), 5%(-3.07), 10%(-2.71) Trend: 1%(-4.45), 5%(-3.78), 10%(-3.44)			

Note: ***, **, and * indicate respectively statistical significance at the 1, 5, and 10 percent levels.

The unit root test of the current study is performed with ADF and Fourier ADF unit root tests. The table above shows that the GREEN variable, which is the explained variable of the study, is not stationary at the level, but becomes stationary after the first difference process. In addition, it is found that the explanatory variables of the study are stationary at the level, but the CDS variable, one of the control variables, becomes stationary after the first difference process. When the results obtained are evaluated in general terms, it can be stated that the explained variable of the study is non-stationary at the level, while the other variables used in the study are stationary at different levels. In order to use the ARDL bounds test approach, the explained variable should be non-stationary at the level (Nur, 2022: 1113). Based on the obtained results, it can be concluded that the basic assumption for the use of the ARDL bounds test approach in the current study is provided.

After the basic assumptions of the ARDL bounds test approach are provided, the first step is to determine the appropriate lag length by using the Akaike and Schwarz information criteria for short- and long-run coefficient estimation. The information criterion results obtained are shown as follows:

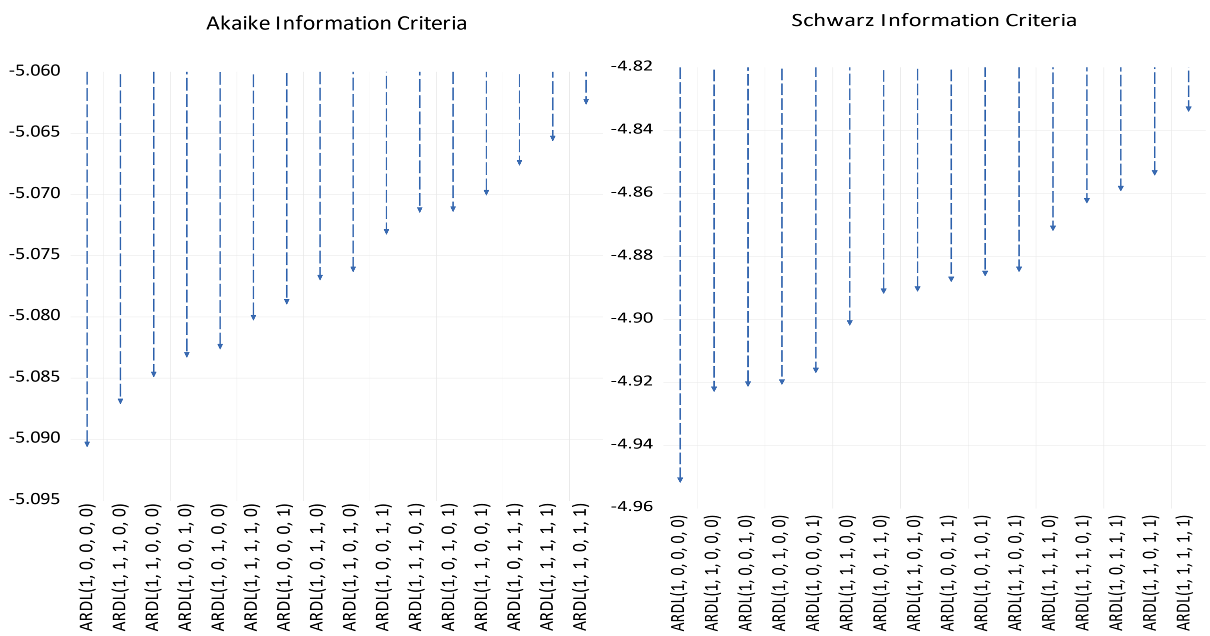

Figure 3: Determination of appropriate lag length

According to the Akaike and Schwarz information criteria above, the ARDL (1,0,0,0,0) model is the most appropriate model for the study data set. Therefore, ARDL (1,0,0,0,0) model is used for short- and long-run coefficient estimation.

After determining the optimal lag length, the ARDL F-Bounds Test is performed to determine whether there is a relationship between the variables in the long run. Determination of the long-run cointegration relationship is important for the validity of the ARDL model. The outputs obtained are given in Table 6 below;

Table 6: Results of ARDL F-Bounds test

ARDL (1,0,0,0,0)				
Test stat.	**Value**	**α**	**I(0)**	**I(1)**
F-stat. k	9.410027 4	10%	3.03	4.06
		5%	3.47	4.57
		2.5%	3.89	5.07
		1%	4.4	5.72

Note: The symbol α indicates confidence intervals.

When the above table containing the results of the long-run cointegration relationship analysis is examined, it is seen that the F-stat. value is determined as 9.41. It is seen that this value is greater than the upper limit of the 1% critical value of 5.72. Therefore, it can be stated that there is a long-run cointegration relationship between the variables at a 1% significance level. In the next stage of the study, the coefficient analysis of the identified long-run relationship is started. The long-run coefficient findings are as in the table below;

Table 7: Results of ARDL long run coefficients

ARDL (1,0,0,0,0)			
Variables	**Coefficient**	**Std. Error**	**t-stat.**
EPU	0.0648***	0.0153	4.2322
CPU	-0.0244***	0.0078	-3.1217
CDS	-0.0408***	0.0148	-2.7494
VIX	-0.0423***	0.0126	-3.3574
	R^2:0.9800 *Adjusted R^2*:0.9568 *F-stat.*:42.325***		

Note: *** indicate statistical significance at the 1 percent levels.

When the above table containing the long-run coefficient results is analyzed, it is seen that the F-stat. value expressing the significance of the model is 42.325. Therefore, it can be stated that the model is significant at a 99% confidence level. However, it is seen that the Adj. R^2 value is determined as 95.68%. In other words, it can be stated that approximately 95.68% of the changes in the Green Bonds variable, which is the explained variable of the study, are due to the explanatory and control variables used in the study. When the results obtained are evaluated in general terms, it is concluded that all explanatory variables used in the study are statistically significant, but the EPU variable has a positive effect on green bond returns, while all other variables used in the study have a negative effect on green bond returns.

The coefficient results indicate that a 1% increase in the EPU variable leads to a 6.48% increase in green bond returns. In a period of increased economic uncertainty and loss of risk appetite in financial markets, volatility in financial markets can be said to be high. The main reason for this is thought to be the deterioration in expectations for the future. Therefore, it is expected that investors who will invest in the mid and long term in such periods will turn more towards sustainable and environmentally sensitive investment instruments. This is because such environmentally sensitive projects are both sustainable in the long term and accepted by investors as a social responsibility towards the environment. It is also thought that this finding may be related to the policies implemented by the economic administration of the period. More precisely, as it is known, the current study is specific to the US country and is conducted for the period 2014-2024. Especially in the 2021-2024 period range, the US economic administration attaches importance to sustainable green investments and renewable energy policies and has taken steps in this regard (returning to the Paris Climate Agreement in 2021 and appointing a special representative, canceling the Keystone XL oil pipeline, expressing discourses to become a leading country in the fight against climate change, etc.); such discourses and directions may affect investors at the decision-making stage in the current global conjuncture where uncertainty factors increase day by day. In other words, while risk factors are increasing on a global scale, it is thought that the world's number one economic administration taking positive and forward-looking steps on green investments may affect investor behavior. Therefore, in times of economic uncertainty, green bonds may be preferred in portfolios in order to minimize risk through portfolio diversification and to hedge against risk. In light of this information, it is expected that investors will focus on green bonds as a sustainable investment instrument in times of economic uncertainty. However, another result of the study is that a 1% increase in the CPU variable leads to a 2.44% decrease in green bond returns. Based on this result, it is thought that green bond investors are concerned about climate uncertainty and reflect this concern through the CPU index. As mentioned in the introduction of the current study, adverse developments in climate-based events have a negative impact on green bond returns. Developments therefore support the situation identified. However, it can be stated that environmentally conscious investors do not only focus on returns (Fama and French, 2007). In this context, it can be interpreted that these investors act in a socially sensitive manner and accept lower returns. Considering that green bond investors are sensitive to the climate factor, increases in climate uncertainty are thought to negatively affect green bond investors and thus green bond returns. It is thought that this finding can be explained in this perspective. Finally, the results obtained for the variables used as control variables in the current study indicate that a 1% increase in both CDS and VIX variables causes a decrease of approximately 4% in green bond returns. Since the CDS variable measures sovereign risk and the VIX variable measures investor fear, increases in these variables are expected to negatively affect investor risk appetite. Therefore, it is thought that green bond investments are also negatively affected by the selling pressure in all financial markets due to the decline in investor risk appetite. The long-term results obtained are similar to those of Wei et al. (2022a), Wei et al. (2022b), Dong et al. (2024), and Attilio (2025), and in the opposite direction to those of Ege et al. (2023), Ren et al. (2023), Dong et al. (2024), and Guo et al. (2024). The main reason for this situation is thought to be that the variables used in the studies differ, different period intervals are examined, and different econometric processes are followed.

After the long-run relationship analysis, the next step of the study is to analyze the short-run coefficient results of the error correction model. The findings are presented in Table 8 below;

Table 8: Results of ARDL error correction model short run coefficients

ARDL (1,0,0,0,0)			
Variables	**Coefficient**	**Std. Error**	**t-stat.**
EPU	0.0442***	0.0090	4.8825
CPU	-0.0043	0.0048	-0.8895
CDS	-0.0022	0.0051	-0.4459
VIX	-0.0412***	0.0070	-5.8858
CointEq(-1)	-0.0551***	0.0085	-6.4794
	*R^2:*0.9452 *Adjusted R^2:*0.9428 *F-stat.:*393.616***		

Note: *** indicate statistical significance at the 1 percent levels.

The table above shows the error correction model results that test the significance of the established model. Firstly, the F-stat. value, which expresses the significance of the model, shows that the result obtained is significant at a 99% confidence level. Therefore, the model as a whole is significant. However, Adj. R^2 value, it is seen that the value determined is 94.28%. Based on this result, it can be stated that the explanatory and control variables used in the study explain most of the changes in green bond returns in the short run. On the other hand, the results obtained for the error correction coefficient CointEq(-1) indicate that the estimated coefficient lies between 0 and -1 and is statistically significant. Therefore, it can be said that short-term deterioration stabilizes in the long run. More clearly, according to the results of the error correction model, approximately 5% of the short-term deviations in green bond returns are eliminated in the long run, that is, they reach equilibrium; however, when a deviation occurs between green bond returns and explanatory variables, this deviation is eliminated after 1.81 (1/0.55) months. When it is remembered that all explanatory and control variables are statistically significant in the long-run analysis results, it is seen that the short-run results differ in this context. According to the short-run results of the error correction model in the table above, EPU and VIX variables provide statistically significant results. Accordingly, in the short run, a 1% increase in the EPU variable causes a 4.42% increase in green bond returns, while a 1% increase in the VIX variable causes a 4.12% decrease in green bond returns. These results are similar to the long-run coefficient results. Therefore, both in the short and long run, EPU and VIX variables have an impact on green bond returns. However, the same conclusion is not valid for CPU and CDS variables. In other words, CPU and CDS variables, which give significant results in the long run, give insignificant results in the short run. The main reason for this is thought to be the dynamic structure of the variables and the maturity periods of the investments. For example, a short-term green bond investor may consider the VIX variable, which is interpreted on a daily and weekly basis, but may ignore the CDS variable, which is more meaningful in the mid and long term, in short-term calculations. Similarly, it is thought that the economic uncertainties of the period are more influential in the investment decisions taken, but in the mid and long term, other uncertainty and risk indicators, such as climate uncertainty, may be taken into consideration by rational investors along with economic uncertainty. The above explanations support the results obtained. When the short-term results obtained are compared with the field studies, it can be stated that they are similar to Haq et al. (2021), Ahmed (2024), and Gyamerah et al. (2024), but not similar to Ren et al. (2023), Tang et al. (2023), and Rahman (2024). Therefore, as in the long-run results, there is no definite finding in the short-run results.

After the short-run analysis results of the error correction model, the next step of the study is the diagnostic test results that test the validity of the ARDL model. The results are given in Table 9 below;

Table 9: Results of diagnostic test

Panel A: Result for Heteroskedasticity		
Test	F-stat.	Prob.
Breusch-Pagan-Godfrey	0.8442	0.7341
Panel B: Result for Autocorrelation		
Test	F-stat.	Prob.
Breusch-Godfrey LM	0.7922	0.6573
Panel C: Result for Normal Distribution		
Test	Coefficient	Prob.
Jargue-Bera	1.9705	0.3733

When the table above, which shows the results of the test for heteroscedasticity, autocorrelation, and normal distribution of the ARDL model established in the current study, is examined, it is seen that the prob. value determined for all diagnostic tests is greater than the critical value of 0.05. Therefore, the H_0 hypotheses of the tests are accepted. In other words, it is concluded that the model established in the study does not have problems of heteroscedasticity and autocorrelation and exhibits normal distribution characteristics.

In the last step of the econometric analysis process, CUSUM and CUSUM-Q charts are tested. The results are shown in figure 4 below:

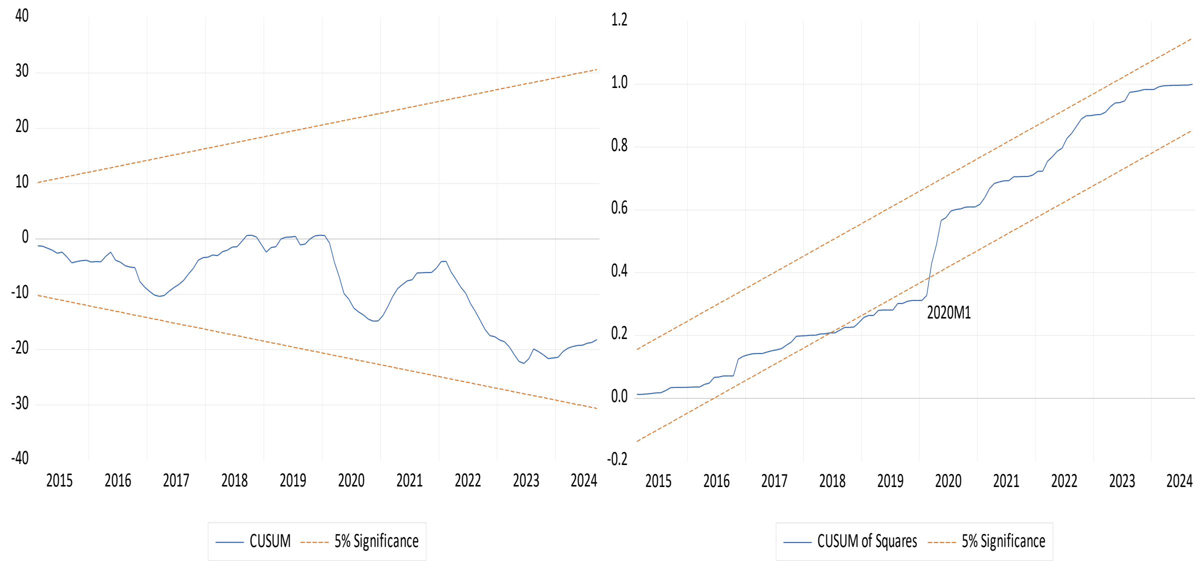

Figure 4: CUSUM and CUSUM-Q charts

When the CUSUM and CUSUM-Q graphs tested for the ARDL model are analyzed in general terms, it is seen that the statistical values obtained in both graphs are within the 5% critical value. Therefore, it can be stated that the coefficients determined in this study are stable as a whole. However, the CUSUM-Q graph shows that the statistical value obtained in the 2020M1 period is outside the 5% critical value. Therefore, it can be mentioned that there is a structural break at the relevant date.

5. CONCLUSION AND RECOMMENDATIONS

Developments in finance are closely linked to changes in the global conjuncture. In other words, it can be stated that newly developed financial investment instruments are actually based on global developments and expectations. In this context, it can be stated that green bond investment instruments have been developed in order to support environmentally and nature-sensitive projects against climate change and to raise awareness on this issue, based on the rapid increase in the signs of climate change in recent years. By offering green bonds, companies fulfill their social responsibilities towards the environment, and investors who invest in this investment instrument act with a sense of social responsibility. Therefore, it is thought that the determination of the relationship between green bond investment instrument, which is a relatively new investment instrument compared to traditional investment instruments, and uncertainty factors will both contribute to the literature and provide useful information to investors at the investment decision stage. In line with this objective, this study aims to determine the short and long-run relationship between the green bond returns and uncertainty factors. In the study, the S&P Green Bond Index variable is taken as the green bond indicator, while Economic Policy Uncertainty (EPU) and Climate Policy Uncertainty (CPU) variables are taken as uncertainty factors. In addition, CDS and VIX variables, which are thought to affect green bond returns, are used as control variables in the study. In this context, the period range of the current study is determined as 09/2014 - 09/2024, and the ARDL bounds test approach, which is frequently used in the literature to identify short- and long-run relationships, is applied.

Based on the short-term results, a 1% increase in the EPU variable causes a 4.42% increase in green bond returns, while a 1% increase in the VIX variable causes a 4.12% decrease in green bond returns. According to the long-run coefficient results, a 1% increase in the EPU variable leads to a 6.48% increase in green bond returns, a 1% increase in the CPU variable leads to a 2.44% decrease in green bond returns, a 1% increase in the CDS variable leads to a 4.08% decrease in green bond returns, and finally, a 1% increase in the VIX variable leads to a 4.23% decrease in green bond returns. When the results obtained are evaluated in general terms, it can be stated that the EPU variable, which is one of the explanatory variables of the current study, and the VIX variable, which is one of the control variables of the current study, affect green bond returns both the short and long run. These results are similar to the studies of Long et al. (2022), Pham and Nguyen (2022), Gök (2023), Raza et al. (2024), and Wang et al. (2024) in the literature.

Finally, the present study also includes some recommendations. In line with the findings detailed above, it is recommended that investors who will invest in green bonds in the long term should consider all the variables used in the study and take them into account in their return and risk calculations. Investors who will invest in green bonds in the short-term are advised to consider the EPU and VIX variables. Considering that green bond returns increase both in the short and long term when economic uncertainty is high, it is suggested that investors may invest in green bonds to diversify their portfolios and hedge risk. However, in order for the green bond market to deepen and develop, it is recommended that policymakers support projects that are sensitive to nature and the environment, provide incentives in this area, and apply tax exemptions. At this point, it is thought that companies that are focused on green investments, develop and implement projects, and transparently share these with the public and relevant authorities may be subject to tax exemptions on their earnings from green financing or lower corporate tax rates may be applied. As an example, it is thought that the practices of countries such as China, Brazil, and Chile, which have developed special tax practices for green investments, can be taken as an example in the first stage. In addition, it is thought that informing the relevant investors by organising trainings and seminars on green investments by supervisory and regulatory institutions will both benefit the financial literacy levels of investors and contribute positively to the development of the green bond market. The current study could be improved by examining different country groups, incorporating different uncertainty indicators into the model, or comparatively analyzing different time periods.

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3. This article was screened for potential plagiarism using a plagiarism screening program (Bu çalışma, intihal tarama programı kullanılarak intihal taramasından geçirilmiştir).