PressAcademia
www.pressacademia.org/conferences
IFC
ISBN 978-625-97685-0-2
PressAcademia Procedia YEAR 2024 VOLUME 20
13TH ISTANBUL FINANCE CONGRESS, December 23, 2024 Istanbul, Turkiye.

# ENERGY CONSUMPTION-OUTWARD FOREIGN DIRECT INVESTMENT-NATURAL RESOURCE RENTS NEXUS: EVIDENCE FROM BRICS-T COUNTRIES

**DOI: 10.17261/Pressacademia.2024.1924**
**PAP- V.20-2024(10)-p.47-55**

**Suat Mumcu[1], Huseyin Ince[2]**
[1]Gebze Technical University, Department of Economics, Kocaeli, Turkiye.
smumcu@gtu.edu.tr, ORCID: 0000-0002-4093-2115
[2]Gebze Technical University, Department of Economics, Kocaeli, Turkiye.
h.ince@gtu.edu.tr, ORCID:0000-0002-5953-6497

**To cite this document**
Mumcu, S., Ince, H., (2024). Energy consumption-outward foreign direct investment-natural resource rents nexus: evidence from BRICS-T countries. PressAcademia Procedia (PAP), 20, 47-55.
**Permemant link to this document:** http://doi.org/10.17261/Pressacademia.2024.1924


## ABSTRACT

**Purpose**- This research measures the impacts of population, economic development, outward foreign direct investment, and natural resource rent on energy consumption in BRICS-T countries (Brazil, Russia, India, China, South Africa and Turkey). The main objective of the study is to evaluate the impact of outward foreign direct investment and natural resource rents on environmental sustainability together and to examine the structure of the relationship between economic growth and energy consumption with the Environmentally Kuznet Curve (EKC) hypothesis.

**Methodology-** This analysis, which was carried out within the framework of the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) theoretical model, examined the effects of factors on energy consumption with Driscoll-Kraay standard error fixed effects estimator as a result of the determination of country heterogeneity and robustness tests.

**Findings-** The analyses show that population and gross domestic product per capita are positively related to energy consumption. At the same time, outward foreign direct investment decreases energy consumption in BRICS-T countries through the reverse spillover effect. The findings on the positive relationship between natural resource rents and energy consumption indicate that energy consumption increases in BRICS-T countries through fossil fuel-intensive production processes. The study also found a statistically significant inverted u-shaped curve between energy consumption and economic growth, but detecting a turning point outside the data set suggests that the EKC hypothesis is not valid in BRICS-T countries.

**Conclusion-** The findings of the study show that outward foreign direct investment makes possible the transfer of environmentally friendly technologies from host countries to the home country and increases energy efficiency in the production process. Therefore, BRICS-T countries need to see outward foreign direct investment not only as an economic gain but also as a tool for environmental improvement. The fact that natural resource rents encourage fossil fuel dependency suggests that some of these resources should be directed to renewable energy projects. In conclusion, it is recommended that BRICS-T countries adopt green growth strategies, gradually remove fossil fuel subsidies and implement environmental regulations such as carbon tax to achieve sustainable development goals.

**Keywords:** Stirpat model, EKC hypothesis, natural resources, outward foreign direct investment, energy consumption.
**JEL Codes:** P18, P28, P48

## 1. INTRODUCTION

Environmental degradation results from economic growth based on human activities has drawn the attention of scientists, organizations, and environmentalists over the last few decades. In this regard, this problem has become a multidisciplinary study focus that concerns many issues such as human health, food security, economic development, etc. In the early stages of their economic development, developing countries such as the BRICS-T, which show features such as growing populations, insufficient human capital development, and substantial economic instability (Osabuohien-Iraborand and Drapkin, 2024), are in a highly energy-dependent production process due to high industrialization. Energy consumption in BRICS-T countries, where economic growth is rapid, is mostly dependent on environmentally damaging energy resources such as fossil fuels. For this reason, considering the dependence of BRICS countries, which were responsible for 42% of global energy consumption in 2023, on fossil fuels, it is of great importance to examine their environmental damage (Enerdata, 2024).

Countries need to plan their developments carefully to minimize environmental problems. It is commonly acknowledged that foreign direct investment contributes positively to economic growth in emerging economies. Thus, foreign direct investment is thought to have a direct or indirect effect on increasing the environmental degradation of both host and home countries (Anyanwu, 2012; Chorn and Siek, 2017). The focus has generally been on the environmental impact of inward foreign investment in the host country (Arain et al., 2020; Huang et al., 2022; Seker et al., 2015; Wang and Zhang, 2022). However, limited study on the relationship between outward foreign direct investment and environmental quality for the home country existed till recently (Mohanty and Sethi, 2022; Osabuohien-Iraborand and Drapkin, 2024; Yang and Zheng, 2021). These studies agree that foreign direct investment reduces environmental pollution in host countries. Parallelly, outward foreign by encouraging technology transfer, which reduces environmental pollution through knowledge and environmentally friendly technology spillover, outward foreign direct investment spillover may improve industrialization and energy efficiency in the host countries (Buckley et al., 2020).

The use of natural resources is an important factor that shapes the energy consumption structures of countries and the environmental impacts resulting from energy consumption. Although much research has been done to examine the factors associated with environmental problems, less focus has been placed on understanding how natural resources affect energy consumption. Extracting natural resources causes environmental deterioration by indiscriminately dumping waste chemicals into the atmosphere, land, and water, as well as increasing energy consumption even during extraction operations (Balcilar et al., 2023). Countries with high natural resources may develop their economies based on fossil fuel production and export, which may increase energy consumption at last. This may encourage energy-intensive production processes while also accelerating environmental degradation. However, if these revenues are channeled to renewable energy investments, they can support environmental sustainability. In this context, the impacts of natural resource rents on energy consumption and environmental deterioration may differ depending on the economic structure, policies, and technology utilization of countries.

The main purpose of this research is to analyse the impacts of outward foreign direct investment and natural resource rents on energy consumption in BRICS-T countries in a holistic framework. Although the environmental impacts of outward foreign direct investment on host countries have been extensively analyzed in the literature, the environmental consequences of outward foreign direct investment in home countries have been addressed in a more limited way. The innovative contribution of our research is to examine the simultaneous effects of these two important factors on energy consumption by considering outward foreign direct investment and natural resource rents together in the BRICS-T countries. In this context, the study aims to provide important implications for policymakers in line with sustainable development goals.

## 2. LITERATURE REVIEW

Over the past several decades, scientists have continued to examine the factors that cause environmental degradation to maintain environmental quality. In these studies, air pollution indicators (Lohwasser et al., in-press), water pollution indicators (Zhao et al., 2014), waste and solid waste indicators (Arbulu et al., 2017) and energy consumption indicators have been used to represent environmental degradation. Several empirical research have so far reported varying conclusions about environmental degradation using many parameters, including economic growth, population, urbanization, trade openness, etc. In this study, the effects of natural resource rents and foreign direct investments, which have been studied in the literature on environmental degradation but have not been emphasized as much as the mentioned factors, will be highlighted.

### 2.1. Outward Foreign Direct Investment and Environmental Degradation Nexus

There is a small but steadily growing body of empirical research on the outward foreign direct investment and environmental deterioration relationship. However, the majority of the literature recently in publication concentrates on studies specific to a single nation, namely China. Some of these mentioned researchs are An et al. (2021), Cai et al. (2021), Kamal et al. (2023), Tan et al. (2021), Yi et al. (2018), and However, the results of the researchs vary. Yi et al. (2018) investigated the impacts of urbanization and outward foreign direct investment on CO2 emissions, covering the data from 1984 to 2016. From a low-carbon regime to a high-carbon regime, the findings demonstrate that outward foreign direct investment has a greater promotion effect on CO2 emissions. Similarly, Cai et al. (2021) indicate that China's outward foreign direct investment can increase CO2 emissions due to the threshold effect of population size, economic development level, technology level, and environmental regulations. Moreover, Kamal et al. (2023) investigated how institutional quality affects the environment of countries participating in the Belt and Road Initiative (BRI) in connection to China's outward foreign direct investment foreign direct investment with the system GMM technique. They concluded that environmental quality suffers as a result of outward foreign direct investment of China. Another striking result of their study is that the interaction effect of China's foreign direct investment with institutional quality yields negative. Although the different stages of urbanization exhibit inverted U-shaped characteristics, Tan et al. (2021), demonstrate that interprovincial outward foreign direct investment has an effect on CO2 emissions with the double threshold effect of urbanization and that outward foreign direct investment expansion will increase CO2 emissions with urbanization.

Empirical studies of the impacts of outward foreign direct investment on environmental deterioration for a few other nations have also been published, aside from China's data. Osabuohien-Iraborand and Drapkin (2024) asserted that the effect of outward foreign direct investment on environmental deterioration is negative through the influence of home country institutions. This implies that home country institutions promote outward foreign direct investment spillover reduce CO2 emissions in emerging countries. Mohanty and Sethi (2022) focused on how outward foreign direct investment affects the link between energy use and environmental quality in the BRICS nations. The findings demonstrate that outward foreign direct investment decreases energy consumption and emission expanding the environmentally friendly and energy-efficient technologies in the host country.

### 2.2. Natural Resources Rent and Environmental Degradation Nexus

Few empirical studies have investigated the effects of natural resource rents on environmental deterioration using different models. The findings of these studies show that there are differences in the effects of natural resource rents on environmental deterioration. For example, Gyamfi et al. (2022) used the stochastic impact by regression on population, affluence, and technology (STIRPAT) model to exemine the impacts of natural resource rents and disaggregated energy consumption on the environmental quality of the G7 economies. Findings revealed that total natural resource rent shows a strong positive correlation with pollution, suggesting that G7 member nations' environmental quality declines as a result of revenue from the extraction and processing of raw materials. Hassan et al. (2019) calculates the impacts of natural resources and economic growth on Pakistan's ecological footprint. According to their empirical findings, natural resources have a positive impact on the ecological footprint that degrades environmental quality. Ulucak and Ozcan (2020) measured the effects of natural resource rents on environmental degradation using CO2 emissions, ecological footprint, and carbon footprint variables as proxies for environmental deterioration in OECD. The findings displayed that the extraction of natural resources stimulates CO2 emissions but its contribution to the ecological and carbon footprints is not statistically significant. Another similar finding indicating the positive relationship between natural resources rent and environmental degradation is exibited by Kwakwa et al. (2020).

There are also studies in the literature showing the ameliorative impacts of natural resources on environmental deterioration. Voumik et al. (2023) displayed the relationship between natural resources and environmental deterioration in South Asian countries such as Bangladesh, Pakistan, India, Nepal, and Sri Lanka from 1972 to 2021 using the STIRPAT model. They found evidence of a negative correlation between natural resources and CO2 emission indicating the improving effect of natural resources on environmental degradation. Yang and Khan (2021) investigated same country groups as in the study of Voumik et al. (2023) except for Afghanistan and Bhutan. They reached also similar results that show the improving effect of natural resources rent on environmental degradation in this e South Asian Association for Regional Cooperation countries group. Moreover, Baloch et al. (2019) analyzed the effect of natural resources on environmental degradation in BRICS countries. The findings revealed that the plentifulness of natural resources reduces CO2 emissions in Russia but it increases emissions in South Africa.

## 3. DATA, ESTIMATION TECHNIQUE, AND MODEL

### 3.1. Data

Our research employs annual balanced panel data covering BRICS-T countries from 1993 to 2022. The countries used in this study consist of Brazil, the Russian Federation, India, China, South Africa, and Turkiye. The World Development Indicator database (WDI, 2024) provided the data employed in this study. The variables investigated in this study included energy consumption, total population, gross domestic product per capita, total natural resources rents, and outward foreign direct investment. Table 1 shows the definitions and sources of the variables.

**Table 1: Definitions and Sources of the Variables**

| Variables | Definitions | Sources |
|---|---|---|
| ec | Energy use (kg of oil equivalent per capita) | WDI |
| pop | Population, total | WDI |
| gdp | GDP per capita (constant 2015 US$) | WDI |
| tnrr | Total natural resources rents (% of GDP) | WDI |
| ofdi | Foreign direct investment, net outflows (% of GDP) | WDI |

### 3.2. Theoretical Model

The STIRPAT model serves as the theoretical and analytical framework of reference in our work, but we also take into account the economic theories that forecast the EKC hypothesis in relation to income. Ehrlich and Holdren (1971) put forward the IPAT (I=PAT) model of population, affluence, and technology as components that stimulate environmental degradation. In the equation, environmental impact is denoted by I, population by P, affluence by A, and environmentally damaging technology by T. The IPAT model, which shows a linear and deterministic structure, can be estimated as a stochastic model called STIRPAT suggested by Dietz and Rosa (1994). The model specification can be given as the following equation in the panel data form:

$$I_{it} = \alpha P_{it}^{\beta_1} A_{it}^{\beta_2} T_{it}^{\beta_3} e_{it} \quad \textbf{(1)}$$

where $I$, $P$, $A$, and $T$ denote the environmental impact, population, affluence, and technology variables, respectively, $\alpha$ is the constant term and the parameters of $\beta$ indicate the elasticities of the variables on environmental impact, and $e$ denotes the stochastic error term. In the literature, the affluence $(A)$ in the STIRPAT model is estimated by the gross domestic product per capita. However, many variables such as the share of the industry sector in gdp, the share of the service sector in gdp, energy intensity, research and development expenditures, and the number of patents have been used as proxies for technology Poumanyvong and Kaneko (2010), and Usman and Hammar (2021). In this study, we used natural resource rent, which has empirical application in the literature but has not been emphasized much, as a proxy of technology $(T)$.

The factors determining a range of environmental impacts have been extensively examined using the STIRPAT model in the literature. Urbanization, trade openness, foreign direct investment, and similar variables are frequently used as additional factors in explaining their environmental impact Shahbaz et al. (2016) and Usman and Hammar (2021). Although the environmental impact of inward foreign direct investment was investigated in detail, the environmental effect of outward foreign direct investment studied in the literature are scarce. Thus, in this study, we try to explain the correlation between outward foreign direct investment and environmental impact including it to the STIRPAT model as an additional factor.

By taking the natural logarithm of the equation, we can convert the exponential function of the model into linear form. In line with all this information, we can show the panel model of energy consumption in equaition 2:

$$lnec_{it} = \beta_0 + \beta_1 lnpop_{it} + \beta_2 lngdp_{it} + \beta_3 lngdp_{it}^2 + \beta_4 lntnrr_{it} + lnofdi_{it} + \theta_i + u_{it} \quad \textbf{(2)}$$

where $i$ refers to country dimension ($i = 1 - 6$) and t refers to time dimension ($t = 1993 - 2022$) in this study. $pop$ stands for total population and $gdp$ stands for gross domestic product per person. while $tnrr$ denotes natural resources rent which is the proxy of technology, outward foreign direct investment is represented by $fdi$ in the equation. $\theta$ dummy variable capture the unobserved-country specific effect in the panel data, and $u$ denotes idiosyncratic error term.

The STIRPAT model offers the opportunity to include not only population, affluence and technology variables but also other environmental determinants. In this framework, to test the validity of the EKC hypothesis in BRICS-T countries, the '$gdp^2$' variable, which is the square of the gross domestic product per capita, is added to the model. According to the EKC hypothesis, there is a nonlinear relationship where environmental degradation increases in the early periods of economic development, while environmental deterioration diminishes in the later periods of development. This relationship can be evaluated within the framework of the following mathematical conditions:

if $\beta_2 > 0$ and $\beta_3 < 0$, then, an inverted u-shaped relationship between energy consumption and economic development arise.

if $\beta_2 < 0$ and $\beta_3 > 0$, then, a u-shaped relationship between energy consumption and economic development arises.

## 3.3. Estimation Technique

In this study, the energy consumption of BRICS-T countries is modeled by panel data analysis methods. In the first stage of the analysis strategy, the descriptive statistics of the variables were examined to gather preliminary information about the central tendency and distributions among the variables. Afterward, multicollinearity results between independent variables were obtained using a correlation matrix and variance inflation factors before deciding the panel models used in this study.

The second stage is to decide which panel data model to use. We performed calculations using pooled ols, fixed effect model, and random effect model in order, taking into account the panel data structure used in our study. The generic static panel model's specifications are as follows:

$$Y_{it} = \beta X_{it} + u_{it} \quad \text{pooled ols}$$

$$Y_{it} = a + \beta X_{it} + \mu_i + \gamma_t + u_{it} \quad \text{fixed effect}$$

$$Y_{it} = a + \beta X_{it} + v_{it}, \quad where \quad (v_{it} = \mu_i + \gamma_t) \quad \text{random effect}$$

$Y_{it}$ represents the explained variable. $X_{it}$ shows a vector of independent variables presumed to affect the variation on $Y_{it}$. While $\mu_i$ catches the individual-specific unobserved effects, $\gamma_t$ captures the time-specific unobserved effects. $u_{it}$ states the idiosyncratic error term. The pooled ols model assumes homogeneity across all cross-sectional and time-series units, without considering individual-specific or time-specific effects. While fixed effect model captures the unobserved individual heterogeneity across cross-sectional units and time units, the random effects model considers them random components, assuming that unobserved individual-specific and time-specific effects do not correlate with the independent variables (Tatoğlu, 2012). Since the time interval covers a wide range, time-specific effects were not detected in the model during the model selection process. Hence, the one way error component model was used as in Bangura and Saibu (2024).

In the third stage of the analysis, after the pooled ols, fixed effects, and random effects models adapted to the STIRPAT model were estimated, several diagnostic tests were applied to identify the model that would work best for this study. F-tests were conducted on fixed effects and pooled ols to select the appropriateness of these two models. Subsequently, Breusch-Pagan Lagrange multiplier tests were applied to determine whether pooled ols or random effect models are more appropriate. Lastly, the Hausman test was applied to decide whether the fixed effect or random effect model is more suitable for the analysis in the model selection process.

The robustness of the chosen model was evaluated in the last stage. To perform post-estimation diagnostic tests, the existence of autocorrelation, heteroskedasticity, and cross-sectional dependence, all of which potentially skew the efficiency of the chosen model, was examined. Firstly, we tested the existence of heteroscedasticity with the Wald test, which states that the null hypothesis of the panel is homoscedastic across units. To identify the autocorrelation, a modified Durbin-Watson test statistic was obtained which was proposed for the fixed effect model by Bhargava et al. (1982). In the final step of diagnostic checking, the presence of cross-sectional dependency was tested employing the Breusch-Pagan Lagrange multiplier test of cross-sectional independence. These problems have been identified in the selected model, and an estimator that eliminates these problems and satisfies the asymptotic requirements arising from the nature of our data has been found, and both safe and robust results have been obtained.

# 4. EMPIRICAL RESULTS

## 4.1. Descriptive Statistics and Multicollinearity Testing

Table 2 indicates the descriptive statistics of the variables employed in this research. The findings state that the energy consumption per capita has a low variability which is seen in the 0.79 standard deviations with the mean value of 9.79, displaying stable energy consumption among the countries analyzed. Another striking result is that the population variable has high variability, which is due to countries such as China and India increasing the dispersion in the data.

We used the pair-wise correlation matrix and variance inflation factors to capture multicollinearity in the data seen in table 3. The presence of multicollinearity among the independent variables can be proven if variables have below -0.8 and above 0.8 pair-wise correlations among them and variance inflation factors exceed 10 (Gujarati and Porter, 2009). Table 3 states the multicollinearity diagnostic results. Pair-wise correlation are quite low among independent variables other than lngpd and lnpop. When controlling variance inflation factors of lngpd and lnpop in particular, we can observe that they are not correlated. Therefore, there was no reason to exclude the independent variables used in the model due to the multicollinearity problem.

**Table 2: Descriptive Statistics of Variables**

| Variables | Obs | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| lnec | 174 | 9.73 | 0.79 | 7.95 | 11.00 |
| lnpop | 174 | 5.44 | 1.27 | 3.75 | 7.25 |
| lngdp | 174 | 8.45 | 0.80 | 6.33 | 9.51 |
| lntnrr | 174 | 1.01 | 1.14 | -1.94 | 3.07 |
| lnofdi | 174 | 2.61 | 0.91 | -3.23 | 3.79 |

**Table 3: Pair-wise Correlation and Variance Inflation Factors Results**

| Variables | lnec | lnpop | lngdp | lntnrr | lnofdi |
|---|---|---|---|---|---|
| lnec | 1.00 | | | | |
| lnpop | -0.54 | 1.00 | | | |
| lngdp | 0.79 | -0.61 | 1.00 | | |
| lntnrr | 0.40 | 0.11 | -0.06 | 1.00 | |
| lnofdi | 0.33 | -0.31 | 0.48 | 0.13 | 1.00 |
| VIF values | | 1.61 | 1.89 | 1.05 | 1.34 |

## 4.2. Econometric Model Selection

Initially, three static models were estimated which are fixed effect, random effect, and pooled ols models. Following that, we perform an array of diagnostic tests to identify the most effective model among the three estimated models.

Table 4 displays the test results used in determining the model. First, the appropriateness of either pooled or fixed panel estimations was assessed using the F test proposed by Moulton and Randolph (1989) after the estimation results were obtained. The pooled ols model's validity was tested against the fixed effect model capturing individual country-specific effects. If F-test results state the validity of the pooled ols model, as mentioned in the literature by Baltagi (2008), omitted variable bias may result from neglecting unobserved heterogeneity. However, The results confirm that the pooled ols produces a biased estimator by ignoring country heterogeneity. Consequently, it can be recognized country-specific heterogeneity is valid for our analysis.

Another capturing method of the existence of country or time heterogeneity is the Lagrangian multiplier test proposed by Breusch and Pagan (1980). This test, which is based on the assumption that the variance of the unit or time effects is zero as the null hypothesis, examines whether the country effects are distributed in the error term in the presence of heterogeneity. Thus, the pooled ols model can be tested against the random effects model with it. LM tests asserted the country heterogeneity in the panel model. This leads us to deduce the random effect model is a better fit for our panel data comparing it to pooled ols.

**Table 4: Selection of the Econometric Model**

| Model comparison | Test | Statistics | Probability |
|---|---|---|---|
| pooled ols versus fixed effect | F test for all ui | F(5, 163)=610.67 | 0.0000 |
| pooled ols versus random effect | Breusch-Pagan Lagrange Multiplier | chi2(1)=1259.44 | 0.0000 |
| fixed effect versus random effect | Hausman | chi2(5)=159.49 | 0.0000 |

After concluding the panel has country heterogeneity, the Hausman specification test was applied to determine between the fixed effect model and the random effect model. When the null hypothesis of the Hausman specification test, which is that there is no correlation between the explanatory variables and the error term, is accepted, it can be concluded that both models produce consistent estimators. However, under the alternative hypothesis that the independent variables and the error term are correlated, the random effects estimators give inconsistent results and the fixed effects estimators give consistent results (Tatoğlu, 2012). The results show that the fixed effects model has consistent estimators.

### 4.3. Robustness Check of the Determined Model

In light of the strong evidence the fixed effect model has for being appropriate, our next step is to evaluate the fixed effect model's resilience by using tests for serial correlation, heteroscedasticity, and cross-sectional dependency.

Table 5 shows autocorrelation test, heteroscedasticity test, and cross-sectional dependence test results. Bhargava et al. (1982) proposed Durbin-Watson test statistics using AR(1) model for the detection of autocorrelation in fixed effect models. The null hypothesis of the test indicates that the error terms are not autocorrelated. The test statistic is 0.421, which is way below the threshold value of 2, indicating that there is autocorrelation in the fixed effects model used.

Modified Wald statistic for group-wise heteroscedasticity in the residuals of fixed effect model was carried out (Greene, 2000). According to the result, there is no group-wise heteroscedasticity hypothesis was rejected. Thus, we concluded fixed effect regression has group-wise heteroscedasticity.

In the final step of the robustness check of regression results, cross-sectional dependence was examined in the fixed effect model. To determine whether there were any indications of cross-sectional dependency in our data, we used the Breusch-Pagan LM test of independence. The main motivation for using this test is that it is suitable for testing cross-sectional dependence in cases where the time dimension is larger than the cross-sectional dimension (Tatoğlu, 2012). The test result suggests that the cross-sectional independent null hypothesis needs to be rejected. The conclusion is that fixed effect regression produces cross-sectional dependent residuals.

**Table 5: Autocorrelation, Heteroscedasticity, and Cross-Sectional Dependence Test Results**

| | Mofied Durbin-Watson Test | Wald Test | Breusch-Pagan Lagrange Multiplier Test |
|---|---|---|---|
| Statistics | 0.421 | chi2 (6) = 323.70 | chi2 (15)=63.997 |
| Probability | | 0.0000 | 0.0000 |

Considering all results given in the table 5, It has became clear that estimators were needed that produced standard errors that would be robust to all common forms of cross-sectional and time-wise correlation in the model. In addition, it must be an estimator that gives reliable results in cases where the time dimension exceeds the cross-sectional dimension. Thus, it was decided to use the (Driscoll and Kraay, 1998) estimator, which produces robust standard errors for all these deviations from the assumptions that undermine efficiency using the fixed effects model and meets the necessary asymptotic requirements in this study.

### 4.4. Estimation Results

The results of the estimation of the fixed effect model using Driscoll-Kraay standard errors are shown in table 6. The joint significance of all the model's coefficients appears to be strongly supported by looking at the probability of F-statistic. In addition, although the impact of outward foreign direct investment on energy consumption is controversial in the literature, the effects of all other variables are consistent with a priori expectations of the STIRPAT model for the BRICS-T country group. It is observed that the effect of population, gross domestic products per person, the share of total natural resources rent in gdp, which are equivalent to population, wealth, and technology variables in the STIRPAT model, respectively, on energy consumption is statistically significantly positive.

The statistically significant negative coefficient of outward foreign direct investment shows that the spillover effect enhances environmental quality in BRICS-T countries by adopting energy-efficient technology in the home country. These results are consistent with the study of Mohanty and Sethi (2022) and Osabuohien-Irabor and Drapkin (2024) concerning the spillover effect of outward foreign direct investment on home countries.

The constant term, which has no definition of the theoretical effect on energy consumption in the model, turned out to be negative and statistically insignificant. The other coefficients represent elasticities due to the stochastic nature of the STIRPAT model. A 1% increase in the population creates an average increase of 0.44% in energy consumption in BRICS-T countries at a 1% level of significance. The elasticity of gross domestic product per person on energy consumption is 1.20 at a 1% level of significance. Even if the effects of the share of total natural resources rent in GDP and outward foreign direct investment are quite low on energy consumption of which the elasticities are 0.052 and -0.070, respectively, statistically significant at 1%.

There are two criteria for testing the EKC hypothesis. The first criterion is the presence of an inverted u relationship and the second is whether the turning point is within the defined data range. When we evaluate the first criterion, in the early stages of economic growth, as can be seen from the statistically significant positive coefficient (1.201), gross domestic product per capita has a feature that increases environmental degradation. The square of the gross domestic product per capita variable, with its statistically significant negative coefficient (-0.035), shows that it has a decreasing effect on environmental degradation in the second stage of economic development. These findings prove that the first criterion was valid for BRICS-T countries. However, the 29,689,491.51$ turning point calculated using the $\exp\left(-\frac{\beta_3}{2\beta_4}\right)$ formula is outside the data set range, indicating that the BRICS-T countries have not yet reached the stage of environmental degradation-reducing stage of economic development and the EKC hypothesis is not supported for this country group. The result also shows that energy-saving technologies stimulated by economic development are quite low in this group of countries. Ultimately, an inverted-u-shaped relationship between and gross domestic product has been revealed according to the results but the turning point proved that the EKC hypothesis was not valid, similar to the findings in the study of Maneejuk et al. (2020).

**Table 6: Driscoll-Kraay Estimation Results**

| Variables | DK-Estimators |
|---|---|
| Constant | -0.149 |
| | (0.536) |
| lnpop | 0.437*** |
| | (0.112) |
| lngdp | 1.201*** |
| | (0.150) |
| $lngpd^2$ | -0.0349*** |
| | (0.00820) |
| lntnrr | 0.0518*** |
| | (0.00928) |
| lnofdi | -0.0704*** |
| | (0.0104) |
| Country Dummies | Yes |
| Year Dummies | No |
| Number of Observation | 174 |
| Number of Groups | 6 |
| F(5, 28) | 4474.39 |
| Prop>F | 0.0000 |
| Within R2 | 0.9397 |

Note: The numbers in the parentheses state the standard errors of coefficients.
*** indicate 1% level of significance.

## 5. CONCLUSIONS

Today, countries aim to continue their economic development with pro-environmental policies and technologies. Countries' effective use of their natural resources and their domestic, and foreign direct investments should be considered as an advantage for their economic development in the circumstances. Therefore, it is important to investigate the environmental impacts of natural resource utilization and investments of the so-called developing BRICS-T countries. Considering the demographic characteristics, economic structures, and geographical features of these countries, they have a very high ranking in natural resource utilization in the world. In line with practices followed by many other countries, these nations develop policies and technologies aimed at fostering growth through pro-environmental strategies. In this context, it is very important to investigate how successful the BRICS-T countries have been in implementing their pro-environmental policies in recent years. For this purpose, this study focuses on the effects of natural resource rents and foreign direct investments on energy consumption and conducts panel data analysis through the STIRPAT theoretical model. The findings indicate the existence of unit heterogeneity in BRICS-T countries. After the diagnostic tests, fixed effects estimators with Driscoll-Kraay standard errors were obtained which are appropriate for our data.

The findings suggest that outward foreign direct investment may have a reducing effect on energy consumption in BRICS-T countries that are home countries. This suggests that outward foreign direct investment may encourage more efficient production processes through capital and technology transfer or increase compliance with environmental regulations. On the other hand, natural resource rents are reached to have an increasing impact on energy consumption. This result supports the argument that in resource-dependent economies, income from natural resources may encourage energy-intensive production processes and increase dependence on fossil fuel use. This finding emphasizes the need for policymakers to direct natural resource revenues to more efficient and environmentally friendly projects in terms of environmental sustainability.

The study also investigated the EKC hypothesis to assess the nonlinear relationship between energy consumption and economic develpment. From our findings, we can infer that the economic growth in the BRICS-T countries has not yet reached a level that reduces energy consumption. Although the analyses point to a statistically significant inverted n-shaped curve in the BRICS-T country group that can confirm the EKC hypothesis, the fact that the turning point occurs at a very high-income level reveals that economic growth has not been achieved by using pro-environmental technologies. This finding indicates that energy consumption in BRICS countries will not decrease nonlinearly with economic growth and this process should be supported by policy interventions.

In this context, policy interventions are necessary to ensure environmental sustainability in BRICS-T countries. To reduce energy consumption, only clean production technology-induced economic growth should be adopted. In this direction, green R&D investments should be supported and environmental taxation mechanisms should be established. Moreover, renewable energy investments should be increased and stricter environmental regulations should be introduced for environmentally damaging production processes in energy-intensive sectors to ensure that the turning point occurs at lower income levels. Outward foreign direct investment can be considered an opportunity to improve the energy efficiency of BRICS-T countries. Outward foreign direct investment should increase technology transfer policies to carry back environmentally friendly technologies and innovations from host countries (BRICS-T countries). In this context, firms investing abroad should be encouraged to import environmentally friendly technologies and the reverse spillover effect should be supported. In terms of natural resource rents, a portion of these revenues should be channeled to renewable energy projects and low-carbon infrastructure to reduce dependence on fossil fuels. Gradually removing fossil fuel subsidies, transferring natural resource revenues to 'green investment funds', and incentivizing energy efficiency projects in energy-intensive sectors are important steps to prevent environmental degradation.

## REFERENCES


An, H., Razzaq, A., Haseeb, M., & Mihardjo, L. W. (2021). The role of technology innovation and people's connectivity in testing environmental Kuznets curve and pollution heaven hypotheses across the Belt and Road host countries: New evidence from Method of Moments Quantile Regression. Environmental Science and Pollution Research, 28, 5254-5270.

Anyanwu, J. C. (2012). Why does foreign direct investment go where it goes?: New evidence from African countries. Annals of Economics and Finance, 13(2), 425-462.

Arain, H., Sharif, A., Akbar, B., & Younis, M. Y. (2020). Dynamic connection between inward foreign direct investment, renewable energy, economic growth and carbon emission in China: Evidence from partial and multiple wavelet coherence. Environmental Science and Pollution Research, 27, 40456-40474.

Arbulu, I., Lozano, J., & Rey-Maquieira, J. (2017). Waste generation flows and tourism growth: a STIRPAT model for Mallorca. Journal of Industrial Ecology, 21(2), 272-281.

Balcilar, M., Ekwueme, D. C., & Ciftci, H. (2023). Assessing the effects of natural resource extraction on carbon emissions and energy consumption in Sub-Saharan Africa: a STIRPAT model approach. Sustainability, 15(12), 9676.

Baloch, M. A., Mahmood, N., & Zhang, J. W. (2019). Effect of natural resources, renewable energy and economic development on CO2 emissions in BRICS countries. Science of the Total Environment, 678, 632-638.

Baltagi, B. H. (2008). Econometric Analysis of Panel Data, Rohn Wiley, 4th Edition.

Bangura, M., & Saibu, O. (2024). Modeling Electricity Demand in the Ecowas Region: New Insights Using Fixed Effect with Driscoll and Kraay Standard Errors. Modern Economy, 15(1), 67-85.

Bhargava, A., Franzini, L., & Narendranathan, W. (1982). Serial correlation and the fixed effects model. The Review of Economic Studies, 49(4), 533-549.

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. The Review of Economic Studies, 47(1), 239-253.

Buckley, P. J., Chen, L., Clegg, L. J., & Voss, H. (2020). The role of endogenous and exogenous risk in FDI entry choices. Journal of World Business, 55(1), 101040.

Cai, L., Firdousi, S. F., Li, C., & Luo, Y. (2021). Inward foreign direct investment, outward foreign direct investment, and carbon dioxide emission intensity-threshold regression analysis based on interprovincial panel data. Environmental Science and Pollution Research, 1-14.

Chorn, S., & Siek, D. (2017). The impact of foreign capital inflow on economic growth in developing countries. Journal of Finance and Economics, 5(3), 128-135.

Dietz, T., & Rosa, E. A. (1994). Rethinking the environmental impacts of population, affluence and technology. Human Ecology Review, 1(2), 277-300.

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. Review of Economics and Statistics, 80(4), 549-560.

Ehrlich, P. R., & Holdren, J. P. (1971). Impact of Population Growth: Complacency Concerning this Component of Man's Predicament is Unjustified and Counterproductive. Science, 171 (3977), 1212-1217.

Enerdata, World consumption statistics, Enerdata Yearbook, [online source]. https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html [Date accessed: 11.12.2024].

Greene, W. H. (2000). Econometric Analysis, Prentice Hall, 4th edition: International Edition.

Gujarati, D.N., & Porter, D.C. (2009) Basic Econometrics, McGraw Hill Inc, 5th Edition.

Gyamfi, B. A., Onifade, S. T., Nwani, C., & Bekun, F. V. (2022). Accounting for the combined impacts of natural resources rent, income level, and energy consumption on environmental quality of G7 economies: a panel quantile regression approach. Environmental Science and Pollution Research, 29(2), 2806-2818.

Hassan, S. T., Xia, E., Khan, N. H., & Shah, S. M. A. (2019). Economic growth, natural resources, and ecological footprints: Evidence from Pakistan. Environmental Science and Pollution Research, 26, 2929-2938.

Huang, Y., Chen, F., Wei, H., Xiang, J., Xu, Z., & Akram, R. (2022). The impacts of FDI inflows on carbon emissions: Economic development and regulatory quality as moderators. Frontiers in Energy Research, 9, 820596.

Kamal, M. A., Ullah, A., Qureshi, F., Zheng, J., & Ahamd, M. (2023). China's outward FDI and environmental sustainability in belt and road countries: does the quality of institutions matter?. Journal of Environmental Planning and Management, 66(5), 1002-1036.

Kwakwa, P. A., Alhassan, H., & Adu, G. (2020). Effect of natural resources extraction on energy consumption and carbon dioxide emission in Ghana. International Journal of Energy Sector Management, 14(1), 20-39.

Lohwasser, J., Bolognesi, T., & Schaffer, A. (in-press). Impacts of population, affluence and urbanization on local air pollution and land transformation–A regional STIRPAT analysis for German districts. Ecological Economics, 227, 108416.

Maneejuk, N., Ratchakom, S., Maneejuk, P., & Yamaka, W. (2020). Does the environmental Kuznets curve exist? An international study. Sustainability, 12(21), 9117.

Mohanty, S., & Sethi, N. (2022). The energy consumption-environmental quality nexus in BRICS countries: the role of outward foreign direct investment. Environmental Science and Pollution Research, 29(13), 19714-19730.

Moulton, B. R., & Randolph, W. C. (1989). Alternative tests of the error components model. Econometrica: Journal of the Econometric Society, 685-693.

Osabuohien-Irabor, O., & Drapkin, I. M. (2024). The spillover effects of outward FDI on environmental sustainability in developing countries: Exploring the channels of home country institutions and human capital. Environment, Development and Sustainability, 26(8), 20597-20627.

Poumanyvong, P., & Kaneko, S. (2010). Does urbanization lead to less energy use and lower CO2 emissions? A cross-country analysis. Ecological Economics, 70(2), 434-444.

Seker, F., Ertugrul, H. M., & Cetin, M. (2015). The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Turkey. Renewable and Sustainable Energy Reviews, 52, 347-356.

Shahbaz, M., Loganathan, N., Muzaffar, A. T., Ahmed, K., & Jabran, M. A. (2016). How urbanization affects CO2 emissions in Malaysia? The application of STIRPAT model. Renewable and Sustainable Energy Reviews, 57, 83-93.

Tan, F., Wan, H., Jiang, X., & Niu, Z. (2021). The impact of outward foreign direct investment on carbon emission toward china's sustainable development. Sustainability, 13(21), 11605.

Tatoglu, F. Y. (2012). Panel Veri Ekonometrisi, Beta Publishing, 5th Edition.

Ulucak, R., & Ozcan, B. (2020). Relationship between energy consumption and environmental sustainability in OECD countries: The role of natural resources rents. Resources Policy, 69, 101803.

Usman, M., & Hammar, N. (2021). Dynamic relationship between technological innovations, financial development, renewable energy, and ecological footprint: fresh insights based on the STIRPAT model for Asia Pacific Economic Cooperation countries. Environmental Science and Pollution Research, 28(12), 15519-15536.

Voumik, L. C., Mimi, M. B., & Raihan, A. (2023). Nexus between urbanization, industrialization, natural resources rent, and anthropogenic carbon emissions in South Asia: CS-ARDL approach. Anthropocene Science, 2(1), 48-61.

Wang, Q., & Zhang, Q. (2022). Foreign direct investment and carbon emission efficiency: The role of direct and indirect channels. Sustainability, 14(20), 13484.

World Development Indicator (WDI), [online source]. https://databank.worldbank.org/source/world-development-indicators [Date accessed: 10.12.2024].

Yang, Y., & Khan, A. (2021). Exploring the role of finance, natural resources, and governance on the environment and economic growth in South Asian countries. Environmental Science and Pollution Research, 28(36), 50447-50461.

Yang, G., & Zheng, Q. (2021). Impact of China's outward foreign direct investment on environmental pollution in the home country. Chinese Journal of Population, Resources and Environment, 19(3), 221-229.

Yi, M., Gong, M., Wu, T., & Wang, Y. (2018). Nonlinear effects of urbanization and outward foreign direct investment on carbon emissions in China. Sustainability, 10(12), 4411.

Zhao, C., Chen, B., Hayat, T., Alsaedi, A., & Ahmad, B. (2014). Driving force analysis of water footprint change based on extended STIRPAT model: Evidence from the Chinese agricultural sector. Ecological Indicators, 47, 43-49.