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Examining The Relationship Between Income Concentration And Environmental Pollution with the STIRPAT Model

STIRPAT Modeli Özelinde Gelir Yoğunlaşması Ve Çevre Kirliliği İlişkisinin İncelenmesi

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Abstract

The impact of rising economic activity, which increases with international economic relations and globalization, on environmental degradation has been subjected to many studies in the literature. Consequently, numerous factors that have both negative and positive impacts on the environment are included in a number of research. Using a sample of BRICS nations and controlling factors for income, population, and urbanization, our study examines the impact of economic disparity on the environment. In our study using the STIRPAT model, second-generation unit root, panel cointegration, and long-run coefficient tests were applied in light of the findings from the cross-sectional dependency and homogeneity tests. The series behave jointly over the long term, which shows that there is a cointegration link between the series, according to the findings of the panel cointegration test that was conducted. Long-term coefficient estimate throughout the panel's data reveals that while CO2 emissions are increased by income disparity and per capita income, they are decreased by population. No significant relationship was found for the whole panelbetween the urbanization variable and the environment. When individual nations are taken into account, it is determined that India's income disparity causes a rise in CO2 emissions.

Keywords: *Income Inequality, STIRPAT Model, CO2 Emissions, Panel Data Analysis, BRICS*

Öz

Ülkelerarası artan ekonomik ilişkilerle birlikte küreselleşmenin etkisiyle artan ekonomik aktivitenin çevreye olan etkisi en çok tartışılan konulardan biri olmuştur. Bu bağlamda literatürde çevreye olumlu ve olumsuz etkisi olan

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birçok değişken kullanılarak analizler yapılmıştır. Bu çalışmada BRICS ülke örneklemi kullanılarak gelir eşitsizliğinin çevre üzerindeki etkisi kişi başına gelir, nüfus ve kentleşme kontrol değişkenleri kullanılarak incelenmektedir. STIRPAT modeli baz alınarak yaptığımız analizlerde, yatay kesit bağımlılığı ve homojenlik testlerinin ardından elde edilen sonuçlar ışığında ikinci nesil birim kök, panel eşbütünleşme ve uzun dönem katsayı tahmincisi testleri uygulanmıştır. Elde edilen panel eşbütünleşme testi sonuçlarına göre değişkenler uzun dönemde birlikte hareket ettiklerinde dolayı eşbütünleşme ilişkisine ulaşılmıştır. Ardından yapılan uzun dönem katsayı tahminci sonuçlarına göre ise panel genelinde gelir eşitsizliği ve kişi başına gelir değişkenlerinin uzun dönemde CO_2 emisyonunu artırdığı sonucuna varılırken, nüfus değişkeninin CO_2 emisyonunu azalttığı sonucuna varılmıştır. Panel geneli için kentleşme değişkeni ve çevre arasında anlamlı bir ilişkiye rastlanmamıştır. Ülkeler tek tek ele alındığında ise gelir eşitsizliğinin Hindistan'da CO_2 emisyonunu artırdığı sonucuna ulaşılmıştır.

Anahtar Kelimeler: *Gelir Eşitsizliği, STIRPAT Modeli, CO2 Emisyonu, Panel Data Analizi, BRICS.*

Introduction

The welfare state period that emerged after the Second World War and the revolution in communication technologies in the early 1990s caused the global economy to proliferate. Global total GDP was 13 trillion dollars in 1960 and exceeded 82 trillion in 2018. The globalization wave and developments of communication technologies in the 1990s brought the growing prosperity of industrialized countries to various countries of the world. In the beginning, these countries are the BRICS countries. As almost all authors who investigate the link between the economy and environmental pollution stated, this enormous economic development has brought environmental and social issues. Although recent data on industrialized countries show that there is a decrease in the rate of carbon emissions, it is seen that developing countries turned this effect into zero, even into a positive one.

Human-induced CO2 emissions significantly contribute to total natural CO2 emissions (Wu and Zie, 2020:2). The six nations that produce the highest greenhouse gas emissions account for 62% of worldwide emissions. (China with 26 %, the USA with 13 %, EU (European Union) with 9 %, India with 7 %, Russia with 5 % and Japan with 3 %). Of these countries, China, India and Russia are BRICS countries. As of 2019, three of these six countries have decreased their carbon emissions. The immense contribution to this decrease came from industrialized countries. These countries are the USA, Japan and the EU (Olivier ve Peters, 2020:5). High emissions in China, as well as in Vietnam, Indonesia, and India are offset by relatively low emissions in the United States, European countries, and Japan. In addition, there has been a decrease in coal consumption, mostly with the contribution of the USA and the EU (Olivier and Peters, 2020:6). These data draw attention to the link between income level and greenhouse gas emissions. Globally, carbon emissions increased by 44 % between 2000 and 2018 (IEA 2019:38). According to the projection made by the IEA (2019), if current policies are continued, carbon emissions will be 24 % higher in 2040 compared to 2018, which is in line with the projected energy demand. While the energy demands of North American and European countries are expected to be more stable, in developing countries led by Asia Pacific countries (especially China), if current policies are continued, between 2018 and 2040, the demand for energy is anticipated to rise by 37%. (IEA, 2019:40).

As of 1989 and 2018, our study deals with the increase in CO_2 emissions and GDP, population, urbanization rate and income inequality in the BRICS countries. As seen in the table, the CO_2 emissions in 2018, compared to the emissions in 1990; Increased by 53 % in Brazil, 287 % in China, 179 % in India, and 11 % in South Africa, and decreased by 23 % in Russia. In all five countries, the increase in GDP was above the CO_2 emissions for the same period. In particular, China's GDP has increased almost tenfold. South Africa and India share the lead in population growth, China has made significant progress in urbanization, and lastly, there is a large increase in income inequality (except for Brazil). The path followed by the CO_2 emissions in these countries for 28 years is shown in Image 1.

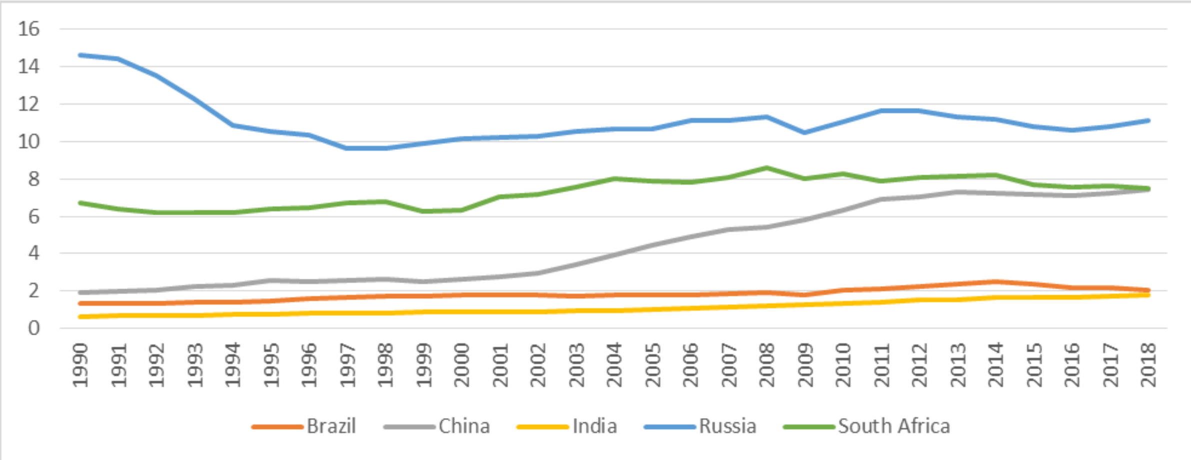

Figure 1. BRICS Countries CO_2 Emissions (metric tons per capita)

Developing countries' CO_2 emissions have exceeded those of industrialized countries. Therefore, developing countries will be responsible for future emissions (Baloch et al., 2017). The reason why BRICS countries are considered in our study is that, as shown by some data above, they both lead the way in CO_2 emissions, which is the main component of greenhouse gases, and are developing countries. Another reason is that these countries are the leading countries in the world in GDP and growth rate, and they are the countries that are predicted to dominate the world both economically and in terms of population in the projection for the coming years. Using the panel data analysis method, this study examines the connection between income disparity and environmental degradation in the BRICS nations. The STIRPAT model, which incorporates variables for income, population, and urbanization, was expanded to include the income inequality variable for the purpose of the analysis. The lack of research on the connection between environmental pollution and income inequality stands out in the literature despite the abundance of studies addressing the interaction between the economy and the environment. Regarding the nation sample, time period of the data set, and the econometric technique employed, we anticipate that our work will add to the body of literature. Following are the study's remaining sections: In the second part, there is the literature review section that includes studies examining the relationship between income and environmental pollution, population, urbanization and income inequality. The third chapter explains the theoretical framework in which the STIRPAT model was created. The fourth chapter includes the introduction of the data, the econometric methodology and findings of cross-section dependency, cointegration, unit root and long-term coefficient estimator tests used in the analysis. Finally, in the conclusion part, the study is summarized and policy recommendations are presented.

Literature Review

The connection between the environment and life and the views on ecology can be traced back to ancient times. However, when climate change is evaluated in the context of its current scope and concerns, its serious consideration begins in the 1960s (Karabıçak and Armağan, 2004:207). In the following years, interest in climate and environmental problems has increased with the contributions of environmental non-governmental organizations operating globally and international organizations such as UNESCO and the European Union. This interest has ultimately spurred the study of the effects of economic developments on environmental quality. Warnings regarding the relationship between economic development and climate change increased during this period (e.g., Elrich and Holdren, 1971; Edmonds and Reilly, 1983; Nordhaus, 1991; Yamaji et al.. 1993; Agostini et al. 1992).

This time period is characterized by a predominance of the belief that environmental quality suffers as a result of economic development. Given the manufacturing techniques, energy sources, and wastes produced by consumption from the industrial revolution to the present, it is only normal to assume a clear negative link between economic expansion and environmental quality. Environmental pollution was characterized by Ehlrich and Holdren (1971) as a result of population expansion, economic development, and technological advancement, and the IPAT (Impact-Population-Affluence-Technology) model served as the foundation for their theoretical framework. However, high technology can offer new opportunities to protect the environment and reduce greenhouse gas emissions, enable the use of new energy types and force individuals and organizations in this direction. In addition, increasing welfare and meeting vital needs can direct people's attention to issues such as the environment from financial difficulties. For example, Barret and Graddy (2000:435) found environmental quality increases that as civil and political freedoms increase. Branis and Linhartove (2012) argue that the probability of solid fuel pollution is higher in regions with low education levels and high unemployment rates in the Czech Republic. These, in turn, are social conditions closely related to economic development and welfare. Therefore, opinions have emerged that economic development can positively affect the environment. Grossman and Krueger (1995) opposed the view that economic developments will have an absolute negative impact on the environment with the Environmental Kuznets Curve (EKC), which they put forward by arranging the Kuznets Curve. The result of the study shows that there is no evidence that economic growth degrades the natural environment in an unavoidable and absolute manner. However, even though the increase in GDP may be related to the deterioration in environmental conditions in low-income countries, they found that air and water quality improved due to economic growth after income exceeded a critical level. After a specific turning point in this inverted U-shaped relationship, they saw a reversal in almost all pollutants (Grossman and Krueger, 1995:370).

Afterward, the EKC hypothesis has been supported by many studies, such as (Kusumawardani and Devi, 2020, Ekeocha, 2021, Wu and Zie, 2020). Studies have also opposed it, such as (Zhou and Li, 2020, York et al., 2003, Baloch et al., 2017). Wealth and CO2 emissions do not inversely correlate, according to Aslanidis and Iranzo (2009). They claimed that an inverted V-shaped connection existed rather than an inverted U relationship, which would indicate that a quick regime transition would occur once a particular threshold was reached. Because it explains how wealth and environmental issues are related, the EKC hypothesis is significant. The impact of wealth increase on greenhouse gas emissions is well-documented in the literature. Among the studies conducted, those that found that an increase in income increases carbon emissions include (Baloch et al., 2017), (Demir et al., 2018), (Ravallion et al., 2000), (Ahmad et al., 2020), and (Ang, 2007), while those that came to the opposite conclusion and found that an increase in income first causes an increase in pollution before decreasing it include. (Aslanidis and Iranzo, 2009). According to Mahallik et al. (2018), wealth growth causes carbon emissions to rise in South Africa, China, and Brazil but to fall in India.

Investigating the relationship between income and environmental quality is not limited to examining the total income level; Income distribution also gains importance at this point. Therefore, it is crucial to understand whether the increase in income or income (wealth) inequality causes environmental degradation (Mahallik et al., 2018:23172). Economic theory developed to explain the connection between environmental deterioration and income inequality since the mid-1990s (Kusumawardani and Devi, 2020; Grunewald et al., 2017; Baloch et al., 2018). Boyce (1994) included the distribution of power and the winners' attitude as a result of economic activity in his thesis on the impact of income inequality on the environment. According to this approach, while the wealthy have a higher ability to degrade and pollute the environment, they also have a higher chance of escaping the negative consequences of the environment. Therefore, while they pollute the environment by taking the profits, they earn from economic activity, the poor bear the cost of this pollution. In this case, if the winner of economic activity is decisive, there will be more environmental degradation than vice versa.

According to Boyce (1994), there are three possible explanations for the environmental degradation caused by inequality: 1) The environmental degradation prevented by the strong losers is insufficient to compensate for the environmental degradation created by the strong winners. 2) The costs of inequality fall on the weak and losers while the gains of the wealthy and powerful increase in value. 3) When there is disparity, natural resources are given a higher rate of time preference. In other words, they consume the brandy of future generations today. (Huang and Duan, 2020:2).

Chen (2019:2), in his study on the energy-producing regions of China, argued that the wealthy are more able to cover relocation csots. Accordingly, the income gap allows the rich in migrating to places with high environmental quality. Thus, their demands for environmental regulations are reduced. The decrease in the demand for environmental regulations leads to an acceleration of environmental degradation in the region. The rich do not demand environmental regulations, as they both cause environmental pollution and can avoid its consequences. When Boyce's (1994) assumption about the behavior of the rich when they are also powerful is added to the findings obtained in Chen (2019)'s study, the probability of income inequality increasing environmental pollution increases.

Another view on the relationship between environment and income inequality was put forward by Ravallion et al. (2000). This viewpoint contends that the marginal willingness to emit may be reduced in proportion to the marginal propensity to consume. In other words, the marginal inclination to consume and, thus, the marginal emission rate may fall as income rises. Therefore, income inequality is expected to increase environmental quality (Huang and Duan, 2020:2, Demir et al., 2018:2). Another view is the view put forward by Jorgenson et al. (2017). According to this view, again, inequality increases emissions, but it does so through another mechanism: As income inequality increases, luxury consumption of the upper-income group increases. This encourages individuals in the lower group and causes them to supply more labor and consume more. The findings of this study on states in America reveal that the increase in the income share of the 10% of the population with the highest income level, that is, the upward concentration of income, is positively related to carbon emissions. The fact that income concentration increases emissions confirm the Veblen approach. This is also called the Veblen effect.

The effects of economic disparity on carbon emissions may be categorized into three separate groups, according to the data. Findings in the first category support the view that inequality increases carbon emissions, as Boyce (1994) predicted. Wu and Zie (2020) found that as income increases, income inequality decreases emissions; In his study of Pakistan, Baloch found that inequality increases emissions; In a study where household consumption and income growth were considered to be the primary causes of emissions, Cao et al. (2019) discovered that inequality in China increased carbon emissions. Huang and Duang (2020) argue that income inequality increases emissions, but income growth decreases it. In addition, Mahallik et al. (2018) showed that the deterioration in income distribution in Brazil, India, and China increased emissions but decreased them in South Africa, on the contrary. Here, too, it can be seen that there may be differences according to geography. Findings in the second category support Ravallion et al. (2000), who argue that income inequality increases carbon emissions. As an example of these studies, Demir et al. (2018) and Zhou and Li (2020) argue that inequality increases carbon emissions at least up to a particular milestone. According to Kusumawardani and Devi (2020), wealth disparity has a detrimental long- and short-term impact on CO_2. In this study, it has been shown that income inequality determines the effect of income level on the environment.

Economic theory has been developed to explain the connection between environmental deterioration and income inequality since the mid-1990s (Kusumawardani and Devi, 2020; Grunewald et al., 2017; Baloch et al., 2018). Boyce (1994) incorporated into his thesis on the effects of income inequality on the environment the distribution of power and the mindset of winners as a result of economic activity.

In the IPAT analysis by Elrich and Holdren (1971:1216), the population is one of the main factors determining environmental quality. This analysis showed that the population’s effect on environmental pollution in the USA is small. Wu and Zie (2020) found that the population did not produce carbon emissions. While York et al. (2003) and Hashmi and Alam (2019) show that population has a strong positive effect on pollution and emissions, Baloch et al. (2017) found a negative relationship between population density and emissions in Pakistan.

Population, population density and urbanization are closely related demographic indicators. Therefore, it is necessary to look at the effect of urbanization on environmental quality. It is predicted that 66% of the world's population will live in cities by 2050, that is, 2.5 billion more people will migrate to cities (World Urbanization Prospect, 2014). This will lead to further strain on limited natural resources. Cao et al. (2019:532) showed that on average in China, CO2 emissions in cities are higher than in villages. The literature mainly argues that urbanization increases CO2 emissions (York et al., 2003; Kusumawardani and Devi, 2020; Ahmad et al., 2020). However, some findings areagainst this view too (Wu and Zie, 2020). Wang et al. (2019) examined the relationship between the efficiency of CO2 emissions, which he formulated as GDP/CO2 instead of CO2 emissions, and urbanization. In the case of China, they show that urbanization reduces the economic efficiency of emissions.

Theoritical Framework

Ehrlich and Holdren (1971) introduced the IPAT model to explain the environmental impact of the interaction between technology, wealth and population:

$$I = P \times A \times T \tag{1}$$

Here, P stands for population, A stands for wealth or economic activity per capita, and T stands for technology. I represents the impact as evaluated by various environmental indicators.

The IPAT model is defined by Dietz and Rosa (1994:278) as the result of the environment (I), population (P), wealth per capita (A), and technology (T). The IPAT model is frequently utilized in ecological discussions on how population, income, and technology affect the environment. The model, however, has significant flaws. For instance, it does not offer an appropriate framework for analyzing the effects of environmental changes brought about by humans. The model is reintroduced by Dietz and Rosa (1994:279) in a stochastic manner, making it appropriate for empirical applications. The model, known as STIRPAT (Stochastic Estimation of Impact by Regression on Population, Affluence and Technology) in this latest incarnation, allows random mistakes in parametric calculations. (Kusumuwardani and Devi, 2020:1):

$$I_{it} = \alpha_i P_{it}^{\beta_1} A_{it}^{\beta_2} T_{it}^{\beta_3} e \tag{2}$$

The advantage of the stochastic model is that it converts the IPAT accounting model to the general linear model. Thus, quantitative social research tools, such as statistical tools, can be applied to this model (Dietz and Rosa, 1994:284). Its natural logarithm should be taken to make this model suitable for regression analysis (Zhou and li, 2020). Extended model by taking the logarithm:

$$lnI_{it} = \alpha_i + \beta_1 lnP_{it} + \beta_2 lnA_{it} + \beta_3 lnT_{it} + \varepsilon_t \tag{3}$$

Different writers have expanded the demographic component of IPAT by substituting a variety of other variables for the population. Urbanization, for instance, raises carbon emissions by boosting energy use and economic activity. The utilization of public goods, lifestyle changes, and the spread of technology can all benefit from economies of scale brought about by urban population increase. Regarding this, the literature doesn't offer any conclusive findings. (Kusumavardani and Devi, 2020:2).

The IPAT model expresses carbon emissions directly as a function of technology, wealth (or income) and population. In addition to these variables, many possible factors are added to econometric models that may affect CO2 emissions. The most frequently discussed factors in the literature are income, urbanization and income inequality. After the model is converted to stochastic form, different factors can be included in the analysis in addition to the initial three essential components. Our study examined, the effects of GDP, population, inequality and urbanization on CO2 emissions. The econometric equation we estimated with the panel data method:

$$lnI_{it} = \alpha_i + \beta_1 lnP_{it} + \beta_2 lnA_{it} + \beta_3 lnS_{it} + \beta_4 lnE_{it} + \varepsilon_t$$

Data, Econometric Methodology and Findings

Our study uses income, population, and urbanization control variables based on the period 1989-2018 to examine how income inequality in the BRICS (Russia, Brazil, South Africa, India and China) countries affects environmental pollution. The World Development Indicators database was used to acquire statistics on carbon dioxide emissions (metric tons per person), GDP per person, population (million people), and urbanization (as a percentage of the total population). The World Welfare and Income database was used to determine income disparity (the percentage of the top 10% of earners). Table 1 shows the variables' symbol, unit, source data.

Table 1. Variables and Sources

Variables	Symbol	Unit	Source
CarbonDioxide Emission	$lnCO_2$	CO2 per capita (metric tons)	World Development Indicators
Income	lnGDP	GDP per capita (constant 2015)	World Development Indicators
Popolation	lnPOP	Million people	World Development Indicators
Urbanization	lnURB	Share in Total Population	World Development Indicators
Income Inequality	lnINQ	The share of the top 10% in total income	World Welfare and Income Database

Descriptive statistics for the logarithms of the variables are shown in Table 2.

Table 2. Descriptive Statistics of Variables

	LCO_2	LGDP	LPOP	LURB	LINQ
Mean	1.278482	8.264605	19.45000	3.964523	-0.744807
Median	1.302696	8.638267	19.02448	4.078765	-0.718363
Maximum	3.263775	9.382252	21.05453	4.460942	-0.424036
Minimum	-0.439898	6.244964	17.39708	3.231002	-1.429202
Std. Dev.	0.931518	0.906378	1.275054	0.408049	0.213800
Observation	150	150	150	150	150

Second-generation econometric methods were utilized in the study since standard econometric methods (first generation econometric techniques) disregard cross-sectional dependency and heterogeneity and do not produce unbiased results in their absence. First, cross-sectional reliance was examined using tests by Pesaran (2004) and Breusch and Pagan (1980). To investigate homogeneity, the delta tests of Pesaran and Yamagata (2008) were used. Second-generation tests were utilized, providing objective data, after the cross-section and heterogeneity were established. Using Peseran's cross-sectional augmented Im Pesaran-Shin (CIPS) test, the stationarity of the variables was first investigated (2007). The series' long-term cooperation was then investigated using Westerlund's panel cointegration test from 2007. The long-term coefficients were finally estimated using the Augmented Mean Group (AMG) estimator created by Eberhardt and Teal (2010, 2011), Eberhardt and Bond (2009).

The relationships between the cross-sections addressed in the panel data should be taken into account in the analysis given the growing economic contact between nations and the impact of globalization. To ascertain the links between the series, homogeneity tests and cross-sectional dependence of the series should be carried out.

To ascertain the cross-sectional dependency, Breusch and Pagan (1980) devised the LM test. This test is expressed as:

$$Y_{it} = \alpha_i + \beta_i X_{it} + \varphi_{it} \tag{5}$$

Here, t = 1, 2,....., T stands for time, and I = 1, 2,...., N for the cross-sectional dimension. The vector of independent variables is represented by X it. The LM test and the null and alternate hypotheses of cross-section dependency are displayed below:

$$H_0: Cov(\varphi_{it}, \varphi_{jt}) = 0 \tag{6}$$

$$H_1: Cov(\varphi_{it}, \varphi_{jt}) \neq 0 \tag{7}$$

$$LM = \mathrm{T} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \tag{8}$$

Since the LM test created by Breusch and Pagan (1980) may be biased, Peseran (2004) developed the CD_{LM} test shown below by making some adjustments to the LM test:

$$CD_{LM} = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(\frac{(T-k)\hat{\rho}_{ij}^2 - \left[(T-k)\hat{\rho}_{ij}^2\right]}{var\left[(T-k)\hat{\rho}_{ij}^2\right]} \right) \tag{9}$$

$\hat{\rho}_{ij}^2$ c shows the binary correlation coefficient obtained from the least-squares method for each cross-section dimension and obtained from equation 1. (Le & Öztürk, 2020). Both cross-section dependency tests are used when the time dimension is greater than the cross-section dimension (T>N).

Table 3. Cross Section Dependency Test Results

	Breusch Pagan LM Test	Peseran CD_{LM}
CO_2	125.388(0.000)*	25.801(0.000)*
GDP	234.529(0.000)*	50.206(0.000)*

POP	267.113(0.000)*	57.492(0.000)*
URB	253.406(0.000)*	54.427(0.000)*
INQ	137.513(0.000)*	28.512(0.000)*

Table 3 indicates the results of the Breusch Pagan LM and Pesaran CD LM tests, which disprove the null hypothesis that there is no cross-sectional dependence at a 1% significance level for all variables. These findings indicate that the series has a cross-section dependency. Then, Peseran and Yamagata (2008) created the Swamy (1970) homogeneity test and introduced the Δ and Δ_{adj} tests in order to assess the homogeneity of the slope coefficients between the horizontal sections: (Aydin, 2019:624)

$$S = \sum_{i=1}^{N} \left(\beta_i - \beta_{WFE}\right)' \frac{X'_i M_\tau X_i}{\sigma_i^2} \left(\beta_i - \beta_{WFE}\right) \quad (10)$$

Burada $\tilde{S}$, değiştirilmiş Swamy modelini göstermektedir. $\overline{\Delta}$ modeli aşağıdaki gibi gösterilmektedir:

$$\overline{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - k}{\sqrt{2k}}\right) \quad (11)$$

Then $\overline{\Delta_{adj}}$, which performs better in small samples, is shown as follows:

$$\overline{\Delta_{adj}} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - k}{\sqrt{\frac{2k(T-K-1)}{T+1}}}\right) \quad (12)$$

The hypotheses of both homogeneity tests created by Pesaran and Yamagata (2008):

$$H_0: \beta_i = \beta \ Slope\ coefficients\ are\ homogeneous. \quad (13)$$

$$H_1: \beta_i \neq \beta \ Slope\ coefficients\ heterogeneous. \quad (14)$$

Table 4. Pesaran & Yamagata (2008) Test Results

Test	Test Statistics	Prob. value
$\hat{\Delta}$	9.106	0.000*
$\hat{\Delta}_{adj}$	10.399	0.000*

The Peseran and Yamagata (2008) homogeneity tests' findings, which are presented in Table 4, indicate that the slope coefficients' homogeneity is not true at the 1% level of significance. The results, it is concluded that the slope coefficients are heterogeneous. a unit root test of the second generation that considers heterogeneity and cross-sectional dependence, the CIPS (cross-sectional augmented Im Pesaran-Shin) test developed by Pesaran (2007), was then used to determine if a unit root existed in the series. After determining the average of the CADF statistics computed for each cross-section, the CIPS statistical values are calculated using the following formula:

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \quad (15)$$

The cross-sectionally improved Dickey-Fuller test statistic in this case is CADFi. The alternative hypothesis of stationarity and the null hypothesis of the absence of a unit root are contrasted in the

CIPS stationarity test. If the test statistic is greater than the critical values, the null hypothesis is disproved and it is inferred that the variable does not have a unit root.

Table 5. Unit Root Test Results

Variables	Level	First Difference	Result
CO_2	1.442(0.925)	-4.233(0.000)*	I(1)
GDP	2.543(0.994)	-3.712(0.000)*	I(1)
POP	-0.699(0.242)	-5.342(0.000)*	I(1)
URB	3.579(1.000)	-3.150(0.001)*	I(1)
INQ	1.515(0.935)	-5.709(0.000)*	I(1)

In Table 5, the results of the CIPS unit root test are displayed. The level values of the variables are known to have a unit root, and it is not possible to rule out the null hypothesis that they do. When the variables' initial differences are taken into account, the hypothesis that all variables have a unit root is rejected at the 1% significance level, and it is shown that the series are I(1) stationary at the first differences. The cointegration connection was then examined for the examination of the series' consistent long-term motions. When examining cointegration in panel data, popular methods like Pedroni (1999) and Kao (1999) are frequently employed. However, as first-generation cointegration tests are predicated on the assumption of cross-section independence, they may result in skewed conclusions in the presence of cross-sectional interdependence (Westerlund, 2007). Based on the error correction model, which does not provide biased findings in the presence of cross-section dependency and heterogeneity, Westerlund (2007) developed four cointegration tests with the letters Gt, Ga, Pt, and Pa. It also adds that when there is a cross-section, robust probability values produce superior results. The Westerlund cointegration test model looks like this:

$$\Delta y_{it} = \delta_i' d_t + \alpha_i (y_{i,t-1} - \beta_i' x_{i,t-1} + \sum_{j=1}^{P_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=-q_i}^{P_i} \gamma_{ij} \Delta x_{i,t-j} + u_{it} \quad (16)$$

d_t denotes deterministic components, α_i denotes error correction term. P_i and q_i show the number of delays and influences, respectively.

Table 6. Panel Cointegration Results

Statistics	Value	Z-value	Robust prob. value
G_t	-8.104	-12.980	0.000*
G_a	-7.804	1.141	0.073***
P_t	-36.435	-26.371	0.000*
P_a	-19.048	-3.098	0.000*

The Westerlund cointegration findings in Table 6 are used to investigate the bootstrap solutions that perform better when cross-sectional dependence is present. The probability values of Gt, Pt, and Pa are at %1 significance level and G a is at %10 significance level, respectively, and the null hypothesis of no cointegration is rejected in light of the data. The link between the variables is therefore steady over the long run and cointegration is present. The long-term coefficients were calculated using the AMG (Augmented Mean Group) estimator created by Eberhardt and Bond (2009) and Eberhardt and Teal

(2010, 2011). There are two steps in implementing the AMG estimator. First, N-1 year dummies are added to obtain the common dynamic effect between variables and to create a pooled regression model. This estimate is based on the first difference least squares method: (Cheng and Yao, 2021:5)

$$\Delta y_{it} = \beta_i \Delta x_{it} + \sum_{t=2}^{T} y_t Dummy_t + e_{it} \quad (17)$$

Then the coefficients of the year puppets, known as the common dynamical process, are used as an intersection point to capture the time-invariant coefficients:

$$y_{it} = \beta_i x_{it} + \phi_i \hat{\gamma}_t + \alpha_i + \lambda_i f_t + \varepsilon_{it} \quad (18)$$

Finally, the coefficients are obtained by averaging each cross section:

$$AMG = 1/\mathrm{N} \sum_{i=1}^{N} \hat{\beta}_i \quad (19)$$

The panel and individual country results obtained by the AMG estimator are presented separately.

Table 7. Augmented Mean Group (AMG) Estimator Panel Results

	Coefficient	Std. Er.	Z value	Prob. value
GDP	0.871	0.257	3.39	0.001*
POP	-5.243	3.054	-1.72	0.086***
URB	8.671	6.273	1.38	0.167
INQ	0.390	0.205	1.90	0.058***
Constant	62.148	49.722	1.25	0.211

Table 7 contains the AMG estimator results for the panel. According to the results, a statistically significant positive relationship at the 1% significance level was found between per capita income and CO_2 emissions for the entire panel. It was concluded that there is a statistically significant negative correlation at a 10% significance level between the population and CO_2 emissions. The 10% threshold of significance revealed a substantial positive correlation between CO_2 emissions and income inequality. No significant relationship was found between CO_2 emissions and urbanization. Then, the individual coefficients for the countries in our sample were estimated by the AMG method.

Table 8. Augmented Mean Group Estimator (AMG) Estimator Country Results

Countries	GDP	POP	URB	INQ
Brazil	1.078(0.000)*	-13.951(0.000)*	20.345(0.000)*	-0.034(0.921)
China	1.091(0.000)*	-8.424(0.000)*	4.933(0.001)*	0.352(0.272)
India	0.300(0.411)	-4.374(0.033)**	-4.317(0.219)	1.169(0.003)*
Russia	0.276(0.156)	-4.155(0.268)	26.286(0.030)**	0.167(0.324)
South Africa	1.612(0.005)*	4.688(0.013)**	-3.892(0.721)	0.299(0.531)

Table 8's individual country data lead to the conclusion that Brazil, China, and South Africa all have a significant and favorable link between CO_2 emissions and per capita income. Brazil, China, and India all obtained substantial and negative results regarding the relationship between CO_2 emissions and population, however South Africa obtained a significantly favorable relationship. Although no significant results were found across the board for the panel on the relationship between urbanization and CO2, significant outcomes were found based on particular countries. Urbanization and CO2 emissions have been found to be positively and significantly correlated in Brazil, China, and Russia.Finally, about the relationship between CO2 emissions and income inequality, only India has a significant positive relationship.

Conclusion

With the economic activities carried out by the countries for the purpose of economic development and growth, environmental degradation has gradually increased. The number of country groups analyzed in the literature is increasing, as factors related to environmental degradation reveal different results in countries. Variables affecting environmental degradation, especially income levels in different countries, reveal different results. This study looks at the connection between income disparity and environmental deterioration in BRICS (Brazil, South Africa, China, Russia, India) countries using income per capita, urbanization and population control variables. Based on the STIRPAT model, the reasons for the low environmental quality in the BRICS countries consisting of developing countries are analyzed by panel data method using income inequality, population, urbanization and income variables. Considering the outcomes obtained after the cross-sectional dependency test, homogeneity tests, second generation unit root tests, panel cointegration test and tests that allow estimation of long-term coefficients were applied. It has been observed that there is cross-sectional dependency and homogeneity in the variables. According to the results of the cointegration test applied after it was obtained that the variables were stationary at their first difference, it was concluded that the variables moved stably in the long run. Last but not least, the estimate test of the long-term coefficients led to the conclusion that in the panel of BRICS nations, per capita income and income disparity increase environmental degradation while population decreases it. For the entire panel, there was no discernible connection between urbanization and environmental quality. When the BRICS nations are assessed separately, it is shown that environmental deterioration is exacerbated in South Africa, China, and Brazil as income rises. While the population variable has been found to have a rising impact on environmental deterioration in South Africa, it has been found to have a decreasing impact in India, Brazil, China, and India. It has been noted that environmental degradation is accelerated by rising urbanization in Brazil, China, and Russia. Finally, it has been noted that environmental degradation is escalating in India as a result of income inequality.

Regarding the impact of economic disparity on environmental quality, a positive association was found for the entire panel which is considered the main theme of the article, supports the thesis of Boyce (1994). In these emerging nations, where there is a lot of economic inequality because most of the surplus obtained in production is collected by the rich, the richer people who collect the profits have higher possibilities of escaping from pollution, causing the cost to be burdened on the poor. In addition, the findings of Chen (2019) in his study show that the rich flee from this cost by immigrating from regions where environmental degradation is proliferating. Another study supporting our results is Jorgenson et al. (2017) study. In this study, it is stated that the increasing luxury consumption of the rich as income inequality increases, encourages the poor and leads the poor to more consumption with the increasing labor supply and increases greenhouse gas emissions. Our finding that income increases CO2 emissions have been reported in the literature by Baloch et al. (2017), Demir et al. (2018), Ravallion et al. (2000), and Ahmad et al. (2020) and Ang (2007). Not giving up on high economic growth rates in developing countries and ignoring many of the negativities arising from this causes environmental degradation to increase gradually. Low infrastructure investments and poor city planning in BRICS countries, which we have concluded that urbanization increases CO2 emissions, cause the negative impact of urbanization on the environment and our result is York et al., 2003; Kusumawardani and Devi, 2020; Supported by Ahmad et al., 2020 studies. Our finding that population growth reduces CO2 emissions is similar to the results in Baloch et al. (2017).

The high economic, political and social inequalities in developing countries such as BRICS countries make it difficult to achieve social reconciliation. Due to the factors listed above, there is more environmental degradation when economic activity-related revenue is concentrated in one area of society. For this reason, the reorganization of the income redistribution system can improve environmental quality by reducing income inequality by enabling governments to develop policies to increase the income of low-income people and to get a larger share of the profits from production. In addition, governments can prevent the migration of people to cities by implementing policies that promote local development and reduce environmental degradation by reducing urbanization rates. On the other hand, governments can prevent increased environmental pollution with increased production by promoting cleaner production, using new low-carbon technologies and better control mechanisms. In addition, governments in these countries need to increase their renewable energy production to achieve sustainable growth. In general, the governments of BRICS countries, while implementing policies encouraging economic activities, should include environmental sustainability in the process and shape their growth and development policies accordingly.

Author Contribution

The authors contributed equally to the study.

Conflict of Interest Statement

There is no conflict of interest with any institution, organization, person related to our article titled "Examining The Relationship Between Income Concentration And Environmental Pollution In The Context Of The STIRPAT Model: The BRICS Countries" and there is no conflict of interest between the authors.

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Genişletilmiş Özet

İkinci Dünya Savaşı'ndan sonra ortaya çıkan refah devleti dönemi ve 1990'ların başında iletişim teknolojilerinde yaşanan devrim, küresel ekonominin güçlenmesine sebep oldu. 1960 yılında küresel toplam GSYİH 13 trilyon dolardı ve 2018 yılında 82 trilyon doları aştı. 1990'lı yıllarda küreselleşme dalgası ve iletişim teknolojilerindeki gelişmeler, sanayileşmiş ülkelerin artan refahını dünyanın çeşitli ülkelerine getirdi. Bu durumda etkilenen ülkelerin başında BRICS ülkeleri yer almaktadır. Ekonomi ile çevre kirliliği arasındaki bağlantıyı araştıran hemen hemen tüm yazarların belirttiği gibi, bu muazzam ekonomik gelişme çevresel ve sosyal sorunları da beraberinde getirmiştir. Sanayileşmiş ülkelere ilişkin son veriler, karbon emisyon oranlarında azalma olduğunu gösterse de, gelişmekte olan ülkelerin bu etkiyi sıfıra, hatta pozitife çevirdiği görülmektedir. İnsan kaynaklı CO2 emisyonları, toplam doğal CO2 emisyonlarına önemli ölçüde katkıda bulunmaktadır (Wu ve Zie, 2020:2). En yüksek sera gazı emisyonlarını üreten altı ülke, dünya çapındaki emisyonların %62'sini oluşturuyor. (Çin %26, ABD %13, AB (Avrupa Birliği) %9, Hindistan %7, Rusya %5 ve Japonya %3). Bu ülkelerden Çin, Hindistan ve Rusya BRICS ülkeleridir. 2019 yılı itibarıyla bu altı ülkeden üçü karbon emisyonlarını azaltmıştır. Bu azalmaya en büyük katkı sanayileşmiş ülkelerden gelmiştir. Bu ülkeler ABD, Japonya ve AB'dir (Olivier ve Peters, 2020:5).

Çin'in yanı sıra Vietnam, Endonezya ve Hindistan'daki yüksek emisyonlar, Amerika Birleşik Devletleri, Avrupa ülkeleri ve Japonya'daki nispeten düşük emisyonlarla dengelenmektedir. Ayrıca kömür tüketiminde çoğunlukla ABD ve AB'nin katkısıyla azalma olmuştur (Olivier ve Peters, 2020:6). Bu veriler, gelir seviyesi ile sera gazı emisyonları arasındaki bağlantıya dikkat çekmektedir.

Gelişmekte olan ülkelerin CO_2 emisyonları sanayileşmiş ülkelerin CO_2 emisyonlarını geçmiştir. Bu nedenle, gelecekteki emisyonlardan gelişmekte olan ülkeler sorumlu olacaktır (Baloch vd., 2017). Çalışmamızda BRICS ülkelerinin ele alınmasının nedeni, yukarıdaki bazı verilerin de gösterdiği gibi, hem sera gazlarının ana bileşeni olan CO_2 emisyonlarında başı çekmeleri hem de gelişmekte olan ülkeler olmalarıdır. Diğer bir sebep ise bu ülkelerin GSYİH ve büyüme oranlarında dünyanın önde gelen ülkeleri olmaları ve gelecek yıllara yönelik projeksiyonda hem ekonomik olarak hem de nüfus olarak dünyaya hakim olacakları öngörülen ülkeler olmalarıdır. Panel veri analizi yöntemini kullanan bu çalışma, BRICS ülkelerinde gelir eşitsizliği ile çevresel bozulma arasındaki bağlantıyı incelemektedir. Gelir, nüfus ve kentleşme değişkenlerini içeren STIRPAT modeli, analiz amacıyla gelir eşitsizliği değişkenini içerecek şekilde genişletilmiştir. Ekonomi ve çevre arasındaki etkileşimi ele alan çalışmaların çokluğuna karşın, literatürde çevre kirliliği ile gelir eşitsizliği arasındaki bağlantıya ilişkin araştırma eksikliği göze çarpmaktadır. Ülke örneklemi, veri setinin süresi ve kullanılan ekonometrik teknik ile ilgili olarak, çalışmamızın literatüre katkı sağlayacağını tahmin ediyoruz.

Çalışmamız BRICS (Rusya, Brezilya, Güney Afrika, Hindistan ve Çin) ülkelerindeki gelir eşitsizliğinin çevre kirliliğini nasıl etkilediğini incelemek için 1989-2018 dönemini temel alan gelir, nüfus ve kentleşme kontrol değişkenlerini kullanmaktadır. Dünya Kalkınma Göstergeleri veri tabanı, karbondioksit emisyonları (kişi başına metrik ton), kişi başına GSYİH, nüfus (milyon kişi) ve kentleşme (toplam nüfusun yüzdesi olarak) hakkında istatistikler elde etmek için kullanılmıştır. Gelir eşitsizliğini belirlemek için ise Dünya Refah ve Gelir veri tabanı kullanılmıştır (en çok gelir elde edenlerin yüzde 10'unun yüzdesi).

Ülkelerin ekonomik kalkınma ve büyüme amacıyla yürüttükleri ekonomik faaliyetlerle birlikte çevresel bozulma giderek artmıştır. Çevresel bozulma ile ilgili faktörlerin ülkelerde farklı sonuçlar ortaya koyması nedeniyle literatürde incelenen ülke gruplarının sayısı artmaktadır. Çevresel bozulmayı etkileyen değişkenler, özellikle farklı ülkelerdeki gelir seviyeleri, farklı sonuçlar ortaya koymaktadır. Bu çalışma BRICS (Brezilya, Güney Afrika, Çin, Rusya, Hindistan) ülkelerindeki gelir eşitsizliği ile çevresel bozulma arasındaki bağlantıyı kişi başına düşen gelir, kentleşme ve nüfus kontrolü değişkenlerini kullanarak incelemektedir. STIRPAT modeline dayalı olarak, gelişmekte olan ülkelerden oluşan BRICS ülkelerindeki düşük çevre kalitesinin nedenleri, gelir eşitsizliği, nüfus, kentleşme ve gelir değişkenleri kullanılarak panel veri yöntemiyle analiz edilmektedir. Yatay-kesitsel bağımlılık testi sonucunda elde edilen sonuçlar dikkate alınarak homojenlik testleri, ikinci nesil birim kök testleri, panel eşbütünleşme testi ve uzun dönemli katsayıların tahminine olanak sağlayan testler uygulanmıştır. Değişkenlerde yatay kesit bağımlılığı ve homojenlik olduğu gözlenmiştir. Değişkenlerin birinci farklarında durağan oldukları elde edildikten sonra uygulanan eşbütünleşme testi sonuçlarına göre değişkenlerin uzun dönemde durağan hareket ettiği sonucuna varılmıştır. Son olarak, uzun vadeli katsayıların tahmin testi, BRICS ülkeleri panelinde, kişi başına düşen gelir ve gelir eşitsizliğinin çevresel bozulmayı artırırken, nüfus azalttığı sonucuna götürdü. Panelin tamamı için, kentleşme ile çevre kalitesi arasında fark edilebilir bir bağlantı yoktu. BRICS ülkeleri ayrı ayrı değerlendirildiğinde Güney Afrika, Çin ve Brezilya'da gelir arttıkça çevresel bozulmanın şiddetlendiği gösterilmektedir. Nüfus değişkeninin çevresel bozulma üzerinde Güney Afrika'da artan bir etkiye sahip olduğu bulunurken, Hindistan, Brezilya, Çin ve Hindistan'da azalan bir etkiye sahip olduğu tespit edilmiştir. Brezilya, Çin ve Rusya'da artan kentleşmenin çevresel bozulmayı hızlandırdığı kaydedildi. Son olarak, gelir eşitsizliğinin bir sonucu olarak Hindistan'da çevresel bozulmanın arttığı sonucuna ulaşılmaktadır.