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IMPACT OF POPULATION GROWTH AND INDUSTRIAL PRODUCTION ON THE ECOLOGICAL CRISIS: A PANEL DATA ANALYSIS OF BRICS-T COUNTRIES

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ABSTRACT: This study, the impact of population growth and industrial production on the ecological crisis is examined by utilizing data from BRICS-T countries (Brazil, Russia, India, China, South Africa, and Türkiye) covering the period between 2000-2020. The dataset includes carbon dioxide (CO_2) emissions, population, and greenhouse gas emissions originating from industrial production. The data employed in the analysis were obtained from the World Bank database were utilized, and econometric modeling was conducted by logarithmically transforming both dependent and independent variables. The findings indicate that a 1% increase in population growth leads to a 0.4454% rise in CO_2 emissions, while a 1% increase in greenhouse gas emissions from industrial production results in a 0.2468% increase in CO_2 emissions. These results highlight the significant role of population expansion and industrial activities in environmental sustainability. The study contributes to the academic literature and provides insights for future research. Additionally, the findings are expected to inform policymakers in designing effective environmental policies and sustainable development strategies for BRICS-T countries.

Keywords: Greenhouse Gas Emissions, Sustainability, Kuznets Curve, Economic Growth, Ecologic balance

NÜFUS ARTIŞI VE ENDÜSTRİYEL ÜRETİMİN EKOLOJİK KRİZE ETKİLERİ: BRICS-T ÜLKELERİ ÜZERİNE PANEL VERİ ANALİZİ

ÖZET: Bu çalışmada, BRICS-T ülkeleri (Brezilya, Rusya, Hindistan, Çin, Güney Afrika ve Türkiye) için 2000-2020 yılları arasındaki sera gazı emisyonu, nüfus ve endüstriyel üretimden kaynaklı sera gazı emisyonu verileri incelenerek, nüfus artışı ve endüstriyel üretimin ekolojik kriz üzerindeki etkisi analiz edilmektedir. Araştırma kapsamında, Dünya Bankası veri tabanından elde edilen veriler kullanılmıştır. Analiz sürecinde, veri setindeki bağımlı ve bağımsız değişkenlerin logaritması alınarak ekonometrik modelleme gerçekleştirilmiştir. Çalışmanın bulguları, nüfus oranlarında meydana gelen %1'lik bir artışın CO_2 emisyonlarını %0.4454 oranında artırdığını, endüstriyel üretime bağlı sera gazı salınımındaki %1'lik bir artışın ise CO_2 emisyonlarını %0.2468 oranında yükselttiğini ortaya koymaktadır. Bu doğrultuda, nüfus artışı ve endüstriyel üretimin çevresel sürdürülebilirlik üzerindeki etkisinin göz ardı edilmemesi gerektiği sonucuna varılmıştır. Çalışmanın, akademik literatüre katkı sunması ve sonraki araştırmalara rehberlik etmesi hedeflenmektedir. Ayrıca elde edilen bulguların, BRICS-T ülkelerinin çevre politikalarının oluşturulması ve sürdürülebilir kalkınma stratejilerinin belirlenmesi süreçlerinde politika yapıcılara referans niteliği taşıması beklenilmektedir.

Anahtar kelimeler: Sera Gazı Emisyonu, Sürdürülebilirlik, Kuznets Eğrisi, Ekonomik Büyüme, Ekolojik denge

INTRODUCTION

Industrialization has evolved in various forms throughout civilization, gaining significant momentum with the Industrial Revolution and accelerating further with modern technological advancements. Key factors in the development of industrialization include capital availability, energy resources, raw material supply, technological capabilities, transportation infrastructure, marketing strategies, and the efficient utilization of human resources. The availability and management of these factors directly influence the sustainability and expansion of industrial activities. Since the Industrial Revolution, rapid population growth and increasing industrial production have exerted substantial pressure on ecosystems, posing serious threats to environmental sustainability on a global scale. As population growth intensifies, human-induced environmental impacts—such as increased fossil fuel consumption, excessive exploitation of natural resources, and the uncontrolled accumulation of industrial waste—continue to escalate. These activities lead to climate change, disrupt ecological balance, and exacerbate ecological crises, including biodiversity mitigation and ecosystem degradation (Meadows et al., 1972; Steffen et al., 2015; Nations, 2022; Dindaroğlu et al., 2023).

The origins of the ecological approach can be traced back to Ancient Greece; however, its conceptual emergence in the scientific literature began in the mid-19th century. The term 'modern ecology' was first systematically introduced by the German biologist Ernst Haeckel in 1866 (Haeckel, 1866). In general, ecology is defined as a scientific discipline that examines the interactions between living organisms and their surrounding environment (Odum & Barrett, 1971). Beyond these biological interactions, ecology also emphasizes the stability and balance of natural ecosystems. In this context, ecological equilibrium refers to the conditions that enable the coexistence of both biotic and abiotic components in a sustainable manner (Townsend et al., 2009). The deterioration of ecosystems leads to ecological degradation, and as these problems intensify, they can culminate in ecological crises (Özkan, 2017).

The balance of ecosystems can be disrupted by external interventions, leading to the emergence of environmental challenges. Human activities—particularly industrialization, urbanization, and the overexploitation of natural resources—have significantly intensified ecological problems (Meadows et al., 1972). The escalating frequency and severity of ecological crises have heightened public awareness of environmental issues and fostered a search for sustainable solutions. Mitigating ecological crises, preserving natural ecosystems, and ensuring sustainability are crucial for the future of humanity (Dindaroğlu, 2021). In this context, ecological approaches serve as the foundation of environmental sustainability. In recent years, climate change and ecological crises have emerged as some of the most pressing global challenges. Since the Industrial Revolution, accelerated fossil fuel consumption, unchecked population growth, and increased industrial production have raised atmospheric carbon dioxide (CO_2) concentrations to 420 ppm, contributing to record-breaking global temperatures (Ercan & Özdemir, 2023).

Population growth is one of the main factors affecting the economic and social structure. The size and dynamics of the population create direct and indirect effects on industrial production, and in this context, contribute to the shaping of the economic functioning in the region (Coskun, 2023). According to the population theory published by Thomas Robert Malthus in 1798, while the population increases in a geometric series as 1, 2, 4, 8, 16, 32..., foodstuffs increase in an arithmetic series as 1, 2, 3, 4, 5, 6... (Malthus, 1798; 2023). The continuous increase in the world population and the continuation of countries' economic growth processes lead to the deepening and compounding of ecological problems. In other words, it has caused the consumption of more resources in nature. In this context, one of the most important studies in the literature examining the relationship between environmental degradation and economic growth is the study published by Simon Kuznets in 1955, which addresses the injustice in income distribution. Also, Kuznets stated that environmental pollution will increase in the initial stages of economic growth, but when per capita income exceeds a certain threshold, individuals and states will become more sensitive to the environment and tend to take precautions (Kuznets, 1955). Based on this hypothesis, in the 1990s, Grossman and Krueger reconsidered Kuznets' approach based on the relationship between income distribution and economic growth within the framework of environmental factors, as environmental problems became increasingly important. Thus, they analyzed the effects of economic growth on the environment and explained this relationship with the concept of the Environmental Kuznets Curve (EKC). This model suggests that environmental pollution initially increases during the economic development process, but after a certain income level, pollution tends to decrease as environmental sensitivity increases (Grossman & Krueger, 1991).

The Environmental Kuznets Curve (EKC) hypothesis indicates an inverted U-shaped relationship between per capita income and certain environmental pollution indicators (Figure 1). According to this hypothesis, environmental pollution tends to increase during the early stages of economic development due to industrialization, urbanization, and rising energy consumption. However, as economic growth progresses, it is anticipated that pollution levels will decline due to increased environmental awareness, improved regulatory frameworks, and the adoption of cleaner technologies. The EKC hypothesis is rooted in the original Kuznets Curve concept, which describes a similar relationship between income inequality and economic development (Kuznets, 1955). Today, the EKC hypothesis serves as a key theoretical foundation for understanding the interplay between economic growth and environmental sustainability. The EKC hypothesis describes the relationship between economic development and environmental degradation. In the early stages of economic growth and industrialization, environmental concerns are often overlooked, leading to increased pollution. However, as income levels rise, public awareness of environmental issues tends to grow, prompting governments to implement policies aimed at pollution reduction and sustainable environmental management (Panayotou, 1995; Grossman & Krueger, 1995).

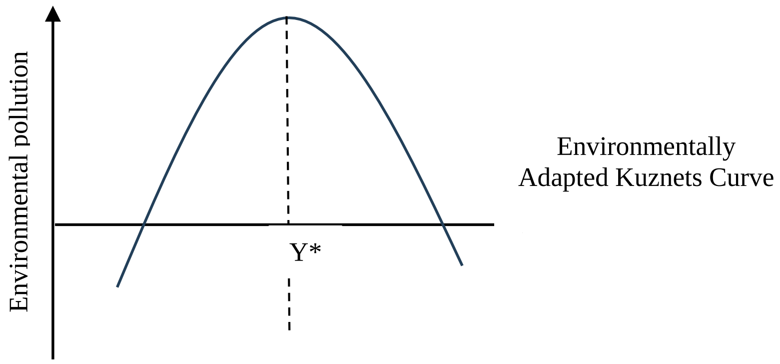

Figure 1. Environmental Kuznets Curve (EKC) Source: (Panayotou, 1993), Reshaped by the Authors.

The aim of this study is to investigate the effects of population growth and industrial production growth on the ecological crisis using panel data analysis using greenhouse gas emission data from the World Bank for the BRICS-T (Brazil, Russia, India, China, South Africa and Turkey) countries between 2000-2020 on greenhouse gas emissions from CO2, total population and industrial production. Such research plays a crucial role in enabling countries to develop sustainable energy strategies and ecosystem-based environmental policies. The findings of this study will provide insights into the environmental impacts of renewable energy sources within the framework of sustainable development goals, emphasizing the necessity of implementing holistic policies that integrate environmental considerations.

MATERIAL AND METHODS

Within the scope of the study, the effects of population growth and industrial production on CO_2 emissions in BRICS-T countries (Brazil, Russia, India, China, South Africa and Turkey) were examined using panel data analysis using data between 2000-2020. Panel data analysis is a powerful method that combines both temporal and cross-sectional dimensions and has the advantage of taking into account the heterogeneity between countries (Baltagi, 2008). The analysis was carried out by taking logarithmic transformations of the dependent and independent variables in the study. The data were obtained from the World Bank, and the variables and their sources are presented in Table 1.

Table 1. Defining Variables

Variables	Explanation	Data Year Range and Source
LCO	Logarithmic Total Greenhouse Gas (CO_2) Emission	2000-2020, World Bank
LNU	Logarithmic Total Population	2000-2020, World Bank
LEND	Logarithmic Greenhouse Gas (CO_2) Emission from Industrial Production	2000-2020, World Bank

The equation with logarithmic transformations is shown in equation 1 below:

$$LCO_{it} = \beta_0 + \beta_1 LNU_{it} + \beta_2 + LEND_{it} + \upsilon_{it} \quad (1)$$

BRICS-T countries were considered in the model used in the study.

i=(1…6) and (t= 2000…2020)

Here, i represent countries and t represents years. Panel data regression analysis was used in estimating the model and various tests were used in model selection.

RESULTS AND DISCUSSION

Before starting the research analyses, the F test and Breusch-Pagan LM test were first applied to determine whether there was a unit and/or time effect in the panel data model (Breusch & Pagan, 1980; Wooldridge, 2010).

According to the F test results, the presence of unit and/or time effects was accepted in the model with a probability value less than 0.05 (Table 2). Similarly, the Breusch-Pagan LM test result showed that the classical model was not suitable. The Hausman test was applied to determine whether fixed or random effects were suitable in the model. According to the Hausman test (p=0.79>0.05), since there was no correlation between the explanatory variables and the error term, it was concluded that the random effects model was suitable (Hausman, 1978).

Table 2. Panel Data Regression Analysis Estimator Tests

	Statistical Values	Probability Values
F Test	70.91*	0.000
LM Test	573.22*	0.000
Hausman Test	0.46*	0.7958

"*" indicates 0.05 significance level.

After estimating the model, diagnostic tests were conducted to assess potential econometric issues. The results of the Levene's, Brown–Forsythe, and Levene (1960) tests indicated the presence of heteroscedasticity (Brown & Forsythe, 1974). Additionally, the Baltagi–Wu test was employed to detect autocorrelation, revealing the presence of autocorrelation in the model (Baltagi & Wu, 1999). Furthermore, the Friedman test was conducted to examine inter-unit correlation, confirming the existence of cross-sectional dependence Table 3.

Table 3. Heteroskedasticity, Autocorrelation and Inter-Unit Correlation Test Results

Heteroskedasticity Test		
	X^2	Prob. value
W0	32.2866*	0.000
W50	8.5576*	0.000
W10	25.1441*	0.000
Autocorrelation Test		
Modified Bhargavavd.Durbin Watson		0.9126
Baltagi –Wu LBI		0.1311
Inter-Unit Correlation Test Results		
	x^2	Prob. value
Friedman Test	18.511*	0.0024

Since problems such as heteroskedasticity, autocorrelation and inter-unit correlation may cause deviations in the model estimates, robust estimates were obtained by using the Driscoll-Kraay robust estimator (Driscoll-Kraay, 1998). The Driscoll-Kraay estimator results are presented in Table 4.

Tablo 4. Driscoll- Kraay Robust Estimator Results

	Coefficient	**DriscollKraaySt**	**t**	**P>ǀtǀ**
LNU	0.4454	0.1812	2.46	0.023
LEND	0.2468	0.0251	9.82	0.000
Constant	-0.8559	1.5048	-0.57	0.576
Prob.	0.000			

According to the Driscoll-Kraay estimator, the effects of population and industrial production on CO_2 emissions are statistically significant. A 1% increase in population increases CO_2 emissions by 0.4454%, while a 1% increase in industrial production increases CO_2 emissions by 0.2468%. These findings are consistent with the literature emphasizing the environmental impacts of population and industrial production (Grossman & Krueger, 1995; Shahbaz et al., 2013). The increasing effect of population growth and industrial production on CO_2 emissions in BRICS-T countries is found to be statistically significant. These findings emphasize the importance of environmental sustainability policies and reveal that industrial policies should be shaped by considering environmental impacts.

Numerous studies have investigated the relationship between energy consumption, greenhouse gas emissions, economic growth, population growth, and environmental pollution—particularly carbon emissions (CO_2)—across various country groups and time periods using panel data analysis methods. These studies have focused on the Organization for Economic Co-operation and Development (OECD) countries, China, Pakistan, Indonesia, BRICS-T (Brazil, Russia, India, China, South Africa, and Turkey), the four Turkic Republics (Kazakhstan, Azerbaijan, Kyrgyzstan, Uzbekistan), the E7 (China, India, Brazil, Russia, Indonesia, Turkey, and South Africa), and several other nations (Hamilton & Turton, 2002; Lee & Chang, 2008; Zhang & Cheng, 2009; Sharma, 2011; Ahmet & Long, 2012; Aşıcı, 2013; Ergün & Polat, 2015; Karakaş, 2016; Özşahin et al., 2016; Erden, 2019; Majeed & Mazhar, 2019; Ilham, 2021; Çelik Bayram, 2022; Yesbolovave et al., 2024; Han, 2024; Wang & Xu, 2025).

Findings from these studies highlight significant cross-country variations in environmental degradation drivers, with rapid population growth, increasing energy demand, declining fossil fuel quality, and economic growth being key contributors. However, some scholars have nuanced these relationships. For instance, Lee and Chang (2008) found a strong long-term positive relationship between energy consumption and economic growth, emphasizing that reductions in energy consumption could negatively impact economic growth. This underscores the critical need for sustainable energy policies. In contrast, Zhang and Cheng (2009) reported that energy consumption and carbon emissions in China do not directly affect economic growth, suggesting that the country can enhance its energy and environmental policies without jeopardizing economic expansion in the long run.

Sharma (2011) adopted a differentiated approach by examining the effects of GDP and energy consumption across income levels, revealing that the impact of economic determinants varies by income group. Similarly, Aşıcı (2013) and Karakaş (2016) determined that income growth generally exacerbates environmental pressure, particularly in middle-income countries. While rising income levels were found to reduce deforestation, they simultaneously increased carbon emissions and mineral extraction. Majeed and Mazhar (2019), in their study covering 131 countries from 1971 to 2017, analyzed the environmental implications of financial development. Their findings suggest that while financial development has the potential to improve environmental quality, factors such as energy consumption, foreign direct investment, and economic growth contributes to environmental degradation, supporting the "pollution haven" hypothesis. Furthermore, Ilham (2021) analyzed data from 31 provinces in Indonesia between 2011 and 2019, examining the effects of economic development, population density, and vehicle ownership on environmental degradation. The study confirmed that these three factors significantly increase pollution levels and emphasized the necessity of transitioning to a green economy model.

CONCLUSION

In this study, the effects of population growth and industrial production on the ecological crisis in the BRICS-T countries (Brazil, Russia, India, China, South Africa and Turkey) in the period 2000-2020 were examined using panel data analysis. The findings show that both variables increase CO_2 emissions at a statistically significant level. It was determined that a 1% increase in the population rate increases CO_2 emissions by 0.4454%, and a 1% increase in greenhouse gas emissions due to industrial production increases CO_2 emissions by 0.2468%. These findings show that population dynamics and industrialization processes constitute a critical pressure element on environmental sustainability. Although the findings of the study are consistent with the Environmental Kuznets Curve (EKC) hypothesis in the literature, it should not be ignored that this hypothesis may yield different results among countries. Considering that most of the BRICS-T countries are in the early stages of industrialization and economic growth, it is understood that scale and structural effects dominate, and technological effects have not yet come into play sufficiently. This situation indicates that the EKC assumption that environmental awareness will increase as income levels increase is not yet fully valid in these countries. The results, which are parallel to similar studies in the literature (Sharma, 2011; Çelik Bayram, 2022), confirm the central role of population and industrial activities in environmental degradation. In this context, it is crucial to implement sustainable development policies in BRICS-T countries without delay. Policymakers should prioritize strategic actions such as urbanization policies that promote sustainable land use, family education programs to raise awareness of environmental issues, and regulations aimed at preserving green spaces. Additionally, transitioning to clean technologies in industrial production, implementing fiscal policies that incentivize renewable energy usage, and adopting energy efficiency strategies are essential for mitigating environmental degradation. Industrial policies should encourage sustainable production methods, while legal frameworks must be established to regulate and minimize carbon footprints. Furthermore, fostering national and international cooperation, as well as introducing mechanisms such as carbon taxes, will be instrumental in achieving long-term environmental sustainability.

This study acknowledges certain limitations, including the restriction of the dataset to the period 2000–2020 and the omission of other critical environmental indicators such as methane emissions and water pollution. Future research should address these gaps by incorporating a broader range of environmental variables, extending the study period, and exploring different country groups. Additionally, interdisciplinary approaches that integrate technological progress and institutional quality into the analytical framework will provide a more comprehensive understanding of environmental impacts. In conclusion, this study serves as a valuable reference for both policymakers and researchers, emphasizing that maintaining ecological balance and achieving sustainable development require urgent, globally coordinated efforts and multidimensional strategies.

AUTHOR CONTRIBUTIONS

Conceptualization, T.K., Z.A. and E.B.; Methodology, T.K. and Z.A.; validation, C.B., A.G.B.M. and C.M.; formal analysis, T.K. and Z.A.; investigation, T.K. and Z.A.; data curation T.K. and Z.A.; writing—review and editing, T.K., Z.A. and E.B.; supervision, EB. All authors have read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICS COMMITTEE STATEMENT

An ethics committee statement is not required for this study.

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