Chapter 3

The Impact of Innovation, Foreign Direct Investments, Trade Openness, Economic Growth on Carbon Emissions in Türkiye

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Abstract

The main purpose of this study is to examine the current energy economics literature in Türkiye by considering the role of innovations, foreign direct investments, economic growth and trade openness in the function of carbon emissions. In the study using 1994–2020 data, vector error correction model (VECM) and ARDL bounds test methods were used to examine the effects of innovation, trade openness, foreign direct investment, per capita GDP on CO2 emissions. Accordingly, it was concluded that trade openness and GDP per capita are among the variables affecting CO2 emissions in Türkiye. GDP per capita and trade openness affect carbon emissions positively in Türkiye. On the other hand, the relationship between FDI, innovation coefficient and CO2 emission coefficient is not significant at the 5% level. The sign of the coefficient of the predicted foreign direct investment and innovation variable is positive. In line with the findings, it primarily targets the energy consumption model, since economic growth is the primary driving force of the country's economy. Policy makers should turn to practices that encourage the use of renewable energy sources rather than the use of fossil fuels. While transitioning to renewable energy sources, R&D units in the country can be used for the development of renewable energy solutions.

1. Introduction

Due to the economic growth targets of the countries, both natural resources are depleted and their living spaces are deteriorated. After the industrial revolution, the increase in mass production and the use of fossil fuels with mechanization has created a significant stress on the ecosystem. This has led

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https://doi.org/10.58830/ozgur.pub138.c715

to problems such as climate change and environmental pollution. After the 20th century, this economic growth model and modern production systems, which threatened the ecosystem, started to attract attention. The threat in question has made many different regulations mandatory. Sustainable development is at the forefront of these regulations (Akyol and Mete, 2021).

The fossil fuels used in the new production method cause a decrease in environmental quality and climate change. As a result of climate change, agriculture-based economies are adversely affected. Today, reducing greenhouse gas emissions along with economic growth is among the primary goals of countries (Zameer et al. 2020). Scientists agree on global warming. Climate change and greenhouse gas emissions have recently attracted the attention of the public. Especially scientists in the field of energy economics have carried out intensive studies on the relationship between CO2 emissions and economic growth (Balsalobre Lorente et al. 2018).

Concerns about environmental pollution, climate change and the destruction of natural habitats are coming to the fore more and more worldwide (Hoffmann, 2007). For this reason, governments are turning to policy practices that promote the green economy model in terms of contributing to a sustainable economy such as green brands and environmentally friendly technologies. In order to implement these innovations within the economic ecosystem, the green finance process has started to come to the fore (Zhou et al., 2020).

Today, a general opinion is that economic growth creates higher energy demand and increases energy efficiency. As a result, it is thought to support economic growth. (Tiba and Omri, 2017). In countries where non-renewable energy sources are dominant, it may adversely affect the environment due to the use of energy required by economic growth. In the literature, this connection has been extensively studied. The results obtained differ according to the countries covered, the time period studied and the model used (Nepal et al. 2021).

Technological innovations both increase energy efficiency and improve economic growth. As a result, carbon emissions decrease and environmental quality increases. Accordingly, innovation is becoming a very important issue in researching the determinants of carbon emissions. Innovation with a high technological level produces more output as well as creating a low energy requirement in production. In addition, it is very important for countries to turn to renewable energy sources in protecting the environmental quality (Wenlong et al. 2023).

The question of how much foreign direct investment, innovation, GDP per capita and trade openness can contribute to achieving sustainable economic growth by reducing carbon emissions in a developing country like Türkiye comes to the fore. Since Türkiye is included in the developing economies, the energy demand and consumption used in production is not flexible. Although there are many studies examining the relationship between economic growth and carbon emissions, studies examining the role of innovation, foreign direct investment, GDP per capita and trade openness are very few. Therefore, it is necessary to examine the relationship between innovation, foreign direct investment, GDP per capita and trade openness. Accordingly, this study aims to examine the impact of innovation, foreign direct investment, GDP per capita and trade openness on carbon emissions in Türkiye.

2. Literature Review

There are many studies in the literature examining the relationship between carbon emissions, foreign direct investments, energy consumption, high value-added exports and economic growth, and the export levels of countries. On the other hand, studies expressing through which channels the renewable energy production will be measured remain at a very limited level. In this context, it is thought that the study will fill this gap in the literature. In this section, studies examining the relationship between innovation, foreign direct investments, GDP per capita, trade openness and CO2 emissions are included.

Adebayo et al. (2019) examined the impact of economic growth, non-renewable energy consumption and trade openness rate on environmental degradation in India. Annual data covering the period 1985-2019 were used in the study. The findings showed that all variables negatively affect the environmental quality in India.

Yalman (2019) examined the importance of indirect foreign capital investments, energy consumption and carbon emissions in increasing the added value of technological products, which have an important place in exports, and to analyze the situation in BRICS countries and Türkiye for the period 2000-2016. High technology, electricity consumption and accordingly carbon emissions affect growth.

According to Shahbaz et al. (2021) investigated the effect of trade openness, energy use, oil prices and per capita GDP on CO2 emissions in India. In the research, annual data covering the period 1980-2019 were used.

The analysis findings showed that the rate of trade openness and energy consumption negatively affect the environmental quality in India.

Kuşçuoğlu and Uzgören (2021) investigated the relationship between real GDP variables, trade openness, human capital and financial development in Türkiye. In the study, annual data for the period 1987-2017 were used. Variables were analyzed using the Cobb-Douglas production function. According to the result, the ratio of human capital and trade openness positively affects real GDP. On the other hand, financial development negatively affects real GDP.

Doğan and Doğan (2021) investigated the effects of innovation and financial development variables on renewable energy production in Türkiye. In the research, annual data for the period 1968-2015 were used. According to the findings, it has been determined that GDP, innovation and financial development have the same effect on renewable energy production. However, it is concluded that CO2 emissions have a negative effect on renewable energy production.

According to Pata et al. (2022) tried to test the environmental Kuznets curve hypothesis on ASEAN countries over the variables affecting CO2 emissions. According to the results of the analysis, while CO2 emissions are positively affected by foreign direct investments and tourism variables, the rate of trade openness is negatively affected.

Wenlong et al. (2023) investigated the impact of energy efficiency, trade openness, technological innovations and institutional capacity on the environment in 10 Asian countries using annual data for the period 1995-2018. As a result, it has been determined that while technological innovations and energy efficiency have a positive effect on environmental quality, trade openness and institutional capacity have a negative effect.

Güven (2023) examined the effects of environmental innovations on the carbon footprint. In the study, annual data for the period 1992-2018 were used. According to the analysis results, while environmental innovations reduce CO2 emissions in the short term, they increase it in the long term.

Yıldız (2023) examined the effects of economic growth and financial development variables on CO2 emissions in Türkiye. In the research, annual data for the period 1980-2020 were used. As a result, it has been determined that financial development and economic growth have a positive effect on CO2 emissions.

3. Data and Methodology

Annual data were used in the study in which the effect of innovation, foreign direct investment, per capita GDP and trade openness rate on CO2 emissions in Türkiye was analyzed for the period covering the years 1994-2020. Taking the studies in the literature as an example and taking the natural logarithm of the variables used in the study, the model was created as follows:

$$LnCO2 = \alpha + ßlnFDI + ßlnGDPP + ßlnINV + ßlnTO + \varepsilon$$

Where lnCO2 represents environmental degradation; lnFDI represents foreign direct investment taken as a percentage of GDP; lnGDPP, GDP per capita (constant 2010 USD) represents economic growth; lnINV represents the total number of patents filed by innovation incumbents and non-residents; real GDP per capita (in 2015 US dollars); InTO, the trade openness ratio represents the ratio of the sum of total exports and imports to GDP. Environmental CO2 emissions, growth, innovation, trade and foreign direct investment data from these series were taken from the World Bank (World Development Indicators) database. In this study, time series were used and analyzes were made in Eviews 10 package program. While analyzing the relationship between variables in the study, the unit root test developed by Augmented Dickey-Fuller (ADF) and Phillips and Perron (PP) and ARDL bounds test approach were used.

4. Result

In Table 1, descriptive statistics of the variables examined in the study are presented. It shows that CO2 emissions and GDP per capita have the lowest standard deviation, while foreign direct investment has the highest standard deviation.

Table 1. Descriptive Statistics

	LOGCO2	LOGFDI	LOGGDPP	LOGINV	LOGTO
Mean	5.335914	-0.295351	9.444293	7.652071	-1.216483
Median	5.326385	-0.479978	9.347289	7.516433	-1.293210
Maximum	5.984208	1.287441	9.973422	9.054271	-0.422537
Minimum	4.515660	-2.025545	8.960214	6.385194	-2.343030
Std. Dev.	0.424086	0.885170	0.312567	0.810812	0.611425

4.1. Unit Root Tests

Most of the models in econometrics are analyzed with time series. As it is known, time series are seasons, trends, conjunctures, etc. It is under the influence of non-regular currents. The properties of time series are generally divided into deterministic and stochastic properties. While the deterministic properties of the series are generally related to whether the series contain constant, seasonality and trend components, stochastic properties are related to the stationarity of the parameters. Therefore, the series analyzed should be stationary in order to obtain meaningful relationships between the variables in econometric terms (Tarı, 2011).

In the study, Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test was applied since the stationarity and degrees of the series should be determined first for econometric analysis application.

Table 2. ADF and PP Unit Root Test Statistics Results

Variables	**ADF Test**		**Phillips-Perron Test**	
	At Level	**First Difference**	**At Level**	**First Difference**
LnCO2	t-İstatistiği -3.6047	t-İstatistiği -6.7281	t-İstatistiği -3.4967	t-İstatistiği -7.0106
	P: ***0.0435***	P: 0.0000**	P: ***0.0549***	P: 0.0000**
lnFDI	t-İstatistiği -2.8226	t-İstatistiği -6.7294	t-İstatistiği -2.7711	t-İstatistiği -12.5728
	P: ***0.1989***	P: 0.0000**	P: ***0.2165***	P: 0.0000**
lnGDPP	t-İstatistiği -2.3476	t-İstatistiği -6.1943	t-İstatistiği -2.3476	t-İstatistiği -6.5963
	P: ***0.3992***	P: 0.0001**	P: ***0.3992***	P: 0.0000**
lnINV	t-İstatistiği -2.7528	t-İstatistiği -4.5561	t-İstatistiği -2.2534	t-İstatistiği -4.5751
	P: ***0.2232***	P: ***0.0046***	P: ***0.4473***	P: 0.0044**
lnTO	t-İstatistiği -0.2494	t-İstatistiği -5.4769	t-İstatistiği -0.3046	t-İstatistiği -5.4769
	P: ***0.9892***	P: ***0.0004***	P: ***0.9874***	P: 0.0004**

Note: Values in parentheses represent lag lengths for ADF and bandwidth for PP. Schwarz Information Criteria (SIC) were used to select the lag length. Bandwidth was determined by Newey West using Bartlett Kernel. ** Significant at 5%

Empirical application results were started by testing ADF and PP unit root tests. These tests were used to determine the stationarity of the data set. The results of the ADF and PP unit root test for both constant and constant and trended models are shown in Table 2. It is seen that all series contain unit root at level. It is observed that the series become stationary at the 1% and 5% statistical significance levels at the first difference. Therefore, it can be stated that all series are I(1) or, in other words, they are integrated at the I(1) order. Therefore, in order to apply the ARDL bounds test approach, it is seen that the assumption that the series should not be I(2) but should be I(0) or I(1) is provided.

Table 3. Diagnostic Tests for the ARDL (1, 1, 0, 0, 0) Model

Test	**Autocorrelation Test (LM-İst.)**	**Heteroskedasticity Test (F-İst.)**	**Normality Test (JB-İst.)**
İstatistik	0.172030	1.196541	3.257763
Prob.	**0.8429**	**0.4095**	**0.196149**

The ARDL margin test approach (1, 1, 0, 0, 0) was examined in terms of autocorrelation, varying variance, and Jarque-Bera diagnostic tests and presented in Table 3. In these tests, the probability (p-value) values of serial correlation, varying variance and normality distribution should be greater than 0.05. Therefore, it is seen that the probability (p-value) values of the hypothetical diagnostic statistics meet the necessary condition. In other words, it is seen that the model does not have autocorrelation, varying variance, and has a normal distribution.

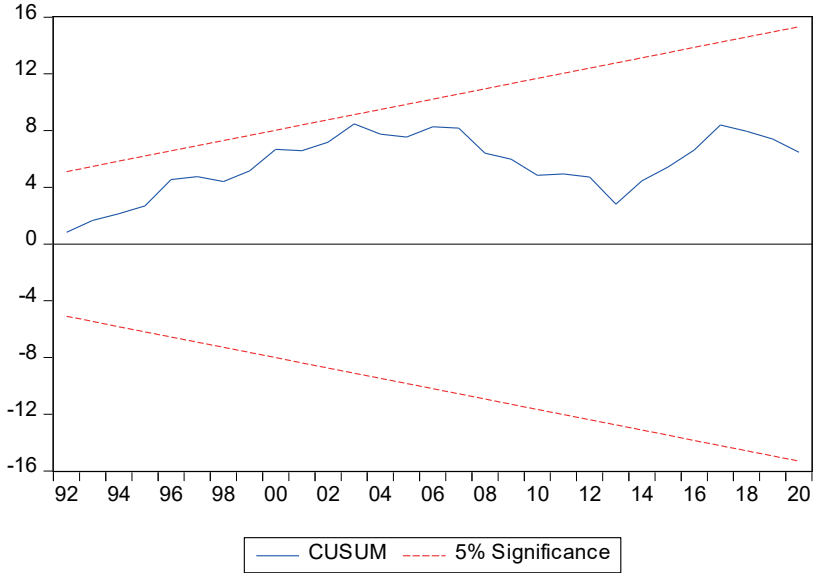

Figure 1. CUSUM Test Chart

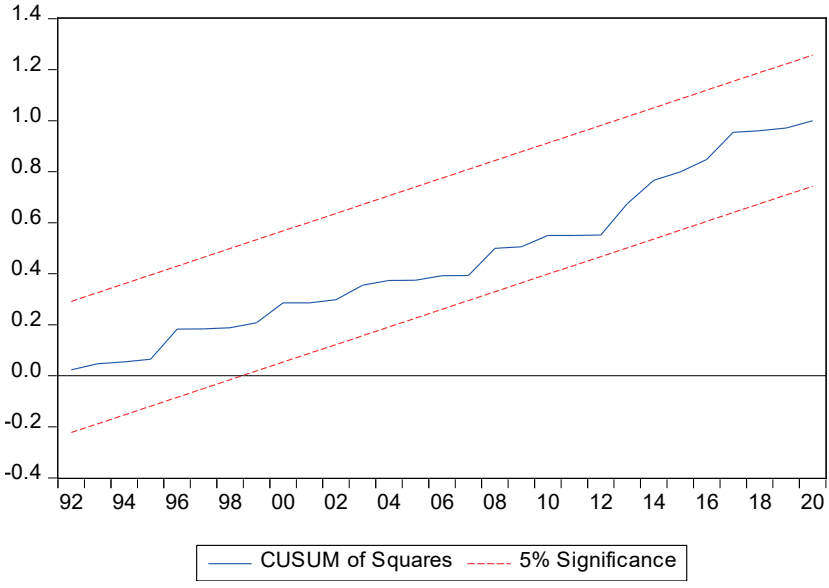

Figure 2. CUSUM of Squares Test Chart

CUSUM and CUSUM2 tests were used to determine whether the coefficients were stable in the short and long term estimations in the model. When the CUSUM and CUSUM of Squares distributions are examined in Figures 1 and 2, it is seen that the coefficients are distributed between the

critical values. In other words, it is concluded that the coefficients have a stable distribution.

4.2. ECM-ARDL Tests

Table 4. Error Correction Model for ARDL (1, 1, 0, 0, 0) Model

Model				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.223364	0.195079	-6.271125	0.0000
D(LOGFDI)	-0.020681	0.011008	-1.878709	0.0704
CointEq(-1)*	-0.500493	0.077235	-6.480168	0.0000

In this section, the Error Correction Model (ECM) for relevant long-term relationships is estimated to determine the short-term impact of innovation, foreign direct investment, per capita GDP and trade openness on CO2 emissions in Türkiye. Table 4 shows the short-run coefficients of the impact of innovation, foreign direct investment, per capita GDP and trade openness on CO2 emissions in Türkiye. The error correction term (ECM(-1)) indicates how long it takes for the model to regain equilibrium after a failure. It shows that a short-term deterioration in the error term has a 0.50% return rate to equilibrium. When the model results obtained are examined, the error term coefficient is negative and significant.

4.3. ARDL Bounds Test and Estimation of Long-Run Relationship

In order to determine the existence of a long-term relationship between CO2 emissions and our explanatory variables (innovation, foreign direct investment, per capita GDP and trade openness), the critical value limits calculated by ARDL Bounds Test results and (Pesaran et al., 2001) are given in table 5.

Table 5. Bound Test Results for ARDL (1, 1, 0, 0, 0) Model

Model				
F-Bounds Test			Null Hypothesis: No level relationship	
t-Statistics	Value	Significance Level	I(0)	I(1)
F Statistics	7.380513	10%	2.45	3.52
k	4	5%	2.86	4.01
		2.5%	3.25	4.49
		1%	3.74	5.06

The result of the ARDL bounds test for the model created shows that there is a long-term relationship between innovation, foreign direct investment, per capita GDP, trade openness and CO2 emissions at 10%, 5%, 2.5% and 1% significance levels. Thus, it reveals the fact that these variables act together in the long run and any deviation in the short run will return to the equilibrium in the long run. Since the F statistical value calculated to test whether there is a long-term relationship in the model is 7.38 and it is greater than the upper limit of 3.52 at the 5% statistical significance level according to the critical values, it has been determined that there is a cointegration between the variables in the long run. After determining the long-term cointegration relationship between the variables, the long-term coefficient estimation of the selected ARDL (1,1,0,0,0) model was performed. The relevant results are presented in Table 6.

Table 6. Long-Run Cointegration Analysis for ARDL (1, 1, 0, 0, 0) Model

Model				
Variables	Coefficient	Standard Error	t-Statistic	Prob.
lnFDI	0.006218	0.031153	0.199609	0.8432
lnGDPP	0.834462	0.131734	6.334462	**0.0000**
lnGINV	0.026504	0.036714	0.721914	0.4761
lnTO	0.210626	0.057293	3.676306	**0.0010**

Table 6 shows that the long-term coefficients of the lnGDPP and lnTO variables are significant at the 5% significance level. According to the findings, we can say that changes in GDP per capita (lnGDPP) and trade openness ratio (lnTO) affect CO2 emissions positively in the long run. It shows that a 1% change in GDP per capita (lnGDPP) increases CO2 emissions by 0.83%. This result shows that the rapid increases in Türkiye's

per capita GDP cause an increase in CO2 emissions, which negatively affect Türkiye's environmental quality. On the other hand, a 1% increase in trade openness causes a 0.21% increase in CO2 emissions. Türkiye's export and import activities cause a decrease in environmental quality. This shows that economic growth and trade openness increase carbon emissions in Türkiye. However, per capita GDP ratio affects environmental quality more negatively than trade openness. Variables of innovation and foreign direct investment do not have a statistically significant effect on CO2 emissions at the 5% significance level. The long-run coefficient sign of the predicted innovation and foreign direct investment variable is positive similar to other variables.

5. Conclsion and Discussion

The main purpose of this study is to examine the impact of innovation, foreign direct investment, per capita GDP and trade openness on CO2 emissions in Türkiye. In the model created, annual time series for the period 1994-2020 are used. Error correction model (ECM) and ARDL bounds test were used to determine the long-run relationship between innovation, foreign direct investment, GDP per capita and trade openness and CO2 emission variables. In the study, the stationarity levels of the variables in the model were tested through the PP and ADF unit root tests. According to the results of the analysis, per capita GDP and trade openness positively affect carbon emissions in Türkiye. The result of the analysis supports each other with the theoretically expected situation.

According to the findings of the study, we can say that changes in GDP per capita (lnGDPP) and trade openness ratio (lnTO) affect CO2 emissions positively in the long run. It shows that a 1% change in GDP per capita (lnGDPP) increases CO2 emissions by 0.83%. This finding is in line with the findings in (Doda, 2014; Çoban, 2015; Kasperowicz, 2015; Acaravcı & Erdoğan, 2018; Öztürk & Saygın, 2020) reporting that GDP per capita has a positive effect on CO2 emissions. This result shows that the rapid increases in Türkiye's per capita GDP cause an increase in CO2 emissions, which negatively affect Türkiye's environmental quality. On the other hand, a 1% increase in trade openness causes a 0.21% increase in CO2 emissions. Türkiye's export and import activities cause a decrease in environmental quality. This finding indicates that the increase in trade openness has a positive effect on CO2 emissions (Durgun Kaygısız, 2018; Mutascu, 2018; Temelli and Şahin, 2019; Özdemir and Koç, 2020; Wang and Zhang, 2021; Shah et al., 2022) is consistent with the findings. Accordingly, it shows that economic growth and trade openness increase carbon emissions in Türkiye. However, per capita GDP ratio affects environmental quality more negatively

than trade openness. Variables of innovation and foreign direct investment do not have a statistically significant effect on CO2 emissions at the 5% significance level. The long-run coefficient sign of the predicted innovation and foreign direct investment variable is positive similar to other variables.

In line with the findings, it primarily targets the energy consumption model, since economic growth is the primary driving force of the country's economy. Policy makers should turn to practices that encourage the use of renewable energy sources rather than the use of fossil fuels. While transitioning to renewable energy sources, R&D units in the country can be used for the development of renewable energy solutions. In addition, international companies currently operating in Türkiye can be encouraged to contribute to increasing the use of renewable energy. Although companies may suffer some short-term losses due to high implementation and renewal costs in the early stages of this transition period, they can contribute to sustainable economic growth and increase environmental quality in the long run.

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