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Testing Pollution Haven and Pollution Halo Hypotheses for the Energy Sector: Evidence from Turkey

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Abstract: *The mobility in foreign direct investment has increased with the liberalization of trade and globalization. Depending on this mobility, changes have occurred in the environmental quality of the countries according to the pollution level of the economic sectors. For this reason, the study's main aim is to examine the energy sector in Turkey in terms of pollution haven and pollution halo hypotheses. In the study, the variables of total greenhouse gas emissions from the energy sector (CO2 equivalent), urban population growth, and foreign direct investment inflows (%GDP) for the period 1990-2019 were used. The Johansen-Juselius (1990) test was used to determine the cointegration relationship between variables. The VECM (vector error correction model) and Toda-Yamamoto (1995) tests were used for causality analysis. According to the results of the analysis, there is a long-term relationship between the variables. In addition, it has been concluded that the pollution haven hypothesis is valid for the energy sector in Turkey in the long term. Therefore, the use of fossil energy resources by foreign direct investments in the energy sector should be deterred by various policies. As a result, administrative and financial regulations must be strong to ensure permanent environmental quality increases.*

Keywords: Pollution Haven Hypothesis, Pollution Halo Hypothesis, Environmental Pollution, Energy Sector, Industrial Flight

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1. Introduction

One of the common problems of our age is environmental pollution caused by the increase in carbon dioxide emissions (CO_2). The main reason for the increases in carbon dioxide emissions is due to natural and anthropogenic causes (IPCC, 2007; Acaravci & Erdogan, 2018: 53). Especially with the industrial revolution, the diversification of production and the rise of competition have revealed the energy needs of the industry. On the other hand, the increasing energy needs of the industry have been met by fossil energy sources that are easier, cheaper and do not require advanced technologies (Black & Weisel, 2010). After the industrial revolution, with the use of fossil energy sources containing carbon due to anthropogenic reasons, increases in carbon dioxide emissions are noteworthy. For example, while the global carbon dioxide concentration was 273 ppm (parts per million) following the industrial revolution, it reached about 420 ppm in 2022 (NOAA, 2022). Since carbon dioxide gas is more permanent in the atmosphere than other greenhouse gases, it causes the greenhouse effect to be strengthened (Tayyar, 2022). Over time, increases in carbon dioxide emissions due to economic activities are taking a leading role in the aggravation of global warming and global climate change (Karl & Trenberth, 2003).

The interaction between economic activities and carbon dioxide emissions is very important. Based on this importance, it is necessary to examine the relationship of economic activity with carbon dioxide

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emissions according to sectors. Table 1 below provides information on total greenhouse gas emissions by economic sectors in Turkey.

Table 1. Total Greenhouse Gas Emissions by Economic Sectors (CO_2 Equivalent)

		Economic Sectors			
Years	**Total**	**Energy**	**Industrial Processes and Product Use**	**Agriculture**	**Waste**
2014	459	325.8	58.7	56.2	18.3
2015	473.3	340.9	57.2	56.1	19
2016	498.9	359.7	61.4	58.9	19
2017	525	379.9	64	63.3	17.8
2018	522.5	373.1	65.9	65.3	18.1
2019	506.1	364.4	56.4	68	17.2

Note: The data in the table show the carbon dioxide equivalent of total greenhouse gas emissions in million tons.
Source: TurkStat, 2022.

According to the data in the Table 1, the share of the energy sector in total greenhouse gas emissions is high. It is seen that the energy sector has a weight of approximately 72% in the total greenhouse gas intensity over the years. Undoubtedly, the distribution of energy resources among countries is unequal. This situation causes countries with less energy resources to obtain cheaper fossil energy resources from other countries (Çetintaş, Bicil & Türköz, 2017: 3). The use of fossil energy resources in countries both increases external dependence on energy and sets the stage for the formation of environmental problems (Tayyar, 2021: 269). In this context, it is essential to benefit from renewable energy sources in order to establish energy supply security and reduce environmental pollution in countries. Renewable or green energy is a type of energy that does not cause environmental pollution, does not decrease as it is used, and has varieties such as wind, solar hydro energy, geothermal and biogas (Yılmaz, 2012: 52). According to the data for Turkey, it is seen that the weight of renewable energy sources on electricity generation is around 42% in 2020 (TEİAŞ, 2022). Despite all its positive aspects, it is necessary to bear high costs in order to benefit from renewable energy sources compared to fossil energy sources (Akdağ & Gözen, 2019). The weak competition among companies and the fact that suitable technologies are still in the development stage can be counted as factors that increase costs. Especially, the high costs in the transformation of renewable energy sources prevent the use of renewable energy sources in countries with insufficient internal financial resources.

The internal financing resource deficit in the transformation of energy resources can be eliminated by direct foreign capital investments (cross-border investment) (Tayyar, 2020: 214). Foreign direct capital investments include long-term cross-border investments made by companies in other countries. In particular, due to the impact of financial liberalization and globalization, there have been increases in the scale and flexibility of foreign direct investment (Balsalobre Lorente et al., 2019). Although foreign direct capital investments are beneficial for developing countries that are short of resources in projects that will be made, there are factors that affect these foreign direct investments. These can be counted as economic and political stability, administrative regulations, cheap labor, country-specific risks and advantages, market size, natural resource richness and flexibility in environmental regulations (Bozkurt & Dursun, 2006). Among the mentioned factors, environmental regulations are directly related to foreign direct investments. In particular, developing countries can relax environmental regulations in order to attract foreign direct investment due to their benefits such as technology transfer, governance skills and capital transfer (Acharyya, 2009; Kılıçarslan & Dumrul, 2017). As a result of this situation, foreign direct investments can increase or decrease environmental pollution depending on the economic sectors. The relationship between foreign direct investment investments and environmental pollution is examined with the help of pollution haven and pollution halo hypotheses (Pao & Tsai, 2011; Lee, 2013; Terzi & Pata, 2020). In this context, if foreign direct investments tend to use fossil energy sources, the environmental pollution problem will increase more.

The main purpose of the study is to examine the energy sector in Turkey in terms of pollution haven and pollution halo hypotheses. In the article, the energy sector-based total greenhouse gas emissions (Co_2 Equivalent), foreign direct investment inflows and urban population growth are used for the period 1990-2019. Johansen and Juselius (1990) cointegration test, VECM (vector error correction model) and Toda and Yamamoto (1995) analyses are used to determine the relationships between variables. According to the studies conducted on the subject, the validity of the relevant hypotheses has been intensively investigated. In addition, the number of studies examining the validity of the hypotheses for economic sectors is very few (Pazienza, 2015). However, since some sectors have a high level of environmental pollution, it is necessary to pay attention to the economic sector distinction in terms of the analysis of hypotheses. Therefore, this article explores the environmental pollution pass-through of foreign direct investments through the energy sector. Two ways can be used to examine the pollution haven and pollution halo hypotheses by economic sectors. First, foreign direct investment can be differentiated by sector and its relationship with carbon dioxide emissions can be examined. As a second way, the economic sectors that make up the total greenhouse gas emissions can be identified and the relationship of these sectors with foreign direct investments can be analyzed. Data on foreign direct investments in the energy sector for Turkey seem to be lacking. Due to the mentioned research limitation, the second method was preferred. For these reasons, it is thought that the study will be beneficial to the relevant literature in terms of method and scope. The article consists of five parts. In the second part of the article, the relationship between foreign direct investments and environmental pollution and studies in this field are examined within the scope of related hypotheses. In the third section, after the data set and methodology are explained, the econometric studies carried out in the fourth section are reported. In the last section, the conclusion and recommendation are given.

2. The Relationship between Foreign Direct Invesment and Environmental Pollution: Theoretical Backgrounds and Studies

Foreign direct investments have great advantages in terms of the economic development of countries. For this reason, especially developing countries try to solve the problem of capital insufficiency by attracting foreign direct investments (Hansen & Rand, 2006). Various incentive policies and the existence of economic stability are important factors in the movement of foreign direct investments towards countries. However, among these factors, the host country's policies on environmental regulations directly affect the mobility of foreign direct investments (Copeland & Taylor, 1994; Nathaniel et al., 2020). At this point, environmental quality is a normal good (Taylor, 2004; Aliyu, 2005). Developed countries with high incomes give more importance to environmental quality. However, since the income level is lower in developing countries, the regulations to ensure environmental quality are more looser. Depending on various industry structures, there are costs for companies to comply with environmental quality (Javorcik & Wei, 2004). Such costs are higher in developed countries that pay more attention to environmental quality. This situation causes industries that have a larger share in environmental pollution to move from developed countries to developing countries. In other words, industrial flight makes it possible for countries that want to attract foreign direct investment to behave more loosely in terms of ensuring environmental quality (Asgari, 2013: 92). On the other hand, the existence of industrial flight leads to increased competition among countries that want to benefit more from foreign direct investments. In particular, the level of competition is related to the regulations made by the countries in order to ensure environmental quality. The high level of competition causes countries to lower the standards related to environmental quality (Mutafoglu, 2012; Ullah et al., 2020). The concessions of the countries on environmental standards make the race to the bottom increasingly intense. It is clear that as a result of the race to the bottom, polluting industries will lead to more environmental pollution in developing countries. However, environmental pollution has no political limits. For this reason, it is a fact that all countries will be directly or indirectly affected by the negative effects of pollution.

The relationships between foreign direct investments and environmental quality are examined with the help of two hypotheses. The first is the pollution haven hypothesis developed by Pethig (1976), Walter and Ugelow (1979), Baumol and Oates (1988), and the other is the pollution halo hypothesis proposed by Porter and van der Linde (1995). Both theories are based on the assumptions that environmental quality is a normal good, income distribution is unequal worldwide, industries differ in terms of pollution intensity, and the regulations made in terms of environmental quality in countries are not the same (Taylor, 2004; Gassner, 2008: 5). In this context, the pollution haven hypothesis argues that there is a positive relationship between foreign direct investments and environmental pollution (Tang & Tan, 2015; Bakırtaş & Çetin, 2017; Bulus & Koc, 2021). In other words, as foreign direct investments increase, there will be a decrease in environmental quality and an increase in environmental pollution. The study by Copeland and Taylor (1994) is very important in expressing the pollution haven hypothesis more clearly. According to the study, within the scope of NAFTA (North American Free Trade Agreement), the countries in the south of the Americas have a comparative advantage in terms of dirty industries compared to the countries in the north (Copeland & Taylor, 1994: 756). This will lead to the movement of industries from northern countries to southern countries. Therefore, NAFTA integration will cause economic problems in the countries in the north and environmental problems in the countries in the south. In addition to the pollution haven hypothesis, the pollution halo hypothesis suggests that cross-border investments are environmentally innocent (Zarsky, 1999; Eskeland & Harrison, 2003; Al-Mulali & Tang, 2013). According to the hypothesis, foreign direct investments reduce environmental pollution in host countries and improve environmental quality. In this context, companies located in countries where environmental policies are more stringent benefit from more efficient and clean production technologies (Kim & Adilov, 2012; Yirong, 2022). This allows host countries to benefit from more advanced and cleaner technologies through foreign direct investments. In addition, the management skills, energy efficiency and environmental quality sensitivity of companies established in the host country through foreign direct investments can be taken as examples by other local companies (Hoffman et al., 2005). The spread of environmental technologies among domestic companies can lead to increases in environmental quality by providing efficiency in production.

The validity of the pollution haven and pollution halo hypotheses can be examined depending on the scale, composition and technical effects put forward by Grossman and Krueger (1991) (Grossman & Krueger, 1991: 3). The scale effect indicates that foreign direct investments stimulate economic activity in the host country. The acceleration of economic activities through foreign direct investments increases both energy consumption and environmental pollution (Cole & Elliott, 2003). In this respect, it is seen that the scale effect supports the pollution haven hypothesis. The composition effect is related to which sectors foreign direct investments will be effective in the host country. In this context, if foreign direct investments focus on industries that cause environmental pollution, there will be decreases in environmental quality (Assamoi et al., 2020). Therefore, it is essential for foreign direct investments to focus on clean industries in order to reduce environmental pollution. The technical impact emphasizes that foreign direct investments provide more efficient and clean technology transfer to host countries. According to this effect, it is argued that there will be increases in environmental quality by using efficient and clean technology in countries (Birdsall & Wheeler, 1993; Liang, 2008). The technical effect supports the pollution reduction hypothesis because it creates increases in environmental quality. Considering all of the effects, it is understood that the pollution paradise hypothesis is valid if the scale effect and composition effects *(if it affects dirty industries*) are greater than the technical effect. For the pollution halo hypothesis to be valid, the technical and composition effects (*if it affects cleaner industries*) must be greater than the scale effect.

On the other hand, there are many studies that question the validity of the hypotheses in terms of selected countries and country communities. According to the results of the studies, it is seen that different hypotheses are valid for the same country. The main reason for this situation is that the data used for the country is different from each other. For example, the concept of environmental pollution is open-ended in terms of measurement technique and has no standard variable. In some studies, it is seen that carbon dioxide emissions, types of greenhouse gases and ecological footprint variables are used to express environmental pollution (Sarkodie & Strezov, 2019; Balsalobre-Lorente et al., 2019). In addition, period differences and the level of development of the econometric methods used may cause different results. The results of national and international studies can be examined with the help of Table 2 below.

Table 2. Econometric Studies For Pollution Haven and Halo Hypotheses

Author(s)	Country	Period	Metodology	Results
Part A: Econometric Evidence For Other Countries				
Pao & Tsai (2011)	BRIC Countries	1980-2007	Panel Data	Pollution Haven
Lee (2013)	G-20 Countries	1991-2009	Panel Data	Pollution Halo
Al-Mulali & Ozturk (2015)	MENA Countries	1996-2012	Pedroni-VECM	Pollution Haven
Pazienza (2015)	30 OECD Countries	1981-2005	Panel Data	Pollution Halo
Shahbaz et al. (2015)	99 Countries	1975-2012	FMOLS-Pedroni	Pollution Haven
Tang & Tan (2015)	Vietnam	1976-2009	Johansen	Pollution Haven
Mert & Boluk (2016)	Kyoto Countries		Panel ARDL	Pollution Halo
Bakırtas & Cetin (2017)	MIKTA Countries	1982-2011	Panel VAR	Pollution Haven
Solarin et al. (2017)	Ghana	1980-2012	ARDL Bound	Pollution Haven
Rana & Sharma (2019)	India	1982-2013	ARDL	Pollution Haven
Sarkodie & Strezov (2019)	5 Countries	1982-2016	Panel Data	Pollution Haven
Bulus & Koc (2021)	Korea	1970-2018	ARDL Bound	Pollution Haven
Part B: Econometric Evidence For Turkey				
Mutafoglu (2012)		1987-2009	Co-integration - ECM	Pollution Haven
Sahinoz & Fotourehchi (2014)		1974-2011	Co-integration	Pollution Haven
Polat (2015)		1980-2013	Co-integration	Pollution Halo
Seker et al. (2015)		1974-2011	ARDL- Granger	Pollution Haven
Gokmenoglu & Taspınar (2016)		1974-2010	ARDL	Pollution Haven
Ozturk & Oz (2016)		1974-2011	Maki Co-integration	Pollution Halo
Kaya et al. (2017)		1974-2010	Engle-Granger	Pollution Haven
Kılıcarslan & Dumrul (2017)		1974-2013	Con-integration	Pollution Haven
Koçak & Sarkgunesi (2017)		1974-2013	Maki Co-integration	Pollution Haven
Yıldırım, Destek & Ozsoy (2017)		1974-2013	ARDL	Pollution Haven
Kurt, Kılıç & Ozekicioglu (2019)		1974-2014	ARDL	Pollution Haven
Mert & Caglar (2020)		1974-2018	Hidden Co-integration	Pollution Halo
Mike (2020)		1970-2015	ARDL	Pollution Haven
Terzi & Pata (2020)		1974-2011	Toda-Yamamoto	Pollution Haven

According to Table 2, when the analyzes made in terms of different countries are examined, there are many studies that prove the existence of the relevant hypotheses, have the opposite result for the same country, or argue that the hypotheses are not valid. The reason for the different results can be counted as the use of different variables in the studies, the poor quality of the data used, and the differences in econometric methods and periods. One of the mistakes made in the research of the pollution haven and halo hypotheses for countries is to consider the economic sectors as a whole. However, the pollution rate of economic sectors is different from each other. The fact that foreign direct investments are proportionally directed towards industries with a high pollution rate indicates that the pollution haven hypothesis is valid in that country. For this reason, the share of economic sectors from foreign direct investments is very important for the validity of the hypotheses. In addition, it is also important from which country the foreign direct investments are made to the host country. For example, since the developed country attaches more importance to environmental quality, the production technique is more advanced and environmentally friendly. Therefore, foreign direct investments from these countries are more likely to be valid in the pollution halo hypothesis. In parallel with this, more realistic results can be obtained in terms of the validity of the hypotheses by considering the mentioned situations.

3. Data and Methodology

This article examines the validity of the pollution haven and pollution halo hypotheses for the energy sector in Turkey. For this reason, annual foreign direct invesment inflows, urban population growth and carbon dioxide emissions from the energy sector are used for the period 1990-2019. In studies on the subject, it is seen that the variable of carbon dioxide emission is generally used as a pollution criterion. Again, foreign direct investment inflows are used as the main independent variable in terms of the validity of the hypotheses (Mutafoglu, 2012; Shahbaz et al., 2015; Öztürk & Öz, 2016; Solarin et al., 2017; Kılıçarslan & Dumrul, 2017). In addition, the urban population growth was included in the analysis as a control variable in order to carry out econometric analyzes more robustly in the study. With the help of Table 3, the information about the variables can be examined.

Table 3. Informations of the Variables Used in the Study

Variables	Explanations	Sources	Units	Transformations
LENERCO2	Total Greenhouse Gas Emissions in the Energy Sector (Carbon Dioxide Equivalent)	TurkStat	Million Tonnes	Logarithmic
LFDI	Foreign Direct Investment Inflows	WorldBank	%GDP	Logarithmic
LURBPOPGRO	Urban Population Growth	WorldBank	%	Logarithmic

In the study, the econometric method used in (Mutafoglu, 2012) and (Kılıçarslan & Dumrul, 2017) studies was used to examine the validity of the hypotheses. In this parallel, the basic function structure established in terms of variables is shown below.

$$lnY_t = \propto + \beta lnX_t + \mu lnZ_t \varepsilon_t \quad (1)$$

The variable lnY_t is the dependent variable and represents the LENERCO2 variable in the model to show the pollution level. The variable lnX_t is the independent variable and represents the LFDI variable. The urban population growth, which is the control variable, is represented by the lnZ_t variable. ε_t shows the error term. In order to obtain more consistent results in the function, the natural logarithm of all variables was taken. The Johansen and Juselius (1990) cointegration test was used to determine the existence of a long-term relationship between the variables. Vector error correction model (VECM) based Granger test and Toda and Yamamoto (1995) causality analyzes were used to determine causality relationships between variables. First of all, in order to apply the Johansen and Juselius (1990) cointegration test, the variables must be stationary in the first order (Mert & Çağlar, 2019). For this reason, the degrees of stationarity of the series were examined using ADF (Augmented Dickey-Fuller) and PP (Phillips-Perron) tests. In the ADF test, the AR(p) process is used to examine the high-order correlation relationship in the variables (Bozkurt, 2013). According to the test, the H_0 hypothesis indicates that the series is not stationary, and the H_1 hypothesis indicates that the series is stationary. If the test statistic calculated for the variable is greater than the critical value, the H_1 hypothesis is accepted and it is understood that the series is stationary. Unlike the ADF test, the PP test takes into account structural breaks (Sevüktekin & Çınar, 2014). In addition, Newey-West and Andrews error correction methods are used for consecutive addiction problems. The hypotheses of the PP test are equivalent to the ADF test. If the test statistic calculated for the variable is greater than the critical value, it is understood that the series is stationary. In addition to the ADF and PP tests, which are standard tests, variables can be affected by external shocks. The presence of level value and trend changes in the series may cause the stagnation process to be misinterpreted (Tayyar, 2018). Despite this possibility, the variables should be examined with unit root tests that take into account structural breaks. According to Lee and Strazich (2003) structural unit root test with two breaks, the break times of the variables are internal (Lee &

Strazicich, 2003). The series is represented by level break model A, slope break model B, and both level and slope break model C. If the test value calculated for the series greater than the critical value, it is understood that the variable does not have a unit root.

If the series are first-order stationary, the Johansen and Juselius (1990) cointegration test can be applied to the variables. With the help of this test, the relationship between the variables is examined as long-term and vectorial. The Johansen and Juselius (1990) cointegration test is based on the VAR model. Whether the cointegration relationship is valid or not depends on the trace and maximum eigenvalue tests. The formulas of the tests can be represented by the following set of equations (Johansen & Juselius, 1990: 179):

$$Trace = -T \sum_{i=r+1}^{p} \ln\left(1-\mu_{r+1}\right) \quad (2)$$

$$Maximum\ Eigenvalue = -T \ln\left(1-\mu_{r+1}\right) \quad (3)$$

According to the formulas, the existence of cointegrating vectors is examined with the help of hypotheses. According to the trace statistics, the H_0 hypothesis shows that there is no cointegrating vector (r=0). The H_1 hypothesis states that there is at least one cointegration relationship (r≤1). If the trace statistics calculated for the variables are greater than the critical value, it is understood that there is at least 1 cointegration relationship. The hypothesis structure of the maximum eigenvalue statistic is different from the trace statistic. In the maximum eigenvalue statistic, the H_0 hypothesis shows that there is no cointegration relationship (r=0). H_1 hypothesis expresses the existence of one cointegration relationship (r=1). Accordingly, if the calculated maximum eigenvalue statistic is greater than the critical value, the H_0 hypothesis is rejected.

If there is a long-term relationship between the variables used in the study, short- and long-term causality relationships can be analyzed with the help of VECM. In this model, even if the variables are not stationary, the causality relationship is examined without applying the difference process. Short-run causality relationships are related to the lag value of the independent variables. Long-term causality relationships are determined based on the value of the error correction term (VECT). On this basis, the VECM equation set in terms of X and Y variables can be shown with the help of the equations below (Mert & Çağlar, 2019).

$$\Delta lnY_t = \alpha_1 + \sum_{i=1}^{k} \beta_{1i}\Delta X_{t-1} + \sum_{i=1}^{k} \theta_{1i}\Delta Y_{t-1} + \mu VECT_{t-1} + \varepsilon_{1t} \quad (4)$$

$$\Delta lnX_t = \alpha_2 + \sum_{i=1}^{k} \beta_{2i}\Delta X_{t-1} + \sum_{i=1}^{k} \theta_{2i}\Delta Y_{t-1} + \mu VECT_{t-1} + \varepsilon_{2t} \quad (5)$$

The variable k in the equations represents the optimal lag length. The μ factor in front of the VECT variable indicates the vector error correction coefficient. The μ factor explains how long it will take for the imbalances that occur after the shock to reach equilibrium. The VECT coefficient must be negative and take values between 0 and 1. If this coefficient is statistically significant, it is understood that the established model is correct. The accuracy of the model shows that the long-term causality relationship between the variables is valid. In addition, a diagnostic analysis based on several tests is required for the robustness of the established model. Autocorrelation, heteroscedasticity and normality tests refer to the aforementioned analyses. In a well-established model, there should be no serial correlation, no heteroscedasticity and the residuals of the model should have a normal distribution.

In order to carry out VECM analysis, preliminary tests about variables (such as unit root and cointegration) are needed. However, in Toda and Yamamoto (1995) analysis, causality relationships between variables can be determined without pre-tests. This analysis shows that even if there are non-stationary variables, VAR models can be established in terms of the level values of the variables. In the causality analysis of Toda and Yamamoto (1995), the VAR model with augmented lag is used (Toda & Yamamoto, 1995). In addition, since the difference is not taken even if the variables are not stationary, information loss about the variables is prevented. In the first stage of the analysis, the highest degree of integration (dmax) of the variables is determined. In the second step, the optimal lag length (k) for the VAR model established is obtained. In the third step, the VAR(k+dmax) model is estimated by summing the highest degree of integration and the optimal lag length. Finally, the hypotheses created are tested with the MWALD (modified WALD) test. According to the analysis, if the H_0 hypothesis is rejected, it is understood that there is a causal relationship between the variables. The accuracy of the VAR model established for Toda and Yamamoto (1995) causality analysis is important. Therefore, the VAR model should be suitable for unit root, autocorrelation (LM and Portmanteau tests), heteroscedasticity and normality analysis.

4. Econometric Findings

In this section, the long-term relationship between LFDI, LENERCO2 and LURBPOPGRO variables will be examined with the help of Johansen and Juselius (1990) cointegration test. Then, VECM and Toda and Yamamoto (1995) causality analyzes will be applied to determine causality relationships. For the cointegration test, the variables must be first-order stationary. In this respect, ADF and PP unit root tests were applied to the variables whose logarithmic transformation was provided.

Table 4. Stability Test Results

Variables	Intercept and Trend Level Value		Intercept and Trend 1st Difference	
	ADF	PP	ADF	PP
LENERCO2	-2.72(0) (0.235)	-2.73(2) (0.231)	-5.84(0) (0.000)	-8.31(8) (0.000)
LFDI	-2.69(0) (0.247)	-2.65(3) (0.259)	-6.01(0) (0.000)	-10.65(27) (0.000)
LURBPOPGRO	-1.41(1) (0.832)	-5.12(3) (0.001)	-3.41(1) (0.070)	-4.46(3) (0.007)
Critical Values	1%→-4.30 5%→-3.57 10% →-3.22	1% →-4.30 5%→-3.57 10% →-3.22	1% →-4.32 5%→-3.58 10% →-3.22	1% →-4.32 5%→-3.58 10% →-3.22

Note: The values in parentheses next to the ADF test statistic show the lag length according to the SIC criterion. The values in parentheses next to the PP test statistic represent the automatic Newey-West bandwidth according to the Barlett-Kernel model. The values in parentheses under the ADF and PP test statistics show the probability values at the 1% level.

Table 5. Two-Break Lee & Strazicich (2003) Unit Root Test Results

Series	Model	Lag	Break Times	Test Statistic(Tau)	Critical Value
LENERCO2	Model A	0	1995, 2006	-3.98	-4.07*
	Model C	2	1999, 2005	-5.87	-7.19*
LFDI	Model A	1	2000, 2003	-4.33	-4.07*
	Model C	2	1999, 2008	-5.70	-7.00*
LURBPOPGRO	Model A	1	1998, 2008	-2.45	-4.07*
	Model C	1	1994, 2009	-4.40	-7.00*

Note: Critical values indicate 1% significance level. The critical values are taken from Lee & Strazicich (2003).

Table 4 shows the ADF and PP unit root test results. According to the ADF test results, the test statistics calculated in terms of all variables are smaller than the critical value at the 1%, 5% and 10% significance levels. Therefore, LENERCO2, LFDI and LURBPOPGRO variables are not stationary at level value according to the ADF test. Again, according to the results of the PP test applied to the level values of the variables, it is seen that the LENERCO2 and LFDI variables have unit roots. However, the LURBPOPGRO variable is stationary at the 1% significance level. For this reason, the first difference of LENERCO2 and LFDI variables was taken and ADF and PP unit root tests were applied again. It was concluded that both variables were statistically significant at the 1% level. Structural breaks are not taken into account in ADF and PP tests. In order to eliminate this deficiency, Lee & Strazicich (2003) two-break structural unit root test was applied to the level values of the variables. The results of the test can be examined with the help of Table 5.

According to the information in the table, since the tau statistical value calculated for Model A in terms of LENERCO2 is less than the critical value, it is understood that the series is not stationary at the level value. The tau statistic calculated for Model A in the LFDI variable is greater than the critical value. Therefore, the LFDI variable is stationary at level for Model A. In the LURBPOPGRO variable, the t statistic calculated for Model A is smaller than the critical value. It is seen that the LURBPOPGRO variable has a unit root in terms of Model A at the level value. Model A shows level breakage, Model C shows both level and slope breaks. Therefore, Model C is in a more important position in questioning the stationarity relationship in variables. It is seen that the tau statistic calculated according to the Model C results for all variables is less than the critical value. In this respect, all variables have a unit root at level value. As a result, according to the results of the ADF, PP and Lee & Strazicich (2003) tests for the variables, it was decided that the series were integrated at 1 degree.

Since all the variables are stationary at the first difference, the Johansen and Juselius (1990) cointegration test can be applied. This method was used to detect the existence of long-term relationships among the variables. First, the optimal lag length for the model needs to be determined. Values taken by various criteria can be examined with the help of Table 6.

Table 6. Determining the Optimal Lag Length

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	62.557	NA	2.59e-06	-4.350	-4.060	-4.266
1	85.415	36.925	9.05e-07	-5.416	-4.690	-5.207
2	113.611	39.039*	2.17e-07*	-6.893*	-5.731*	-6.558*
3	119.328	6.596	3.11e-07	-6.640	-5.043	-6.180
4	125.351	5.560	4.83e-07	-6.411	-4.379	-5.826

Note: LR sequentially modified LR test, FPE final prediction error, AIC Akaike information criterion, SIC Schwarz information criterion and HQ Hannan-Quinn information criterion.

According to the table, it has been determined that the optimal lag length in terms of criteria is 2 (k=2). In addition, the established model was found to be compatible in various diagnostic tests. Then, Johansen & Juselius (1990) cointegration test was applied under the condition of k=2. The trace and maximum eigenvalue statistics values of the test can be examined with the help of Table 7.

Table 7. Johansen Cointegration Test Results (Trace and Maximum Eigenvalue Statistics)

Cointegration Hypotheses	Trace Statistics	Critical Value(%5)	Probability**
No cointegration*	35.324	35.192	0.048
At most 1 cointegration	13.001	20.261	0.363
At most 2 cointegration	3.271	9.164	0.531
Cointegration Hypotheses	**Maximum Eigenvalue**	**Critical Value(%5)**	**Probability****
No cointegration*	22.322	22.299	0.049
At most 1 cointegration	9.730	15.892	0.359
At most 2 cointegration	3.271	9.164	0.531

Note: The (*) sign indicates that the relevant hypothesis was rejected at the 5% level. The (**) sign represents MacKinnon-Haug-Michelis (1999) probability values.

According to the trace statistics in the table, the null hypothesis shows that there is no cointegration. In this respect, it is seen that the trace statistics value of the null hypothesis is greater than the critical value. Therefore, it is understood that there is cointegration at the 5% significance level by rejecting the null hypothesis. According to the maximum eigenvalue test, the null hypothesis shows that there is no cointegration between the variables, and the H_1 hypothesis shows that there is only one cointegration relationship. In the table, the maximum eigenvalue statistical value of the null hypothesis is greater than the critical value at the 5% significance level. For this reason, the H_0 hypothesis is rejected, and it is understood that there is 1 cointegration relationship between the variables. According to the results of both tests, there is a long-term relationship between the LENERCO2, LFDI and LURBPOPGRO variables.

4.1. VECM and Short-Long-Run Causality Analysis

After determining the existence of a long-term relationship between the variables by cointegration tests, causality analysis can be made. Because the existence of cointegration does not show a causal relationship in terms of variables. Therefore, it is necessary to apply VECM analysis to variables in order to detect both short- and long-term causality relationships. It is very important that the variables used in VECM analysis are dependent or independent. For this reason, a weak externality test was applied using constraints for each variable. The results of the test are listed below.

Table 8. Weak Externality Test

Variables	Chi-Square Test	Probability Value	Hypothesis	Results
LENERCO2	11.547	0.000	H_0 Reject	Dependent Variable
LFDI	0,669	0.413	H_0 Accept	Independent Variable
LURBPOPGRO	0.001	0.973	H_0 Accept	Independent Variable

Table 9. VECM(2) Estimate Results

Long-Run Equation Results			
	$\mathbf{LENERCO2}_t$		
INTERCEPT	4.742*** (-6.927)		
$\mathbf{LFDI}_t$	0.387*** (-5.751)		
$\mathbf{LURBPOPGRO}_t$	1.178 (-1.474)		
$\mathbf{LENERCO2}_t$	-		
Short-Run Equation Results			
	$\Delta\mathrm{LENERCO2}_t$	$\Delta\mathrm{LFDI}_t$	$\Delta\mathrm{URBPOPGRO}_t$
$\mathbf{VECT}_t$	-0.22*** (-4.700)	0.44 (0.828)	0.000 (0.031)
$\Delta\mathbf{LENERCO2}_{t-1}$	-0.222 (-1.263)	4.738 (2.401)	0.071 (0.687)
$\Delta\mathbf{LENERCO2}_{t-2}$	-0.231 (-1.265)	-2.374 (-1.155)	-0.125 (-1.162)
$\Delta\mathbf{LFDI}_{t-1}$	-0.027 (-1.376)	0.012 (0.058)	-0.002 (-0.209)
$\Delta\mathbf{LFDI}_{t-2}$	-0.016 (-0.888)	-0.167 (-0.811)	-0.006 (-0.607)
$\Delta\mathbf{LURBPOPGRO}_{t-1}$	-0.948 (-2.376)	-1.717 (-0.383)	0.991 (4.220)
$\Delta\mathbf{LURBPOPGRO}_{t-2}$	0.753 (2.899)	0.819 (0.281)	-0.397 (-2.597)

Note: The (***) sign indicates statistical significance at the 1% level. Since long-term equation results are vector, the sign of the results in Eviews 10 is inverted.

According to the weak externality test, the null hypothesis is tested with the Chi-Square test statistic. In this parallel, if the null hypothesis is rejected, it is understood that the variables are dependent variables. When the table is examined, it is seen that the chi-square test probability value of the LENERCO2 variable is less than the 1% significance level. In this respect, the null hypothesis is rejected and it is understood that the LENERCO2 variable is the dependent variable. In the LFDI and LURBPOPGRO variables, the chi-square test statistic probability value is greater than 5% significance level. Therefore, the H_0 hypothesis is accepted. The variables LFDI and LURBPOPGRO are understood to be independent variables. After the weak externality test, VECM analysis is performed because the series are cointegrated. For this reason, VECM(2) was estimated using model 2 with the help of Eviews10 program. The results are in Table 9.

In Table 9, it is seen that the VECT coefficient of the model established with the LENERCO2 variable as the dependent variable is -0.22. This value is negative between 0 and 1 and is statistically significant at the 1% level. Therefore, it is understood that the error correction mechanism works in the established model. When the VECT coefficient is examined, the short-term imbalances in the LENERCO2 variable improve after about 4.5 years (1/0.22) and reach the long-term equilibrium. According to the long-term equation results, the LFDI variable affects the LENERCO2 variable at 1% significance level. In this respect, a 1% increase in the LFDI variable in the long run increases the LENERCO2 variable by 0.38%. Therefore, the increase in foreign direct investment in Turkey in the long term increases the carbon dioxide emissions from the energy sector. This confirms the pollution haven hypothesis for the energy sector for Turkey. In Table 9, it is seen that the VECT coefficient is 0.44 in the model established with LFDI as the dependent variable. Since the VECT coefficient is positive and statistically insignificant, it is understood that the model to be established is not robust. Again, in the model established as the LURBPOPGRO dependent variable, the VECT coefficient was found to be positive and statistically insignificant. After the model estimation, it is necessary to examine the short- and long-term causality relationships of the variables. For this reason, VECM-based Granger test was used to determine short-term causality. VECT coefficient values were taken into account in determining the long-term causality. Short and long term causality test results can be analyzed with the help of Table 10 below.

Table 10. VECM Long- and Short-Run Causality Results

Long-Run Casuality	VECT	t Statistics
f(LENERCO2|LFDI, LURBPOPGRO)	-0.22	-4.700***
f(LFDI|LENERCO2, LURBPOPGRO)	0.44	0.828
f(LURBPOPGRO |LENERCO2, LFDI)	0.00	0.031
Short-Run Causality	**Chi-Square Test**	**Probability Value**
f(LENERCO2|LFDI, LURBPOPGRO)	8.681	0.069
f(LFDI|LENERCO2, LURBPOPGRO)	9.067	0.059
f(LURBPOPGRO |LENERCO2, LFDI)	2.177	0.703

Note: The (***) sign indicates statistical significance at the 1% level.

According to the weak externality test performed in the previous steps, it was found that the LENERCO2 variable was the dependent variable and the LFDI and LURBPOPGRO variables were independent variables. In addition, the VECT coefficient was obtained by estimating the model. While the VECT coefficient is significant for the LENERCO2 variable, the VECT coefficients of the LFDI and LURBPOPGRO variables are statistically insignificant. Therefore, there is only a long-term causality relationship from the LFDI and LURBPOPGRO variables to the LENERCO2 variable. It is seen that the probability value of the Chi-Square test statistics, which is made with LENERCO2 as the dependent variable in the short term, is less than 10%. This shows that there is causality from the LFDI and LURBPOPGRO variables to the LENERCO2 variable in the short run. It is seen that the probability value of the Chi-Square test statistics, which is also the LFDI dependent variable, is less than 10%. Therefore, there is a causal relationship from LENERCO2 and LURBPOPGRO variables to LFDI in the short run. In addition, it is seen that there is no causality relationship from LFDI and LENERCO2 variables to LURBPOPGRO variable in the short run. In the last stage, diagnostic tests should be performed in terms of the validity of the estimated model. For this reason, autocorrelation, heteroscedasticity and normality tests were applied to the model, respectively. The results are in Table 11.

Table 11. VECM Diagnostic Test Results

	Lag	LRE	Probability	Rao-F	Probability
Autocorrelation Test	1	8.829	0.453	1.001	0.456
	2	7.274	0.608	0.808	0.611
	3	7.670	0.567	0.857	0.570
	4	4.980	0.836	0.537	0.837
Heteroscedasticity Test	**Chi-Square**			**Probability**	
	81.416			0.559	
Normality Test	**Jarque & Bera**			**Probability**	
	6.843			0.335	

The existence of correlation between the residuals of the model estimated in the table was examined with the help of LRE and Rao F tests. Since the series are annual, the number of delays was determined as 4. The probability values of the LRE and Rao F statistics are greater than 5%. In this respect, there is no autocorrelation problem in the model. In addition to the autocorrelation test, the existence of the heteroscedasticity problem between the residuals of the model should be examined. As a result of the analysis, it is seen that the probability value of the chi-square test statistic is greater than 1%. Therefore, it is understood that there is no heteroscedasticity problem in the model. Finally, the residuals of the estimated model should conform to the normal distribution. Normality analysis was performed with the Jarque and Bera test, and the probability value was found to be greater than 1%. According to the diagnostic tests, it was concluded that the model was robust.

4.2. Toda & Yamamoto (1995) Causality Analysis

If there is a cointegration relationship between the variables, the F statistic may not be suitable for the standard distribution. In addition, many preliminary tests are needed for the determination of Granger-based causality relationships. However, the causality relationship can be examined with the help of the Toda and Yamamoto test without the need for pre-tests on the variables. For this, the maximum degree of integration (dmax) of the series must be known. In previous tests, dmax=1 result was obtained. In addition, it was determined that the lag length for the determined VAR model was 2. In this respect, the VAR model was estimated as k+dmax=3. The null hypotheses about the test were tested with the MWALD test. The test results can be examined with the help of Table 12 below.

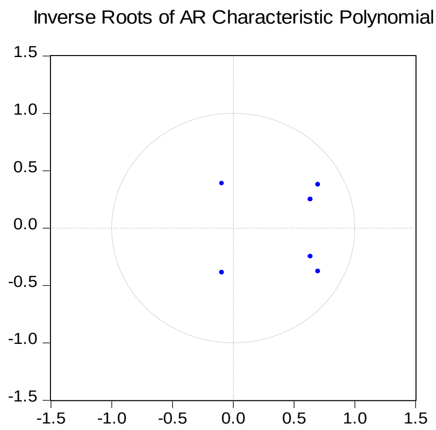
Table 12. Toda & Yamamoto (1995) Causality Results

Hypotheses	Lag Length (k+dmax=3)	Chi-Square	P Value	Results
LFDI, LURBPOPGRO≠→LENERCO2	3	8.276	0.082	H_0 Reject**
LENERCO2, LURBPOPGRO ≠→LFDI	3	9.609	0.047	H_0 Reject*
LENERCO2, LFDI ≠→ LURBPOPGRO	3	2.186	0.701	H_0 Accept

Note: The (*) sign in the table indicates that the H_0 hypothesis was rejected at the 5% level, and the (**) sign at the 10% level of H_0 hypothesis.

According to the test results, it is seen that there is one-way causality from the LFDI and LURBPOPGRO variables to the LENERCO2 variable in the first line. Because the probability value of the Chi-Square test statistic of the causality relationship is less than 10% significance level. Therefore, the null hypothesis was rejected. In the second line, there is a one-way causality relationship from the LENERCO2 and LURBPOPGRO variables to the LFDI variable. The probability value of the Chi-Square test statistic of the relationship is less than 5%. Therefore, the null hypothesis was rejected. Finally, in the third line, it is seen that there is no causality relationship from LENERCO2 and LFDI variables to LURBPOPGRO variable. Since the probability value of the Chi-Square test statistic was more than 10% significance level, the null hypothesis was accepted. For the accuracy of the Toda-Yamamoto analysis, the stability conditions of the estimated VAR model should be examined. The results of the diagnostic tests performed in Table 13 can be analyzed.

Table 13. Diagnostic Tests for the Identified VAR Model



Autocorrelation Tests				
Lag	LRE*stat	Prob	Q-Stat	Prob.
1	11.05	0.272	5.301	-
2	4.69	0.860	6.499	-
3	4.35	0.886	10.662	0.299
Heteroscedasticity				
Chi-Square		Probability		
103.783		0.070		
Normality				
Jarque-Bera		Probability		
9.339		0.155		

The autoregressive characteristic roots of the VAR equation system must be less than 1. Therefore, according to the analysis, the roots of the system are located in the unit circle. Therefore, the fact that the values of the roots are less than one provides the stability condition. As another diagnostic test, there should be no serial correlation in the model. LM and Portmanteau tests were used to detect serial correlation. In the study, the delay value was determined as 3. According to the results of both tests, it was understood that there was no serial autocorrelation up to 3 delays. In addition, White's test was used to detect the presence of heteroscedasticity problem in the model. The probability value of the chi-square test statistic was found to be greater than the 1% statistical significance level. Therefore, there is no problem of heteroscedasticity in the estimated model. Finally, the residues in the VAR equations should conform to the normal distribution. Therefore, according to the results obtained using the Jarque & Bera test, the residues are in accordance with the normal distribution. As a result, the estimated VAR model satisfies all conditions at 1% error level as a suitable model.

5. Conclusion and Suggestions

In recent years, the increase in carbon dioxide emissions has reached serious dimensions. This situation causes environmental pollution and negatively affects all life. One of the main reasons for the increase in carbon dioxide emissions is the energy consumption based on fossil sources. Increasing economic competition between countries leads to the fact that energy need to be met with fossil energy sources. Especially the fact that they are more accessible and cheaper than renewable energy sources causes the industry to prefer fossil energy sources. Renewable energy sources can be used to prevent increases in global carbon dioxide levels. However, the process of converting renewable resources to energy is quite costly and countries must have sufficient internal financial resources. For this reason, countries with internal financing problems resort to foreign direct investments to provide more efficiency from renewable energy sources. At this point, it is very important for the energy sector whether foreign direct investments will create environmental pollution. In terms of the energy sector, the relationship between foreign direct investments and environmental pollution is examined with the help of pollution haven and pollution halo hypotheses. The pollution haven hypothesis suggests that an increase in foreign direct investments will reduce environmental quality. In this context, if the pollution haven hypothesis for the energy sector is valid, it is understood that foreign direct investments mostly prefer fossil energy sources in energy conversion. According to the pollution halo hypothesis, it argues that the increase in foreign direct investments in the country will increase the environmental quality. In this context, if the pollution halo hypothesis is valid for the energy sector in the country, it can be said that more renewable energy sources are used in energy conversion.

The main purpose of the article is to examine whether the pollution haven or pollution halo hypotheses are valid in terms of the energy sector in Turkey. In the study, total greenhouse gas emissions (CO_2 equivalent) from the energy sector, urban population growth and foreign direct investment variables were used for the period 1990-2019. The Johansen and Juselius (1990) test was used to investigate the cointegration relationship between the variables. In addition, VECM, and Toda and Yamamoto tests were used for causality analysis. According to the results of the Johansen and Juselius (1990) cointegration test, there is a long-term relationship between the variables. VECM analysis was applied because there was a cointegration relationship between the variables. According to the test results, a 1% increase in foreign direct investments in the long term increases carbon dioxide emissions originating from the energy sector by 0.38%. In addition, there is a one-way causality relationship from foreign direct investment and urban population growth variables to carbon dioxide emissions originating from the energy sector in the long run. VECM-based Granger test was used to determine the short-term causality relationship. Accordingly, there is a causality relationship from foreign direct investment and urban population growth variables to carbon dioxide emissions originating from the energy sector in the short run. Again, it is seen that there is a causality relationship from the variables of carbon dioxide emissions originating from the energy sector and the urban population growth to the variable of foreign direct investment. Except for the VECM-based Granger test, Toda-Yamamoto (1995) analysis was used to determine the causal relationships between the variables. It is seen that the results of the Toda-Yamamoto (1995) causality test performed in terms of variables are equivalent to the results of the VECM-based Granger test. As a result, the pollution haven hypothesis is valid for the energy sector in Turkey in the long run. Unlike other studies, the examination of the validity of the relevant hypotheses in terms of the energy sector shows the contribution of the study to the literature. In this direction, the use of fossil energy resources by foreign direct investments in the energy sector should be deterred by various policies. In this context, additional financial regulations and bureaucratic obstacles may be applied for foreign direct investments that prefer fossil energy sources. In addition, some of the feasibility costs (as much as a proportion of the foreign direct investment made) can be covered by the state in order for foreign direct investments to be directed more towards renewable energy sources. As a result, in order to achieve permanent increases in environmental quality, the administrative and financial regulations made by the state should be strengthened.

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