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The Effect of Environmental Regulations on Carbon Emissions within the Framework of the EKC Hypothesis: The Role of Energy Consumption and Trade Openness

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EKC Hipotezi Çerçevesinde Çevre Düzenlemelerinin Karbon Emisyonlarına Etkisi: Enerji Tüketimi ve Ticari Açıklığın Rolü

Abstract

Environmental pollution is a widespread problem worldwide. One of the primary factors contributing to environmental pollution is the emission of CO_2. According to some opinions, environmental regulations have a reducing effect on CO_2 emissions. This study aims to investigate the direct impact of environmental regulations on carbon dioxide (CO_2) emissions. In this regard, the period from 1993 to 2018 has been taken as the basis for the Next-11 countries. The relationship between the variables has been investigated using CUP-FM and CUP-BC estimators. According to the results obtained, environmental regulations have been shown to reduce CO_2 emissions.

Keywords : Environmental Regulations, CO_2 Emissions, Energy Consumption, EKC Hypothesis, Trade Openness.

JEL Classification Codes : Q5, Q56, Q57.

Öz

Çevre kirliliği konusu tüm dünyanın ortak sorunu olarak karşımıza çıkmaktadır. Çevre kirliliğine neden olan en büyük faktörlerden biri ise CO_2 emisyonudur. Bazı görüşlere göre çevresel regülasyonların CO_2 emisyonu üzerinde azaltıcı etkisi bulunmaktadır. Bu çalışmanın amacı çevresel regülasyonların CO_2 emisyonu üzerindeki doğrudan etkilerini araştırmaktır. Bu doğrultuda Next-11 ülkeleri için 1993-2018 dönem aralığı baz alınmıştır. Değişkenler arasındaki ilişki CUP-FM ve CUP-BC tahmincileri ile araştırılmıştır. Elde edilen sonuçlara göre çevresel regülasyonlar CO_2 emisyonunu azaltmaktadır.

Anahtar Sözcükler : Çevresel Regülasyonlar, CO_2 Emisyonu, Enerji Tüketimi, EKC Hipotezi, Ticari Açıklık.

1. Introduction

Environmental pollution began to pose a threat to living things and ecological balance with the onset of the Industrial Revolution, which occurred in the late 18th century. While the replacement of manpower by machines has accelerated production, on the other hand, environmental quality has begun to deteriorate due to the release of greenhouse gases and other environmental waste into the air (Ozcan & Apergis, 2018). Greenhouse gases are randomly released into the atmosphere due to the use of fossil fuels, and increases in temperatures occur due to the anthropogenic effects of these released gases (Montzka et al., 2011). As a result of all these factors, these gases contribute to global warming and climate change (Zhang et al., 2017). Global climate change has numerous adverse effects on human health, biodiversity, agriculture, water resources, forest areas, and the seas. For example; It contains many other potentials such as epidemics, acid rain, climate-related deaths, decreases in air and water quality, erosion, floods and overflows, storms, loss of biodiversity, decrease in natural habitats, changes in energy consumption and costs, decreases in forest health and productivity (Dincer, 2000). Therefore, if the necessary precautions are not taken, the disparity in welfare between the current generation and future generations will be inevitable due to the increasing global temperature (Stern, 2007).

To prevent climate change, many scientists frequently investigate the factors that contribute to CO_2 emissions, which constitute a significant portion of greenhouse gases. Some factors affect CO_2 emissions: renewable energy (Waheed et al., 2018; Sinha & Shahbaz, 2018; Dong et al., 2017; Çetinkaya et al., 2024; Cheng et al., 2019; Godil et al., 2021; Aydoğan & Vardar, 2019; Busu & Nedelcu, 2021; Caglar et al., 2024), foreign direct investments (Zhang & Zhou, 2016; Tang & Tan, 2015; Sung et al., 2018; Zafar et al., 2020; Özkan et al., 2024), technological innovation (Destek & Manga, 2021; Sinha et al., 2020; Yu & Du, 2019; Khan et al., 2020), human capital (Chen et al., 2019; Mahmood et al., 2019; Sarkodie et al., 2020), financialisation (Destek, 2019; Destek & Sarkodie 2019; Khan et al.2019; Xu et al. 2022; Liu & Song, 2020; Greiner et al. 2024), urbanisation (Salahuddin et al. 2019; Wang et al., 2018; Sadorsky, 2014; Ulucak & Khan 2020; Xu et al., 2024; Özkan et al., 2024) and industrialisation (Liu & Bae 2018; Wang et al., 2020; Mentel et al., 2022; Borsha et al., 2024). Since all the factors listed here are either a result of or a cause of economic growth in countries, there are arguments that economic growth is the main factor affecting climate change. In this regard, it is accepted that there is a close relationship between economic growth and environmental pollution. Therefore, the relationship between economic activity and environmental deterioration has emerged as one of the most fascinating research areas. The Environmental Kuznets Curve (EKC) theory was proposed in this context.

The most researched theory to explain the connection between environmental pollution and economic growth is the Environmental Kuznets Curve hypothesis. According to the EKC hypothesis, environmental degradation increases up to a certain point in the early periods of economic growth. After a certain point, economic development reduces environmental pollution, thus creating an inverted U-shaped relationship between economic growth and environmental degradation (Panayotou, 1993). This hypothesis is essentially based on Kuznets's (1955) inverted U-shaped link between economic growth and income disparity. It was Grossman and Krueger (1991) who first proposed adapting the theory to the surroundings. Grossman and Krueger (1991) grouped the effects of economic activities on environmental degradation into three groups: scale effect, composition effect and technical effect. Accordingly, while pollution increases due to the scale effect, pollution begins to decrease thanks to structural and technical impacts.

It is anticipated that environmental pollution can be reduced through environmental regulations. Environmental regulations specifically refer to the internalisation of negative externalities through environmental taxes. Non-renewable energy resources used during production and other toxic wastes generated are among the negative externalities described as market failures. Production-oriented factories contribute to environmental pollution by generating negative externalities. The marginal private cost exceeds the marginal societal cost when there is a negative externality (Sankar, 2008). Government policy tools play a crucial role in mitigating negative externalities. Carbon taxes and financial subsidies are the two most important policy tools governments use to promote a low-carbon economy. While taxes are applied based on the “polluter pays” principle, subsidies are provided to support the development and improvement of technologies and products that cause negative externalities. They play a crucial role in reducing environmental pollution by replacing polluting technologies with environmentally friendly green technologies, thanks to subsidies (Yuejun & Defu, 2011). Of course, to prevent environmental pollution, it is crucial to develop environmental policies that enhance societal welfare. In addition, natural resources must be used efficiently, and both legal and economic tools must be implemented by international legislation (Barde, 1994). Tax implementation is crucial in preventing negative externalities from occurring during the production process. The most commonly used public solutions, which claim that externalities can be reduced through taxes, are the taxes proposed by Pigou and referred to as “Pigouist Taxes” in the literature. Pigouvian taxes, which are used to internalise negative externalities, aim to impose a tax equal to the difference between marginal private cost and marginal social cost. These taxes are specific-based, levied on emissions and/or pollution per unit (Pigou, 1952). However, taxation is not made on the product itself, but on the pollution caused by waste, or in other words, on waste emissions. A tax on a firm's profits is different from a tax on waste emissions. Another issue is the rate at which tax is collected on waste. This situation includes elements related to public revenues as well as environmental costs. Therefore, determining environmental taxes should be done together with financial managers and environmental regulators. In addition, a given tax rate may be viewed as inadequate by environmentalists, while it may be perceived as too high in terms of efficiency losses in the public economy (Oates, 1995).

While developing countries were responsible for 33.2% of CO_2 emissions in 1960, this rate increased to 62.2% in 2018 as their industrialisation rate increased. In light of this data, it is evident that developing countries cause more environmental damage. In addition, while energy-related CO_2 emissions are expected to remain constant in developed countries, an increase in CO_2 emissions is scheduled for developing countries. Because the increase in population affects the rise in production, it brings with it the risk that the environment will be polluted more by the increased use of fossil fuels. It is more challenging for the Next-11 countries (Bangladesh, Egypt, Iran, Mexico, Nigeria, Pakistan, Philippines, Türkiye, South Korea, Indonesia, and Vietnam), which are relatively more industrialised among developing countries, to sustain their economic growth without causing environmental pollution. For all these reasons, it is of vital importance to investigate the effects of environmental regulations on carbon emissions, particularly for developing countries, to take measures to reduce their carbon footprint. Environmental regulations can internalise negative externalities. Therefore, it is of great importance to investigate their effects on CO_2 emissions.

The potential contributions of this study to the literature are as follows: i) While most studies examine the effects of environmental regulations generally for EU member states and developed countries, this study focused on developing countries. ii) There are limited studies analysing environmental regulations through environmental innovation. This study examines the direct effects of environmental regulations on environmental pollution, highlighting how environmental policies can be strengthened through the application of technology and innovation. This emphasises the integration of environmental innovation with environmental protection strategies. iii) In addition to environmental regulations, factors such as energy consumption, economic growth and trade openness were added to the empirical model as control variables. In this way, more comprehensive results were obtained. v) The study's evaluation of the effects at different quantiles using generalised quantile regression analysis enables an understanding of the effects of environmental policies at varying pollution levels. This method adds depth to the results obtained by demonstrating that environmental policies do not have a uniform effect across all countries and periods. v) The study also tests the EKC hypothesis, providing a new perspective on existing discussions on the complex relationships between economic growth and environmental impacts. vi) Additionally, cross-sectional dependence was taken into account in this study. vii) It is expected that this study will not only provide new evidence to the literature but will also help reduce CO_2 emissions with the policies it suggests.

The study continues with a literature review. Then, the model, data and method are introduced. Then, empirical analyses are performed, and the results obtained are discussed. Finally, the study concludes with conclusions and policy recommendations.

2. Literature

Studies investigating the relationship between environmental regulations and environmental pollution have not yet reached a sufficient number. However, studies conducted have shown that heterogeneous results have been obtained. It is noteworthy that these studies have primarily been conducted in China, which has made rapid advancements in industrialisation over the last 20 years. Several studies suggest that environmental regulations in China have led to a reduction in pollution. For example, Chen et al. (2018) and Hashmi and Alam (2019) found evidence in their empirical studies using the GMM method that environmental regulations reduce pollution. Similarly, in their empirical study using the Dynamic Spatial Panel method for 30 provinces in China, Cheng et al. (2017) found that environmental regulations reduced pollution, based on the period from 1997 to 2014. In their analysis, conducted using the Bayesian posterior probability approach for 30 provinces in China from 2003 to 2016, Zhang et al. (2019) investigated the impact of industrialisation and environmental regulation on environmental degradation. As a result, he suggested that while industrialisation pollutes the environment, environmental regulations reduce pollution. However, according to this study, regulations combined with industrial accumulation have been noted to increase environmental pollution. In addition, Wang and Liu (2019) found that environmental regulations reduced pollution in China's Central and Western regions from 2000 to 2014 using the PCSE method. In parallel with these studies, Pei et al. (2019) for China; Zhang (2020) for 30 provinces of China; Song et al. (2020) for 253 cities of China; and Zhou et al. (2019) for 277 cities of China have reported similar results, indicating that environmental regulations reduce environmental pollution. In contrast to these findings, there are also studies suggesting that environmental regulations do not reduce environmental pollution. For example, using the GMM method, Hao et al. (2018) reported results indicating that environmental regulations do not reduce pollution in 283 cities in China.

Some studies have revealed an inverted U-shaped relationship between environmental regulations and pollution. For example, two studies conducted using the GMM estimator -one by Wenbo and Yan (2018) for China and another by Wang and Zhang (2022) for 282 cities in China- have determined that there is an inverted U-shaped relationship between environmental regulations and pollution. Similarly, Yin et al. (2015) found a reverse U-shaped relationship between environmental regulation and CO_2 emissions in their study, which used the GLS method to analyse 29 provinces in China from 1999 to 2011. K. Wang et al. (2019) found in their research, which used the Difference-in-differences method for China during the period from 2006 to 2014, that different environmental policies had varying effects on pollutants. Li ve Ramanathan (2018) conducted a study using Panel OLS for China during the period from 2004 to 2014. According to the findings of this study, the impact of command and control regulation and market-based regulation on environmental performance is not linear, but it is positive. Additionally, it emphasises that the role of informal regulations is uncertain. In a study conducted using the Conditional Logit model for China from 2006 to 2010, Yang et al. (2018) found that the results indicated different environmental regulations had varying effects on the pollution haven hypothesis (PHH), leading to heterogeneous outcomes of the PHH.

It can be observed that other studies have been conducted using data from the United States, European Union, and OECD countries, yielding heterogeneous outcomes. For example, Jiang et al. (2019) found in their study, which employed the Granger Causality method, that uncertainty in economic policies affects CO2 emission rates across all sectors in the United States during the period from 1985 to 2017. In their study, using panel threshold analysis for OECD countries from 1998 to 2015, Ouyang et al. (2019) found a heterogeneous relationship between environmental policies and environmental pollution.

Albulescu et al. (2019) suggested in their empirical analysis, using both dynamic and static GMM estimators for EU countries from 1990 to 2017, that the impact of environmental regulation on carbon emissions is uncertain. Ahmed et al., (2024), conducted based on international panel data for 26 EU countries spanning from 1994 to 2019 and using the Common Correlated Effects Average Group (CCE-MG) method to estimate the coefficients of the variables, they found that environmental regulations are an effective monitoring and control tool that can significantly reduce CO_2 emissions. Dabuo et al. (2023) conducted a study across 30 provinces in China, utilising the spatial Durbin model from 2004 to 2019. The results revealed that the combined effect of R&D intensity, environmental regulation, and energy consumption contributed to the increase in carbon emissions across Chinese provinces. Similarly, Koçak (2024a) employed the CCE-MG method for 17 EU countries between 1995 and 2018 and found that environmental regulations led to a reduction in CO_2 emissions.

Upon examining the literature, it becomes apparent that environmental regulations are often implemented through environmental taxes. However, this is possible, especially for EU member countries and developed countries that apply high-level environmental standards. Since environmental tax data are generally not available in developing countries, it is evident that the impacts of environmental regulations on the environment are often measured through environmental technological innovation, and the number of studies is limited. The reason for this is that environmental regulations encourage the use of cleaner and more efficient technologies in industrial and production processes. Legal regulations require businesses to adopt cleaner technologies to limit carbon emissions. Since environmental tax data are not available for the NEXT-11 countries, the effects of environmental innovation on pollution are examined. Studies on environmental taxes in the literature are usually limited to a single country or a limited geographical area. This study aims to fill the gap in the literature by examining the effects of environmental taxes in various countries using a comprehensive dataset. This will enable comparisons to be made regarding the effectiveness of different economic conditions and environmental policies. Closing these gaps will help develop more effective solutions in both the academic field and policy-making processes.

3. Empirical Strategy

3.1. Model and Data

This study aims to examine the impact of environmental regulation on carbon emissions for the Next-11 countries (Philippines, Türkiye, Vietnam, Mexico, Iran, Indonesia, and South Korea). Annual data covering the period from 1993 to 2018 were used in the analysis. The empirical model was created following the Omojolaibi & Nathaniel (2020) and Ulucak et al. (2020) studies, as follows, with a dynamic panel data form:

$$CO_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 GDPSQ_{it} + \alpha_3 EC_{it} + \alpha_4 ER_{it} + \alpha_5 TRA_{it} + \varepsilon_{it} \quad (1)$$

Of the variables in this equation: CO, CO_2 emissions (metric tons per capita); GDP, gross domestic product per capita in dollars at constant 2015 prices; GDPSQ, square of gross domestic product per capita in dollars at constant 2015 prices; EC, energy intensity level of primary energy (MJ/$2011 PPP GDP); TRA, trade as a percentage of gross domestic product; ER, environment-related technologies (total value) and “ε_{it} represents the error term, respectively.

“CO, GDP and TRA” data are obtained from the World Bank, “EC” data from the Energy Information Administration and “ER” data from the OECD Statistics website. Additionally, all variables were used in their logarithmic form.

3.2. Methodology

3.2.1. Preliminary Tests

Cross-sectional dependency tests constitute the first step of panel data analysis. This analysis is followed by unit root and cointegration analyses. Verifying interdependency is crucial in panel data econometrics to obtain robust and dependable conclusions (Destek & Manga, 2021). Tests of cross-sectional dependence represent the first stage of empirical analysis in this direction. To detect the cross-sectional dependency between the sections, the LMadj test by Pesaran et al. (2008), the CD test by Pesaran (2004) and the LM and CD_{LM} tests by Breusch and Pagan (1980) are used. Since the economic and environmental policies of developing countries may be interdependent, taking into account cross-sectional dependence enhances the accuracy of the results. The CIPS panel unit root test, created by Pesaran (2007), is used in this investigation. The CIPS unit root test has the benefit of accounting for cross-sectional dependency between cross-sections. For this purpose, the following equation is used:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i(N,T) \tag{2}$$

The CIPS unit root test determines whether the series is stationary or not, allowing us to analyse more accurate long-term relationships. The Durbin-Hausman panel cointegration test, developed by Westerlund (2008), was used in conjunction with the unit root test to examine the long-term relationship between the variables. Group-DH and Panel-DH statistics are the two estimators used in the Durbin-Hausman test. There is cointegration between the variables if the null hypothesis of no cointegration is rejected. Additionally, the Durbin-Hausman test is more beneficial and reliable than other tests when calculated based on standard parameters (Ulucak & Bilgili, 2018). The Durbin-Hausman test examines the long-term relationship between different variables, enabling the study to provide more precise answers to the question it focuses on: “Can Environmental Regulations Reduce Environmental Pollution?”

3.2.2. Panel Long-Run Estimators

After determining the cross-sectional dependency and cointegration relationship, the stage of long-term coefficient estimation can be initiated. According to Zaidi et al. (2019), the CUF-FM and CUP-BC estimators function as follows:

$$\hat{\beta}_{cup}, \hat{F}_{cup} = argmin \frac{1}{nT^2} \sum_{i=1}^{n} (y_i - x_i\beta)' \, M_F (y_i - x_i\beta) \quad (3)$$

Where I_T and F stand for the identity of matrix dimension T, and $M_F = I_T - T^{-2}FF'$, I_T and F The following are these estimators' most significant supremacies: I These estimators account for the series' unobservable endogeneity and cross-sectional dependency. These estimators can be applied to series with varying degrees of cointegration. Additionally, Generalised Quantile Regression was used alongside the CUP-FM and CUP-BC predictors to ensure the robustness of the long-term coefficients. It provides more reliable results by eliminating the effects of autocorrelation and non-stationary series within series.

4. Empirical Findings

Table: 1
CSD Test Results

	CO	GDP	GDPSQ	EC	ER	TRA
LM	234,070***	61,134***	160,766***	36,933***	45,582***	55,112***
CD_{LM}	32,877***	6,193***	1,838***	2,459***	3,793***	5,264***
CD	-3,472***	-2,668***	-0,351***	-2,854***	-3,040***	-2,316**
LM_{adj}	26,046***	13,718***	20,486***	10,335***	-1,249	1,815**

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

When the findings in Table 1 are examined, it is evident that the null hypothesis of “there is no dependency between cross-sections” is rejected for all four different dependency tests, indicating that countries are affected by each other's economic and political shocks. According to the LM test results, it is seen that all series have cross-sectional dependence at a statistically significant level of 1%. Similarly, CD_{LM} test results revealed cross-sectional dependence in all series at a 1% significance level. According to the CD test results, it is observed that the CO, GDP, EC, and ER series exhibit cross-sectional dependence at a 1% significance level, while the TRA variable shows cross-sectional dependence at a 5% significance level. According to the LM_{adj} test results, while the CO, GDP, and ER series exhibit cross-sectional dependence at a 1% significance level, the TRA variable shows cross-sectional dependence at a 5% significance level. According to the LM_{adj} value, there is no cross-sectional dependence in the ER variable.

The results of the CIPS unit root test, used to determine the stationarity levels of the variables, are presented in Table 2.

Table: 2
Unit Root Test Results

Variables	CO	GDP	GDPSQ	EC	ER	TRA
CIPS (Level)	-2,088	-1,737	-1,617	-1,749	-2,014	-1,405
CIPS (First Differences)	-4,830***	-4,063***	-4,594***	-4,388***	-5,900***	-3,792***

Note: Critical values for 10%, 5%, and 1% levels are -2.12, -2.25, and -2.51, respectively.

According to the CIPS unit root test results in Table 2, each of the variables is non-stationary at its level values, but becomes stationary at the first difference values.

Table: 3
Panel Cointegration Test Results

	Durbin-Hausman Cointegration	
	Statistics	p-value
DH_Panel	2,542***	0,006
DH_Group	1,292*	0,098

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

According to Table 3, which presents the cointegration test results, the H0 hypothesis was rejected, indicating a long-term relationship between the series for the entire panel. According to these results, it was decided to estimate long-term coefficients for the variables.

Table: 4
Cointegration Long Run Coefficient Results

	CUP-FM		CUP-BC	
	Coefficient	t-statistics	Coefficient	t-statistics
GDP	0,037**	2,242	0,022***	4,161
GDPSQ	-0,011***	-3,701	-0,012***	-2,750
EC	0,018***	4,253	0,091***	3,278
ER	-0,057***	-3,017	-0.047***	-8,131
TRA	0,065**	2,169	0,023**	2,418

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

When the findings in Table 4 are evaluated, it is first observed that the coefficient of the GDP variable, representing economic growth, is positive, and the square of this variable is negative, according to both estimators. This finding suggests that the inverted U-shaped Environmental Kuznets Curve hypothesis applies to emerging economies. This finding is consistent with Koçak (2024a), Mahmood et al. (2023), Barak et al. (2024), Kostakis et al. (2023), Wang et al. (2024), and Özkan et al. (2024). In developing countries, the industrialisation process usually begins in a period when environmental standards are low. In the early stages, policies aimed at protecting the environment may be inadequate and environmental pollution may increase rapidly. In the early stages of economic growth, increased pollution is a natural consequence of increased industrial activity and the consumption of fossil fuels. However, as a country matures, economic growth takes a different form. During this period, key elements such as the development of environmentally friendly technologies, the utilisation of renewable energy sources, and the enhancement of waste management systems emerged. Developing countries are increasingly taking steps to protect the environment in response to international pressures and domestic demands. In addition, the concepts of sustainable development and green growth have become central to development policies. This transformation leads to a decrease in environmental damage and even the integration of environmentally friendly innovative technologies into the economy. At this point, the relationship between economic growth and environmental pollution begins to reverse. The negative square of GDP is an indicator of this transformation. In other words, as growth progresses, environmental pollution begins to decrease after a certain point.

It is observed that a 1% increase in energy consumption results in a 0.018-0.091% increase in carbon emissions. This finding is consistent with those of Begum et al. (2015), Al-Mulali et al. (2013), and Chen et al. (2016). There are several possible reasons for this. If the growing energy demand is met by high-carbon energy sources, such as fossil fuels (coal, oil, and natural gas), this will lead to increased carbon emissions. In developing countries, outdated energy infrastructure and technologies consume more energy, leading to increased carbon emissions. The sectoral structure of an economy also determines the impact of energy consumption on carbon emissions. For example, if a country is a newly industrialised country and has a large manufacturing sector, energy consumption will generally be more carbon-intensive. In economies based on agriculture and service sectors, energy intensity and, therefore, carbon emissions may generally be lower. Furthermore, if a country has weak environmental regulations and no pricing mechanism for carbon emissions, energy consumption will increase while carbon emissions remain high. This is especially true in developing countries, where energy demand is growing rapidly.

A 1% increase in trade openness results in a 0.023% to 0.065% increase in carbon emissions. This finding is consistent with those of Hdom and Fuinhas (2020), Dou et al. (2021), and Musah et al. (2021). As a country's foreign trade increases, more goods need to be exported and imported abroad. Ships, containers, aeroplanes, and other means of transport used in this process are a significant source of energy consumption and contribute to increased carbon emissions. It is well known that in open economies, particularly in developing countries, production is typically concentrated in the industrial and manufacturing sectors. These sectors are generally characterised by activities that lead to high carbon emissions, as most industrial production relies on fossil fuel-powered machines and energy-intensive production processes. Increased trade means that more products need to be produced. If this production is conducted using old fossil fuel-powered technologies, the increase directly contributes to higher carbon emissions. In some countries, increased foreign trade may require more industrialisation and increased energy demand. In this case, if renewable energy sources have not become widespread enough, this energy demand is met by fossil fuels. This is a factor that contributes to increased carbon emissions. Trade openness can also refer to a country's "environmental imports." A country may import environmentally damaging products from other countries. This is especially true for imports involving industrial processes or raw materials that generate high carbon emissions. The length of global supply chains, which increases with trade, can also lead to higher carbon emissions. Longer supply chains result in increased transportation, production, and energy consumption. This can indirectly increase carbon emissions. Environmental regulations can often be weaker in developing economies where trade is increasing, resulting in dirtier production processes and higher energy consumption.

When the environmental effects of environmental regulations are examined in relation to the study's overall purpose, it is concluded that a 1% increase in regulations results in a reduction of carbon emissions by 0.047-0.057%. This finding is consistent with Hashmi and Alam (2019), Ulucak et al. (2020), Zhang et al. (2020), A. Omojolaibi and P. Nathaniel (2020), Zhang et al. (2024), Neves et al. (2020), and Koçak (2024b). Environmental regulations are generally implemented to reduce the environmental impacts of industrial production and other economic activities. These regulations produce these results through various mechanisms that directly affect carbon emissions. Environmental regulations encourage the use of cleaner and more efficient technologies in industrial and production processes. Legal regulations require businesses to adopt cleaner technologies to reduce carbon emissions. In this case, innovative solutions such as the use of cleaner energy sources, efficient energy production methods and carbon capture technologies can be adopted to reduce emissions. For example, switching from carbon-intensive energy sources, such as coal, to renewable energy sources, like solar, wind, or hydroelectric, can directly reduce emissions. Environmental regulations can provide incentives to increase energy efficiency, allowing businesses to produce the same amount of production with less energy. This can directly help reduce carbon emissions.

Table: 5
Generalised Quantile Regression Results

	Q20	Q40	Q50	Q60	Q80
GDP	3.766***	3.692***	3.646***	3.616***	3.546***
GDPSQ	-0.173***	-0.169***	-0.167***	-0.165***	-0.161***
EC	0.103***	0.107***	0.126***	0.133***	0.147***
ER	-0.417***	-0.044***	-0.053***	-0.056***	-0.063***
TRA	0.262***	0.269***	0.274***	0.276***	0.283***

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

According to the GQR results in Table 5, the GDP variable is positive and statistically significant at all quantile values (Q20, Q40, Q50, Q60, Q80). This result indicates that the effect of economic growth on environmental pollution remains consistent across all quantiles. However, the slight decrease in the coefficients along the quantile suggests that the impact of economic growth is stronger at lower quantiles (lower pollution levels). The GDPSQ variable is negative and statistically significant at all quantile values. According to this result, it is seen that the EKC hypothesis is valid. This means that, initially, economic growth increases environmental damage, but after a certain level of income is reached, this damage begins to decrease. The effect of the EC variable on environmental pollution increases significantly from Q20 to Q80. This suggests that increased energy consumption leads to greater environmental degradation at high pollution levels, and any increase in energy use has a significant impact on pollution. The coefficients of the ER variable are negative and statistically significant in all quantiles. This suggests that environmental regulations have a positive impact on reducing pollution. However, a trend across quantiles suggests that the effect of regulations is decreasing. This indicates that regulations are more effective at lower pollution levels. The TRA variable is positive and statistically significant in all quantiles. The coefficients increase across quantiles, indicating that the effect of trade on pollution is more pronounced at higher pollution levels.

5. Conclusion

The purpose of this article is to examine the impact of environmental regulations on CO_2. In this direction, the study was conducted for the NEXT-11 countries over the period from 1993 to 2018. First, a cross-sectional analysis was performed in the study. Then, the stationarity status of the variables was examined. Then, Panel Cointegration Test, Long-Term Coefficient Estimation and Generalised Quantile Regression Analysis were performed.

The EKC hypothesis was confirmed in the study. Accordingly, while an increase in environmental pollution was detected in the early stages of economic growth, a decrease was detected in the later stages. This situation illustrates that polluting sources and outdated technologies were used until the turning point, after which environmental improvements were implemented. Improved technologies have led to a reduction in pollution, resulting from the impact of environmental policies and increased environmental awareness. In developing economies, this transformation typically begins later because the early stages of industrialisation often lead to environmental degradation. However, as a country develops, environmental improvements and green growth strategies are implemented, confirming the inverted U-shaped Environmental Kuznets Curve hypothesis. Another variable used in the study, trade openness, was found to increase CO_2. This result is due to the direct relationship between the increase in foreign trade and various economic activities, including energy consumption, production processes, transportation, and logistics activities. Trade openness refers to the degree of openness an economy has to foreign trade, specifically measured by the ratio of exports and imports to the country's overall economic activities. An increase in trade openness generally means the growth of foreign trade and the strengthening of economic integration, but this also has a significant impact on environmental impacts. Energy consumption has been shown to contribute to increased CO_2 emissions. As economic growth increases, so does energy demand. This demand is usually associated with energy use in industrial production, transportation and buildings. If the use of fossil fuels increases, more carbon emissions occur. Energy consumption is generally very intense in the industrial sector. As industrialisation progresses, more energy is used and therefore more CO_2 emissions arise. Outdated technologies and industrial processes with low energy efficiency can lead to increased emissions. The primary purpose of the study, environmental regulations, was found to have a reducing effect on CO_2. Environmental regulations encourage investment in renewable energy and ensure the use of cleaner production technologies. They also require carbon pricing mechanisms that limit emissions and more efficient industrial production processes. In addition, strategies are developed to reduce emissions in the transportation and industrial sectors. For example, innovative solutions such as carbon capture and storage (CCS) technologies can be promoted to reduce carbon emissions. Cleaner production techniques can also be applied in areas such as water use, waste management and energy efficiency. Environmental regulations provide powerful tools to reduce carbon emissions across various sectors, including energy production, industrial production, transportation, and consumption. These regulations can significantly reduce environmental impacts by encouraging the transition to renewable energy, limiting the use of fossil fuels and expanding clean production technologies.

Based on all these results, some policy recommendations will be made. To minimise environmental impacts and ensure sustainable growth alongside economic growth, clean and innovative technologies should be invested in. While the increase in energy consumption and trade in developing economies may lead to higher emissions, the transition to renewable energy should be accelerated to offset this increase. Governments can encourage innovations in low-carbon technologies such as solar energy, wind energy and energy efficiency. Additionally, tax breaks or direct financial incentives can be offered to companies that invest in these technologies. Market-based tools, such as carbon pricing (carbon tax or emissions trading system), can be applied to limit carbon emissions using economic instruments. As energy consumption and trade openness increase, carbon pricing can be used to reduce the environmental impacts of these activities. Carbon tax or emissions trading systems encourage businesses to reduce carbon emissions. Such policies provide a financial incentive for companies to reduce their carbon footprint. Additionally, for developing countries, these systems can facilitate the adoption of environmentally friendly production methods as part of international trade. Energy efficiency and low-carbon transportation policies should be adopted. It is observed that an increase in energy consumption leads to increased emissions. Therefore, policies to increase energy efficiency should be developed. In developing countries, clean energy vehicles (such as electric vehicles and public transportation systems) can be promoted to enhance the energy efficiency of buildings, improve industrial processes, and reduce carbon emissions in the transportation sector. Increasing commercial activities increase carbon emissions. Green trade agreements and environmentally friendly trade policies can be implemented to balance this situation. Countries can encourage the trade of sustainable products by imposing customs duties and trade barriers on polluting sectors. Additionally, incentives can be created for the import and export of products produced using environmentally friendly methods. Green trade policies should be developed to reduce the environmental impacts of trade. Environmental regulations play a crucial role in reducing carbon emissions. These regulations should be tightened further, and effective inspections should be conducted to ensure compliance. Regulations can direct industrial sectors to environmentally friendly production methods. They can also deter activities that harm the environment. Additionally, it is crucial to enhance the capacity of local governments and relevant institutions to ensure that these regulations are implemented effectively. Education and awareness programs should be initiated to increase environmental awareness. Raising public awareness about environmental regulations and carbon emissions can encourage sustainable lifestyles. Awareness should be increased, especially about energy efficiency, recycling and environmentally friendly products. Additionally, employee training programs can be offered to companies to encourage the adoption of environmentally friendly practices. Global environmental cooperation should be enhanced. Environmental problems should be solved on a global scale. Developing countries can receive technological assistance from developed countries to adopt environmentally friendly production methods. Additionally, participation in global environmental agreements and carbon trading systems can help further reduce greenhouse gas emissions.

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