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# Employing the Panel Quantile Regression Approach to Examine the Role of Natural Resources in Achieving Environmental Sustainability: Does Globalization Create Some Difference?

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**Abstract:** In the modern era of globalization, natural resources have become an important factor in shaping a sustainable future; however, the evidence on the role of globalization in reducing the adverse environmental impacts of natural resources is relatively scarce. The current study explores the dynamic interaction between energy consumption, economic development proxied through the human development index, population, natural resources, globalization, and ecological footprint under the core idea of the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT). This research applies panel data for the period from 1999 to 2018 in nine countries with the highest oil production (Brazil, Canada, China, Iran, Kuwait, Russia, Saudi Arabia, United Arab Emirates, and the United States). The results of this study are based on the panel Method of Moments Quantile Regression (MMQR). Empirical findings foundthat economic development, energy consumption, population, and natural resources contribute to increased environmental degradation, while globalization seems the main source of environmental sustainability. Concerning the indirect impacts of globalization, expanded interaction and integration among oil-producing countries helped to inhibit ecological footprint; nevertheless, natural resources complicate the design of a sustainable future by promoting environmental degradation. Additionally, a bidirectional causality relation was discovered between population, energy consumption, globalization, and ecological footprint; however, the panel Dumitrescu and Hurlin causality test results revealed a unidirectional causality association from economic development to ecological footprint and from natural resources to ecological footprint. Our findings shed new light on the criticality of globalization in achieving environmental sustainability by providing cleaner practices that will prevent rent-seeking.

**Keywords:** ecological footprint; globalization; natural resources; panel quantile regression; STIRPAT

**MSC:** 62J99; 91B76



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## 1. Introduction

With the emergence and vast development of technology, the world has witnessed a well-recognized connectivity between the nations across the globe, and the world has become a global village [1]. Globalization is a major shift form unreachable and confined economies with cultural diversities, barriers to, and regulations for interconnectivity between nations [2]. Much of the trade between nations in term of export, import, and the movement of capital and investment is considered as the proxy of such a shift in the globalization era [3]. In the end of 20th century, transformations took place all over the world, which gave the rise to what is called the phenomenon of globalization, which, eventually, led to significant changes in several aspects including economic conditions [4]. Moreover, the influences of economic globalization are instantly rising in all aspects of human lives, which include investments migration and technology transfers, as well as rising in consumption. The above-mentioned benefits that emerge with globalization might also have negative aspects and adverse consequences on environmental quality and sustainability [4,5], which have become the major concerns of all nations and the international community.

Together with the trending effects of globalization, the nexus between environment and economics has been clearly noticeable in the literature. It is assumed that drastic development changes including technological developments, increase of economic activity, urbanization, and the increase of affluence across the globe accompany the decline in the environmental quality [6,7]. Therefore, several models have emerged to interpret these developmental changes, one of which is the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model that mainly explains the influence of urbanization–population, technology, and affluence on the environment [8,9]. Past studies have examined multiple factors that could influence the environment in alignment with the current trends of a well-connected world. The findings of these studies substantiated that globalization is detrimental to environmental quality [1,4]. Despite these findings, other research has indicated that environmental quality can be enhanced with globalization [10]. Climate change and global warming have been vital issues in the era of globalization that pose major threats to global sustainable development [5]. Climate change originates from the rise in greenhouse gases (GHGs) as well as in the increase in human activities through the consumption of non-renewable energy [11], and, hence, environmental degradation becomes a by-product. Herein, the overdependence on fossil fuel energy and population growth are reported to have adverse environmental impacts [12].

Furthermore, modern research has shown the critical interest in the linkage between natural resources and environmental quality [13–17]. It plays a major role in the development of nations. Additionally, natural-resources-dependent countries depend heavily on extracting natural resources to sustain their economic growth and enhance the national income, so these societies have become affluent [5,18]. Several pieces of evidence show that natural resources promote economic growth of countries in different parts of the world [15,19]. Although natural resources are considered bounties for these countries, and they are not detrimental to the environment, the methods by which these resources are extracted are damaging to the environment [15]. According to the treadmill hypothesis of production proposed by Schnaiberg [20], accelerated development and growth normally drive the search for natural resources by specific countries resulting in human exploitation for resources that are not green-friendly such as minerals, crude oil, and natural gas. This also motivates the economic agent to pursue the maximum objective of growth opportunities, which further places pressure on energy demand and investment to exploit the natural resources. Consequently, environmental degradation is the product of such behavior [2,15].

Another striking factor that has great influence on the environment is economic development. Several theories including the Environmental Kuznets Curve (EKC) hypothesis have explained the relationship between environmental quality and economic growth. According to the EKC hypothesis, there is an inverted U-shaped link between environment and economic development. The approach followed has indicated that economic expansion is divided into three phases. Phase I, the scale effect, is reached in the early stages of economic emancipation; meanwhile, the technology and composition effects (Phases II and III) take place in the later stages of economic emancipation. Some authors such as Chu [21] argue that the scale effect is relevant for emerging economies, while the other two phases are linked to advanced nations. Therefore, the EKC hypothesis highlights that deterioration in environmental quality is high in the early phases of economic growth, and after the predetermined cutoff value of affluence, the tendency changes to being positive; hence, higher levels of income are beneficial for the environment [22,23].

From the human development perspective, it is human capital that contributes to the production process [24]. The human development index is an index comprising health, knowledge, education, work experience, training, and skills of the people in a specific nation. Within the framework of STIRPAT, a large amount of literature [9] argued that industrialization is driven by economic growth, which further increases the extraction of natural resources. This, by implication, would lead to an increase in consumption, so economic growth exacerbates natural resource extraction and puts pressure on environment. Wang et al. [14] argued that human development enhances economic growth with the synergy of human capital through education and learning-by-doing; consequently, production level and income level will increase. Such trends would create more awareness about environmental effects and might lead to a lower consumption of energy and reduction of environmental problems [11]. On the contrary, in higher income countries, there is a tendency for lower educated people to consume more energy and, hence, leads to environmental degradation.

The objective of the current study is to investigate the relationship between energy consumption, economic development, population, natural resources, globalization, and ecological footprint under the theoretical underpinnings of STIRPAT framework. The annual panel data are collected for the period from 1999 to 2018 in nine countries with the highest oil production (Brazil, Canada, China, Iran, Kuwait, Russia, Saudi Arabia, United Arab Emirates, and the United States). Although the literature to date [5,25] examines the relationship between the variables of interest, it left some critical aspects unaddressed. The findings of our study are expected to address these aspects and to contribute to the existing literature in four areas. First, this study concerns the factors of globalization and natural resources for the nine countries with the highest oil production. These countries are blamed for the increase in natural resource extraction and consumption that contributes to economic growth and, within the treadmill hypothesis, would largely aid in environmental degradation. Second, in recent works, natural resources have become an important factor in shaping a sustainable future; however, the evidence on the role of globalization in reducing adverse environmental impacts of natural resources is relatively scarce. Several studies have examined the role of globalization in various regions; however, the effects of globalization on the nine producing countries still lack evidence, given the fact that these countries have different growth and advancement trends. Third, a growing gap in economic realities of oil-producing and their non-oil-producing counterparts would produce further empirical evidence that may exhibit important directions for decision makers. In addition, many prior studies have utilized the EKC framework [12,22], while this study falls within the framework of STIRPAT. Lastly, in addition to economic globalization, this study analyzes whether trade globalization aids in mitigating the adverse environmental impacts of natural resources extraction. Based on this backdrop, the study aims to answer the following questions. (1) Do natural resources influence ecological footprint? (2) Is there an impact of globalization on ecological footprint? (3) Does globalization reduce the adverse environmental impacts of natural resources?

This paper is arranged as follows. The following section comprehensively reviews the existing past studies and defines the hypothetical relationship among the variables. Then, data, model specifications, and estimation methods are presented in Section 3. Empirical analysis is presented in Section 4. Lastly, Section 5 completes the study and underlines the major policy implications, limitations, and recommendations for future research.

## 2. Literature Review

The recent studies focused on natural resources, globalization, income (economic development), and environment nexus are presented below. These studies are organized under the following sub-headings:

### 2.1. Nexus between Natural Resources and Environmental Sustainability

In nations, it is considered that natural resources are the most critical contributor to sustainable development and environmental sustainability as well as economic growth [1,26,27]. Several research studies have been conducted to explore the impact of natural resources on ecological footprints [2,16,25,28,29]. According to Hassan et al. [28], there is a positive relationship between natural resources and ecological footprint in Pakistan. Ahmad and Wu [25] collected the data for G-20 countries and found that natural resources reduced ecological efficiency in the period from 1990–2016, outlining that natural resources aid in environmental degradation. Luo and Mabrouk [16] examined the nexus between natural resources and ecological footprint in resource-rich economies from 1990 to 2018 utilizing the cross-sectional augmented autoregressive distributed lags (CS-ARDL) model. They found that the natural resources factor is mainly responsible for the increased interest in environmental issues. Jahanger et al. [5] have investigated the role natural resources play in environmental sustainability using a panel data technique in selected countries. Their results demonstrated that natural resources negatively contribute to environmental quality. Ahmed et al. [24] validated this relationship for the case of resource-rich economies, including Russia, India, Saudi Arabia, Brazil, and China using data between 1984 and 2016. The long run cointegration was documented in the study, which reported that natural resources considerably affected the expansion of ecological footprints in the long run. In this manner, the study reported that sustainable environments could be achieved with certain policies that help reduce ecological footprints. Similarly, Zuo et al. [29] examined the nexus between natural resources and ecological footprints in higher income Belt and Road Initiative (BRI) countries for the period from 1991 to 2018. Their findings indicated that natural resources ruin environmental quality.

Since natural resources registered a positive impact on ecological footprint, we expect that the rise in natural resources promotes the ecological footprints of the selected countries. Building on the treadmill hypothesis of production proposed by Schnaiberg [20] and the above empirical literature review [24,25,29], the following hypothesis was developed:

**Hypothesis 1 (H1).** *Natural resources are expected to reflect a positive impact on ecological footprint.*

### 2.2. Nexus between Globalization and Environmental Sustainability

The evolution of technological advancement has greatly influenced societies and made the globe into a village. Various theoretical frameworks [4,5,30] have explained the relationship between globalization and environmental degradation. These include the pollution haven hypothesis and the pollution halo hypothesis. Under the pollution haven hypothesis, Walter and Ugelow [31] contended that trade and foreign investment in the light of globalization create ways to export pollutant-production tools abroad. The approach has criticized globalization with regard to its impact on environmental degradation. On the other hand, Birdsall and Wheeler [32] have proposed the pollution halo hypothesis, which indicates that globalization could provide means for technological transfer between advanced nations and developing nations. The transfer of technological tools for production can be translated into environmental gains that lower environmental degradation. In [4,5], authors examined the impact of globalization on environmental degradation, and they found that globalization and environmental degradation are negatively related, which further indicates the importance of integration among countries. These findings lend credence to Xiaoman et al. [10] because they found that globalization improves the environmental quality of the Middle East and North Africa (MENA) economies. Using the case study of the European Union, a negative association is found between social and political dimensions of globalization and environmental degradation [30]. Herein, these two dimensions of globalization are effective in reducing climate issues. In another study, in the case of the South African economy, Joshua et al. [33] demonstrated that globalization leads to positive effects in environmental quality in both the long- and the short-run. In particular, globalization is viewed as an agent that aids in environmental protection of the

South African economy. In their work, Jahanger et al. [5] showed the negative association between globalization and ecological footprint in the African and Latin American countries for the period from 1990 to 2016.

Based on the empirical literature review, globalization promotes environmental quality [4,5,30]. In view of the above findings, the following hypothesis is proposed:

**Hypothesis 2 (H2).** *Globalization is likely to influence ecological footprint negatively.*

### *2.3. Nexus between Economic Development and Environmental Sustainability*

Previous studies' evidence on the relationship between environmental degradation and economic development has produced numerous findings [11,34,35]. In [35], authors identified economic development as an important explanatory variable in environmental degradation considering the case of Bangladesh. Damrah et al. [11] revealed the relationship between the human development index and the environment in the six oil-exporting countries. The results of panel quantile regression showed the positive association between the human development index and the carbon intensity. Furthermore, this study confirmed the validity of the EKC hypothesis in the case of the inspected countries. Jena et al. [23] explored the relationship between ecological footprint, carbon dioxide emissions, and economic growth. Their findings outlined that economic growth and non-renewable energy use hinder environmental quality. Another manuscript by Satrovic et al. [36] used the case study of the Gulf Cooperation Council (GCC) and found a positive association between economic development and carbon dioxide emissions. Using panel data regression models, Hussain and Dey [34] proved the validity of the EKC hypothesis as relationship between the human development index and carbon dioxide emissions for a panel of 30 countries in the time span between 1990 and 2016. Xiaoman et al. [10] analyzed the relationship between economic growth and environmental quality considering the case of the Middle East and North Africa (MENA) economies. The authors showed that economic growth significantly aids in environmental degradation. Finally, Ahmad and Wu [25] outlined the positive association between economic development and environmental degradation in the case of G-20 countries. Given the review of the foregoing literature, economic development carved a positive relationship with ecological footprints [11,34,35]. In light of the most related findings, we propose the following hypothesis:

**Hypothesis 3 (H3).** *Economic development is expected to reflect a positive impact on ecological footprint.*

## 3. Data, Model Specifications, and Estimation Method

### *3.1. Data*

The main purpose of this study is to explore how globalization moderates the effects of natural resources on ecological footprint in the presence of economic development, energy consumption, and labor force participation rate. The data on labor force participation rate and natural resources were attained from the World Bank-2021. Furthermore, the data on economic and trade globalization were retrieved from Gygli et al. [3]. This study uses the data from the human development index, which is taken as a measure of economic development, collected from the United Nations Development Programme—UNDP-2020. Furthermore, the data on ecological footprint are obtained from the Global Footprint Network—GFN-2022, whereas the data on energy consumption are retrieved from the Organisation for Economic Co-operation and Development—(OECD). Detailed descriptions of the inspected variables and data sources are presented in Table 1.

**Table 1.** Variables and data sources.

| Variable | Description | Source |
|---|---|---|
| FPEC | Ecological footprint in global hectares (gha) per person | GFN (2022) |
| HDI | Human development index | UNDP (2020) |
| PRLF | Labor force participation rate, total (% of total population ages 15+) | WB (2021) |
| EIND | Energy consumption in industry, % total energy consumption | OECD (2022) |
| NR | Total natural resources rents per capita in constant 2015 USD (abundance) | WB (2021) |
| EGL | Economic globalization index | Gygli et al. (2019) |
| TGL | Trade globalization index | Gygli et al. (2019) |

We investigate the balanced panel data of nine oil-producing countries from 1999 to 2018. The list of the oil-producing countries includes Brazil, Canada, China, Iran, Kuwait, Russia, Saudi Arabia, United Arab Emirates, and the United States. The adopted study period and scope of inquiry are based on data availability constraints. Note that the ecological footprint data were not available before 1999 and beyond 2018 for Kuwait. The main reason for choosing the selected oil-producing countries is that socio-economic effects of oil consumption are different from oil production [37]. All countries are oil-consuming, but not all countries are oil producers. Considering the adverse effects associated with oil producing, a separate study on the economic development–ecological footprint nexus is required to be conducted for these countries. In addition, there can be a growing gap in economic realities of oil-producing and their non-oil-producing counterparts. Table 2 records the summary statistic for all the variables investigated.

**Table 2.** Descriptive statistics.

| Stat./Var. | FPEC | HDI | PRLF | EIND | NR | EGL | TGL |
|---|---|---|---|---|---|---|---|
| Mean | 6.20 | 79.08 | 63.49 | 33.89 | 4083.28 | 57.82 | 56.07 |
| St. Dev. | 3.07 | 8.19 | 10.34 | 12.29 | 5480.07 | 15.81 | 18.98 |
| Max | 13.60 | 92.80 | 80.77 | 66.26 | 22318.80 | 87.00 | 93.00 |
| Min | 1.88 | 57.90 | 39.99 | 17.01 | 36.96 | 24.00 | 22.00 |
| Skewness | 0.423 | −0.152 | −0.605 | 0.730 | 1.497 | −0.245 | 0.318 |
| Kurtosis | 2.010 | 2.482 | 2.740 | 2.672 | 4.348 | 2.159 | 2.220 |

From Table 2, the highest mean was natural resources abundance with 4083.28 per capita (constant 2015 USD), and the lowest mean was 6.20 with ecological footprint per capita. The maximum value of natural resources abundance was documented for Kuwait in 2005 and minimum for China in 1999. The highest value of ecological footprint was displayed for the United Arab Emirates in 2001, whereas the lowest value was associated with China in 1999. As far as the human development index is considered, maximum value is documented for Canada in 2018 while China reports minimum value in 1999. The United Arab Emirates reported a maximum labor force participation rate in 2017; however, Iran reported a minimum value in 2011. Table 2 displays the average energy consumption of 33.89% with the maximum value reported for the United Arab Emirates in 1999 and the lowest value for the United States in 2009. Iran reports the minimum value of the economic globalization index, whereas the highest values are obtained for the United Arab Emirates. As far as trade globalization is considered, Table 2 outlines the average of 56.07%, with the maximum reported for the United Arab Emirates and the minimum value for Iran. Table 2 suggests that the inspected variables exhibit positive and negative skewness. Specifically, the ecological footprint, energy consumption, natural resources, and trade globalization are positively skewed while the other variables are negatively skewed.

### 3.2. Theoretical Framework and Model Specifications

A key concern nowadays is ensuring a balance between environmental and economic well-being. Countries recognize the importance of a sustainable future whereby rapid economic development may lead to poor environmental quality. Herein, this study aims to analyze whether faster economic development leads to poorer environmental quality. Unlike other similar studies where environmental quality is proxied through carbon dioxide emissions, in this study ecological footprint is taken as an environmental proxy. In addition, economic development is proxied through the human development index instead of real gross domestic product (GDP) per capita. In this vein, the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) framework developed by the authors in [38] is the foundation of this analysis. The STIRPAT framework is an advancement of the IPAT model claiming that environmental impact (I) is the function of population (P), affluence (A), and technology (T). The particular reasons to employ the STIRPAT framework are twofold: first, to evaluate the environmental impact of population, affluence, and technology; and second, to reveal causality associations between the variables. Equation (1) formalizes the STIRPAT in the form of non-logarithm as follows:

$$I_{it} = \alpha_{it} P_{it}^{\beta 1} A_{it}^{\beta 2} T_{it}^{\beta 3} \varepsilon_{it} \tag{1}$$

where $i$, $t$, $\alpha_{it}$, and $\varepsilon_{it}$ show the number of cross-sections, study period, country effects, and disturbance term, respectively. Although $i = 1, \ldots, N$, $t = 1, \ldots, T$. $\beta 1 - \beta 3$ are showing the effects of $P$, $A$, and $T$, respectively. By taking the natural logarithm of each of the variables, the STIRPAT framework is shown as Equation (2):

$$LI_{it} = \alpha_{it} + \beta_1 LP_{it} + \beta_2 LA_{it} + \beta_3 LT_{it} + \varepsilon_{it} \tag{2}$$

where $L$ represents the natural logarithm. This study explores direct and indirect interactions of globalization with ecological footprint. Particularly, it evaluates whether globalization positively or negatively moderates the influence of natural resources on ecological footprint. In the extended layout (Equation (3)), environmental impact $(I)$ is the function of labor force participation rate (measure of population); human development index (measure of affluence); and energy consumption in industry, % total energy consumption (measure of technology):

$$LFPEC = \alpha_{it} + \beta_1 LHDI_{it} + \beta_2 LPRLF_{it} + \beta_3 LEIND_{it} + \beta_4 LNR_{it} + \beta_5 LGL_{it} + \varepsilon_{it} \tag{3}$$

where $FPEC$ is used for ecological footprint. From Equation (3), the variables $HDI$, $PRLF$, $EIND$, and $NR$ refer to the human development index, labor force participation rate, energy consumption in industry, and natural resources, respectively. The variable GL represents indicators of globalization, namely economic globalization index $(EGL)$ and trade globalization index $(TGL)$.

Although various studies to date [9,11,12,39,40] used carbon dioxide emissions as a measure of environmental impact, it does not appear that this measure alone can depict all environmental degradation, as it primarily focuses on air pollution. In other words, in addition to carbon emissions, there are other critical determinants of environmental degradation that should be taken into consideration. For instance, it is of great importance to analyze the role of deforestation, loss of biodiversity, water pollution, etc. Consequently, there is a need for a more holistic indicator of environmental impact. The indicator known as ecological footprint was developed by Rees [41] and Wachernagel and Rees [42]. It actually links anthropogenic emissions to all other human demands on nature and measures how much nature we have and how much we use. Herein, it clearly shows how much area is needed to meet all human demands on nature, as well as the absorption of anthropogenic emissions. In this vein, the appropriateness of ecological footprint as a more comprehensive proxy of environmental impact has been strongly supported by [14,43–46]. As the affluence factor, we introduce the human development index. Unlike the plethora of previous studies analyzing the income-environmental degradation nexus [22,23], our study affirms the appropriateness of the human development index as a measure of development. The human development index is used as a credible alternative for GDP per capita since it is seen to better represent the social welfare and supports international policies in poverty reduction [34]. The inspected countries are committed to tackle climate change. In this view, the adoption of welfare implications is highly important for improving environmental performance.

Considering the aforementioned, the sign of $\beta_1$ is expected to be positive (i.e., $\frac{\partial FPEC}{\partial HDI} > 0$). Population growth increases the need to produce consumer products. This, in turn, intensifies the emission of greenhouse gases and over-exploitation of natural resources. Hence, excessive population growth contributes to increased environmental degradation [47,48] by fostering energy consumption implying that the predicted sign of $\beta_2$ is positive (i.e., $\frac{\partial FPEC}{\partial PRLF} > 0$). One of the main factors in producing anthropogenic emissions is energy use. Considering the recent studies [6,7,49], we expect a positive linkage amid energy consumption and environmental indicators (i.e., $\frac{\partial FPEC}{\partial EIND} > 0$). According to the "natural resources curse" hypothesis, countries with the most natural resources have environmental issues associated with anthropogenic emissions from resource extraction. Herein, there is a rising interest among scholars in evaluating the linkage between natural resource abundance and environmental degradation.

Natural resources nowadays seem to boost economic growth and in the same vein to increase environmental pressure. As discussed in [19], in our study, natural resource abundance is taken as a measure of natural resources. It is of critical importance to consider natural resource abundance in our analysis because oil-producing countries in our sample are natural-resources-rich. The criticality of environmental impact of natural resource abundance can be elaborated as following. First of all, exploitation of natural resources, such as natural gas, coal, and oil, boosts anthropogenic emissions [50]. In other words, natural-resources-rich countries are limited by the "resource curse" phenomenon. An important characteristic of the countries confined by this phenomenon is low environmental quality. Second, if natural resources are recognized as revenue from the exploitation process, environmental problems occur under the condition that the exploitation process is carried out in an environmentally unfriendly manner [13]. Herein, we may deduce that a rise in natural resource abundance may contribute positively to environmental degradation (i.e., $\frac{\partial FPEC}{\partial NR} > 0$).

Globalization has heightened environmental awareness worldwide. As such, globalization seems a main source of a sustainable development, in a manner that it is a prerequisite for sustainable production and consumption as well as the adoption of environmentally friendly technology. In this view, it is of great importance to examine the role of economic and trade globalization in shaping the linkage between natural resources and ecological footprints in oil-producing countriesto identify whether the globalization trend in the sample of interest has contributed to new strategies and guidelines towards environmentally friendly production processes [1,10]. On one hand, globalization can help countries to adopt cleaner technologies and to improve environmental quality. On the other hand, globalization may have adverse environmental impacts associated with failure of countries to benefit from environmentally friendly technologies and practices [1,5]. In addition, the implementation of environmentally friendly technologies can reduce competitiveness with rivals in the international market. Hence, mixed evidence on the moderating impact of globalization on linkage between natural resources and ecological footprint is deduced (i.e., $\frac{\partial FPEC}{\partial (GL*NR)} > 0$ or $< 0$).

In this study, we analyze the moderating role of economic and trade globalization in modifying the environmental performance impact of natural resource abundance within the extended STIRPAT structure. The augmented versions of our baseline models take the following forms (Equations (4) and (5)):

$$LFPEC = \alpha_{it} + \beta_1 LHDI_{it} + \beta_2 LPRLF_{it} + \beta_3 LEIND_{it} + \beta_4 LNR_{it} + \beta_5 LMod1_{it} + \varepsilon_{it} \quad (4)$$

$$LFPEC = \alpha_{it} + \beta_1 LHDI_{it} + \beta_2 LPRLF_{it} + \beta_3 LEIND_{it} + \beta_4 LNR_{it} + \beta_5 LMod2_{it} + \varepsilon_{it} \quad (5)$$

where *Mod*1 = EGL ∗ NR, *Mod*2 = TGL ∗ NR. The trade globalization index is introduced as a credible independent variable for a robustness check.

### 3.3. Methodology

The study employs the three cross-sectional dependence (CD) methods namely Pesaran [51] scaled Lagrange multiplier (LM), Frees [52,53], and Friedman [54] to choose the appropriate econometric techniques. Panel data for nine oil-producing countries are likely to exhibit cross-sectional dependence, which may occur due to their interconnectedness. In the presence of cross-sectional dependence, first-generation panel data estimators are consistent, although biased and inefficient. To avoid these problems, we test the null hypothesis of cross-sectional independence. In our case, the study period (T) is larger than the number of countries (N), directing us to place more attention on the scaled LM test [51]. In particular, the CD test equation can be written as (Equation (6)):

$$CD = \left( \frac{TN(N-1)^{\frac{1}{2}-P}}{2} \right) \quad (6)$$

where $\mathrm{P} = \left(\frac{2}{\mathrm{N(N-1)}}\right) \sum_{\mathrm{i=1}}^{\mathrm{N-1}} \sum_{\mathrm{j=i+1}}^{\mathrm{N}} \mathrm{P_{ij}}$, $\mathrm{P_{ij}}$ stands for the correlation coefficients.

Friedman's statistic is based on the average Spearman's correlation and can be formalized as (Equation (7)):

$$\mathrm{R_{ave}} = \frac{2}{\mathrm{N(N-1)}} \sum_{\mathrm{i=1}}^{\mathrm{N-1}} \sum_{\mathrm{j=i+1}}^{\mathrm{N}} \hat{\mathrm{r}}_{\mathrm{ij}} \quad (7)$$

where $\hat{\mathrm{r}}_{\mathrm{ij}}$ represents the rank correlation coefficient.

Frees [52,53] proposed a test statistic based on a squared rank correlation coefficient (Equation (8)):

$$R_{ave}^2 = \frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{r}_{ij}^2 \quad (8)$$

Another potential issue that is likely to occur in panel data is slope heterogeneity. Pesaran and Yamagata's [55] approach is used to check the potential slope heterogeneity.

To avoid disregarding cross-sectional dependence in panels, our study tests the stationary properties of the inspected variables using the second-generation panel data unit root tests, namely Im et al.'s [56] cross-sectionally augmented (CIPS) panel unit root test proposed by Pesaran [57]. The CIPS unit root test statistics can be formalized as (Equation (9)):

$$CIPS = N^{-1} \sum_{i=1}^{n} CADF \quad (9)$$

where *CADF* stands for the cross-sectional augmented Dickey–Fuller (CADF) regression that can be written as (Equation (10)):

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \delta_{0i} \Delta \overline{y}_t + \delta_{1i} \Delta \overline{y}_{t-1} + \varepsilon_{it} \quad (10)$$

The null hypothesis is $\mathrm{H_0} : \beta_\mathrm{i} = 0$ for all cross-sections versus the alternatives $\mathrm{H_1} : \beta_\mathrm{i} < 0$.

In the third step, Westerlund [58] is used to obtain the proof of the long-run linkage amid inspected variables. For the sake of robustness check, our study applies Kao cointegration test [59].

In the step four, as proposed by Gyamfi et al. [8], the long-run linkage amid inspected variables is estimated using the ordinary least squares (OLS) regression with Driscoll–Kraay standard errors and panel Method of Moments Quantile Regression (MMQR) with fixed effects introduced by Machado and Silva [60]. Despite the fact that OLS controls for heteroscedasticity, autocorrelation, and cross-sectional dependence, the MMQR is superior to the OLS for various reasons elaborated by Gyamfi et al. [8]. This study applies OLS and panel quantile regression models to estimate the robust long-run impact of affluence, population, energy consumption, natural resources, and globalization on ecological footprint. In addition, these models will show how globalization moderates the influence of natural resources on environmental degradation. Our MMQR findings contribute to the proclamation of oil-producing countries with low, intermediate, and high levels of ecological footprint. The model for MMQR introduced by Machado and Silva [60] can be shown as (Equation (11)):

$$Q_{Y_{i,t}}(\tau|X_{it}) = \alpha(\tau)'X_{it} + \beta_i, \quad i = 1,\ldots,N,\ t = 1,\ldots,T \tag{11}$$

Here, $Y_{it}$ captures the ecological footprint, $X_{it}$ represents the determinants of ecological footprint, $a(\tau)$ stands for the unknown coefficients, and $\beta_i$ signals the unobserved individual effects. Our models in Table 6 are formalized as (Model 1—Equation (12); Model 2—Equation (13); Model 3—Equation (14); and Model 4—Equation (15)):

$$Q_{LFPEC}(\tau|X_{it}) = a_{1\tau}LHDI_{it} + a_{2\tau}LPRLF_{it} + a_{3\tau}LEIND_{it} + a_{4\tau}LNR_{it} + a_{5\tau}LEGL_{it} + \beta_i \tag{12}$$

$$Q_{LFPEC}(\tau|X_{it}) = a_{1\tau}LHDI_{it} + a_{2\tau}LPRLF_{it} + a_{3\tau}LEIND_{it} + a_{4\tau}LNR_{it} + a_{5\tau}LMod1_{it} + \beta_i \tag{13}$$

$$Q_{LFPEC}(\tau|X_{it}) = a_{1\tau}LHDI_{it} + a_{2\tau}LPRLF_{it} + a_{3\tau}LEIND_{it} + a_{4\tau}LNR_{it} + a_{5\tau}LTGL_{it} + \beta_i \tag{14}$$

$$Q_{LFPEC}(\tau|X_{it}) = a_{1\tau}LHDI_{it} + a_{2\tau}LPRLF_{it} + a_{3\tau}LEIND_{it} + a_{4\tau}LNR_{it} + a_{5\tau}LMod2_{it} + \beta_i \tag{15}$$

Based on Equations (13) and (15), Mod1 = EGL $*$ NR, Mod2 = TGL $*$ NR.

Finally, our study implements a procedure proposed by Dumitrescu and Hurlin [61] for detecting Granger causality in panel datasets.

## 4. Results and Discussion

### *4.1. Pre-Estimation Diagnostics*

This current study begins with the cross-sectional dependency (CD) and slope heterogeneity analysis. In Table 3, we offer the test statistics of the Pesaran [51] scaled Lagrange multiplier (LM), in [52,53] Frees, in [54] Friedman CD tests, and delta tests for slope homogeneity proposed by Pesaran and Yamagata [55].

**Table 3.** Results of cross-sectional dependence (CD) and slope homogeneity tests.

| Test | Model 1 | Model 3 |
|---|---|---|
| Pesaran [51] scaled LM | 30.213 $^a$ | 37.133 $^a$ |
| Frees's CD test | 1.177 $^a$ | 0.982 $^a$ |
| Friedman's CD test | 16.238 $^b$ | 13.863 $^c$ |
| Pesaran and Yamagata [55] Δ | 7.603 $^a$ | 6.929 $^a$ |
| Pesaran and Yamagata [55] Δ adj | 9.430 $^a$ | 8.594 $^a$ |

Note: *p* values in parentheses, $^a$ $p < 0.01$, $^b$ $p < 0.05$, $^c$ $p < 0.10$, L-natural logarithm.

Cross-sectional dependence can substantially reduce the efficiency of panel data if neglected. It may arise for several reasons, often due to common unobserved factors, spatial correlations, or economic distance. Disregarding cross-sectional dependence in panels may disturb the exact parametric values of estimations. According to the statistics of the three cross-sectional dependence tests, it is revealed that our econometrics models are cross-sectional in nature. In other words, null hypothesis is rejected in favor of the alternative of verifying the presence of cross-sectional dependence in our panel data. Cross-sectional dependence for our variables such as natural resources, globalization, and energy consumption is quite expected due to dynamic interconnections of oil producers' that may induce spillover effects across the inspected countries. It is evident from the significant values of Pesaran and Yamagata Δ and Pesaran and Yamagata Δ adj tests that our all models suffer from slope heterogeneity [55].

Because of the cross-sectional dependence and slope heterogeneity issues, a first-generation unit root test may guarantee the inefficient and misleading results. Herein, we check the stationarity of the variables using the second generation of the unit root tests, namely Im et al.'s [56] cross-sectionally augmented (CIPS) panel unit test, for which the results are depicted in Table 4.

**Table 4.** CIPS unit root tests.

| Var. | Levels | 1st Diff | Levels | 1st Diff |
|---|---|---|---|---|
| | No Trend | With Trend | No Trend | With Trend |
| LFPEC | −2.54 [b] | −2.53 | −4.15 [a] | −4.33 [a] |
| LHDI | −1.51 | −1.72 | −3.32 [a] | −3.51 [a] |
| LPRLF | −0.62 | −1.78 | −2.46 [b] | −2.84 [c] |
| LEIND | −1.47 | −1.30 | −3.44 [a] | −3.85 [a] |
| LNR | −2.51 [c] | −2.93 [b] | −4.73 [a] | −4.81 [a] |
| LEGL | −1.90 | −2.56 | −3.87 [a] | −4.04 [a] |
| LTGL | −2.23 [c] | −2.51 | −4.25 [a] | −4.43 [a] |

Note: [a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.10$.

The results presented in Table 4 suggest that the probability values are greater than conventional for four variables (LHDI, LPRLF, LEIND, LEGL) at their levels (intercept only) showing that the factors under examination are not free from unit root. Considering the second case (intercept and trend), six out of seven factors under examination are not seen as stationary. However, CIPS unit root tests confirm that all variable series are integrated at first order I(1). In other words, all variables turned stationary at their first differences, assessing both cases: (i) intercept only; and (ii) intercept and trend. The null hypothesis of "the panel data has a unit root" was rejected for the respective variables at their first difference suggesting that all the variables are integrated with the same order (I(1)), which led us to a second generation of the panel cointegration tests, namely Westerlund's panel cointegration test [58], for which the results are shown in Table 5.

**Table 5.** Cointegration tests.

| Test | Statistic | Model 1 | Model 3 |
|---|---|---|---|
| | | Value | Value |
| Westerlund [58] | Gt | −3.051 [a] | −2.896 [b] |
| | Ga | −7.408 | −7.177 |
| | Pt | −12.585 [a] | −13.652 [a] |
| | Pa | −8.304 | −8.638 |
| Kao [59] | t-stat | −3.813 [a] | −3.744 [a] |

Note: [a] $p < 0.01$, [b] $p < 0.05$.

All results of cointegration tests presented in Table 5 approve the existence of cointegration among the variables of interest. Specifically, all tests indicate the null hypotheses of no cointegration among variables in all models are rejected at a 1% statistically significant level. For the sake of robustness check, this study employs Kao's [59] cointegrating test. Given the $p$ value below 5%, the findings of Kao's cointegration test [59] are taken as evidence of long-run association among inspected variables.

### 4.2. Estimation Results and Robustness Tests

The estimation results of Equations (3)–(5) by the OLS and panel quantile regressions are presented in Table 6 and Figure A1 (Appendix A) from which the study will focus more on the findings of the MMQR. From Table 5 (Models 1 and 2), the OLS estimates, where the dependent variable is ecological footprint, we observe that (1) Economic development proxied through the human development index has a statistically significant positive effect (at 1%) on ecological footprint in the oil-producing economies. Precisely a per cent increase in HDI will cause an estimated 1.404% increase in ecological footprint. (2) The coefficient of population proxied through the labor force participation ratio is 0.655 and is not statistically significant. (3) The 1% increase in technology proxied through energy consumption in industry increases carbon emissions by about 0.649%, ceteris paribus.

(4) Natural resources also showed a significant influence on ecological footprint. The result indicates that if natural resource use increases by 1%, ecological footprint will increase 0.068%, ceteris paribus. (5) Economic globalization and the combined effect of economic globalization and natural resources showed a negative and statistically insignificant association with ecological footprint. The robustness check is carried out by applying an alternative indicator of globalization, namely trade globalization. Results from Table 5 present that the outcomes of Models 3 and 4 are in line with those of the baseline models. In summary, affluence, population, technology, and natural resources increase the ecological footprint while trade globalization mitigates environmental degradation.

**Table 6.** Panel quantile regression model and ordinary least square (OLS).

| **Mod.** | **Var./QR** | **OLS** | | **0.1 QR** | | **0.3 QR** | | **0.5 QR** | | **0.7 QR** | | **0.9 QR** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Coef.** | **p > z** | **Coef.** | **p > z** | **Coef.** | **p > z** | **Coef.** | **p > z** | **Coef.** | **p > z** | **Coef.** | **p > z** |
| | LHDI | 1.474 [a] | 0.000 | 1.561 [a] | 0.009 | 1.504 [a] | 0.000 | 1.469 [a] | 0.000 | 1.441 [a] | 0.000 | 1.404 [a] | 0.000 |
| | LPRLF | 1.605 [b] | 0.024 | 2.776 [b] | 0.021 | 2.009 [a] | 0.002 | 1.534 [a] | 0.000 | 1.152 [a] | 0.006 | 0.655 | 0.303 |
| 1 | LEIND | 0.646 [a] | 0.002 | 0.643 | 0.145 | 0.645 [a] | 0.009 | 0.647 [a] | 0.000 | 0.648 [a] | 0.000 | 0.649 [a] | 0.006 |
| | LNR | 0.112 [a] | 0.000 | 0.167 [b] | 0.028 | 0.131 [a] | 0.002 | 0.109 [a] | 0.000 | 0.091 [a] | 0.001 | 0.068 [c] | 0.096 |
| | LEGL | −0.347 [c] | 0.070 | −0.316 | 0.528 | −0.336 | 0.230 | −0.349 [c] | 0.055 | −0.359 [b] | 0.039 | −0.373 | 0.164 |
| | LHDI | 1.474 [a] | 0.000 | 1.561 [a] | 0.009 | 1.504 [a] | 0.000 | 1.469 [a] | 0.000 | 1.441 [a] | 0.000 | 1.404 [a] | 0.000 |
| | LPRLF | 1.605 [b] | 0.024 | 2.776 [b] | 0.021 | 2.009 [a] | 0.002 | 1.534 [a] | 0.000 | 1.152 [a] | 0.006 | 0.655 | 0.303 |
| 2 | LEIND | 0.646 [a] | 0.002 | 0.643 | 0.145 | 0.645 [a] | 0.009 | 0.647 [a] | 0.000 | 0.648 [a] | 0.000 | 0.649 [a] | 0.006 |
| | LNR | 0.459 [b] | 0.027 | 0.483 | 0.358 | 0.468 | 0.113 | 0.458 [b] | 0.017 | 0.450 [b] | 0.014 | 0.440 | 0.118 |
| | LMod1 | −0.347 [c] | 0.070 | −0.316 | 0.528 | −0.336 | 0.230 | −0.349 [c] | 0.055 | −0.360 [b] | 0.039 | −0.373 | 0.164 |
| | LHDI | 1.239 [a] | 0.000 | 1.303 | 0.131 | 1.263 [b] | 0.015 | 1.236 [a] | 0.000 | 1.210 [a] | 0.000 | 1.182 [a] | 0.005 |
| | LPRLF | 1.515 [b] | 0.031 | 2.664 [c] | 0.077 | 1.942 [b] | 0.029 | 1.464 [b] | 0.011 | 1.011 [b] | 0.035 | 0.507 | 0.490 |
| 3 | LEIND | 0.602 [a] | 0.003 | 0.572 | 0.315 | 0.591 [c] | 0.083 | 0.603 [a] | 0.006 | 0.615 [a] | 0.001 | 0.629 [b] | 0.022 |
| | LNR | 0.115 [a] | 0.000 | 0.171 [c] | 0.080 | 0.136 [b] | 0.019 | 0.113 [a] | 0.003 | 0.091 [a] | 0.004 | 0.066 | 0.164 |
| | LTGL | −0.255 [a] | 0.001 | −0.289 | 0.399 | −0.268 | 0.192 | −0.253 [c] | 0.053 | −0.240 [b] | 0.028 | −0.225 | 0.173 |
| | LHDI | 1.239 [a] | 0.000 | 1.303 | 0.131 | 1.263 [b] | 0.015 | 1.236 [a] | 0.000 | 1.210 [a] | 0.000 | 1.182 [a] | 0.005 |
| | LPRLF | 1.515 [b] | 0.031 | 2.664 [c] | 0.077 | 1.942 [b] | 0.029 | 1.464 [b] | 0.011 | 1.011 [b] | 0.035 | 0.507 | 0.490 |
| 4 | LEIND | 0.602 [a] | 0.003 | 0.572 | 0.315 | 0.591 [c] | 0.083 | 0.603 [a] | 0.006 | 0.615 [a] | 0.001 | 0.629 [b] | 0.022 |
| | LNR | 0.370 [a] | 0.000 | 0.460 | 0.232 | 0.404 [c] | 0.080 | 0.366 [a] | 0.013 | 0.331 [a] | 0.007 | 0.291 | 0.118 |
| | LMod2 | −0.255 [a] | 0.001 | −0.289 | 0.399 | −0.268 | 0.192 | −0.253 [c] | 0.053 | −0.240 [b] | 0.028 | −0.225 | 0.173 |

Note: [a] ($p < 0.01$), [b] ($p < 0.05$), [c] ($p < 0.10$), Mod1 = EGL ∗ NR, Mod2 = TGL ∗ NR, QR = Quantile regression.

One of the main shortcomings of the OLS estimator is that it only estimates average effects and does not evaluate the impact of each regressor on the environmental indicator for various quantiles over ecological footprint. In contrast, panel quantile regression considers heterogeneity depending on the ecological footprint and was further employed in our study. As such, novel MMQR approach findings can be used to support and direct policy initiatives.

According to the panel quantile regression results, economic development positively affects ecological footprint across all the quantiles in Models 1 and 2 [34,35,62]. Precisely, an increase in economic activities in oil-producing countries exerts strong environmental pressure, and the implication of this can be found with the explosion of industrialization, which leads to more anthropogenic emissions causing environmental degradation (H3). Hence, the objectives of supporting economic development exert strong environmental pressure and harm environmental quality of oil-producing countries. The coefficients of the human development index show a decreasing trend in different quantiles (i.e., from lower to higher quantiles), implying that the negative environmental impact of economic development is reduced for oil-producing countries while moving from low to high levels of ecological footprint. Accordingly, at the initial level, economic development contributes positively to environmental degradation, and with the passage of time, the negative environmental impact is reduced suggesting oil producers' dedication to achieving economic development in an environmentally sustainable manner.

Second, population proxied through a labor force participation ratio increases the ecological footprint at all quantile levels. The coefficients of the labor force participation ratio show a decreasing trend in different quantiles (i.e., from lower to higher quantiles), implying that the negative environmental impact of the population is reduced in oil-producing countries with higher ecological footprint. Furthermore, for countries with high ecological footprint levels, the coefficient value is calculated as 2.009 but is statistically insignificant. Consequently, rapidly growing population is one of the major causes of anthropogenic emissions. More specifically, population growth raises demand for energy use in the industrial sector resulting in anthropogenic emissions from fossil fuel. In addition, with increasing population, pressure on agricultural land is exerted and causes deforestation. In this vein, rapidly growing population raises demand for food, which encourages agricultural production that relies heavily on pesticides and is responsible for pollutant emissions. The lower environmental pressure of population growth attributed to countries with higher ecological footprints can stem from the fact that countries with higher pollution levels are more exposed to the effects of environmental degradation that helped grow environmental awareness. The positive coefficient of population is analogous to the findings of [5,19,36,48,63].

Technology, captured by energy consumption in industry, is positively associated with ecological footprint in all quantile levels. The coefficients of the energy consumption show an increasing trend from lower to higher quantiles, suggesting that the adverse environmental impact of technology is intensified in oil-producing countries with higher ecological footprints. Overall, from a statistical perspective, the impact of energy consumption is statistically significant and positive at lower (0.20–0.30), middle (0.50), and higher (0.70–0.90) quantiles, with the coefficient increasing from around 0.64 at the 10th quantile to 0.65 at the 90th quantile. That said, the increasing energy demand in countries with higher levels of ecological footprint significantly increases environmental degradation, a result concurring with the findings of [6,7,49,64]. More specifically, the contribution of burning fossil fuels to environmental degradation increases with the quantile level. As such, rapidly growing energy use is considered one of the critical determinants of environmental degradation. There are various environmental issues arising from energy consumption including water and air pollution, rising temperatures, and mismanagement of solid waste. The positive effect of energy consumption on ecological footprints in oil-producing countries is quite natural, as expected considering that these countries are still shifting strategic imperatives of the oil and gas industry since these industries generate a significant amount of revenue.

In addition, the outcomes discovered for natural resource abundance are positive and statistically significant across the observed quantiles lending credence to H1. From a statistical perspective, the impact of natural resources is statistically significant and positive in all quantile levels, with the coefficient decreasing from around 0.17 at the 10th quantile to 0.07 at the 90th quantile. Accordingly, the significant impact of natural resources on ecological footprints is expected in our sample of interest considering that the selected oil producers are natural-resources-rich. Studies to date have presented conflicting perspectives on the connection among natural resources and environmental degradation. On one hand, economic development, rising population, and the intensification of the industrial sector increase the demand for exploitation of natural resources, leading to more anthropogenic emissions. In addition, resource extraction is having adverse impacts on (i) biodiversity by destructing habitats; (ii) air, soil, and water quality by increasing the pollutant emissions and waste; (iii) subsidence by reducing the availability of fresh water and causing deforestation; and (iv) human health by altering ecosystems and causing climate change. Our study supports the positive association between natural resources and environmental degradation concurring with the findings of [13,19,24,50]. On the other hand, Xiaoman et al. [10] report the opposite suggesting that natural resources decrease the import of fossil fuels by discouraging their imports. In that vein, the pollutant emissions associated with fossil fuels are reduced supporting the transition towards green energy sources.

Fifth, economic globalization mitigates ecological footprints in the oil-producing countries (H2). These results are analogous to the findings of [1,10,14,65]. The economic development of oil producers is strongly dependent on natural resource exports. As such, economic globalization plays a critical role in the interactions between oil producers and the rest of the world. The results presented in Table 6 unveil that population, affluence, technology, and natural resources are increasing environmental degradation; thus, we observed the role of globalization (economic—Models 1 and 2 and trade—Models 3 and 4) in the model. Globalization is critical in adopting environmentally friendly technology. It can also increase the pace of technological diffusion providing a unique opportunity for environmental advancements. Due to the strong reliance on natural resource exports, globalization plays an important role in the economic development of oil-producing countries. The strong reliance on globalization (economic and trade) lies in the export of natural resources and also in the absorption and advancement of technology. Overall, from a statistical perspective, the impact of globalization is statistically significant and negative at middle (0.50) and higher (0.60–0.90) quantiles, with the coefficient decreasing from around −0.316 at the 10th quantile to −0.373 at the 90th quantile. These findings are robust to the measure of globalization. Consequently, the increasing affluence, population, technology, and intensive natural resource extraction and export significantly increase ecological footprints while trade globalization (Table 6, Models 3 and 4) is critical to environmental quality of oil-exporting countries.

Most importantly, this study gauged the joint effects of globalization and natural resources by including the interaction term of both the variables. Models 2 and 4 explain the role of globalization on ecological footprint with two instruments: (i.e., economic globalization—Model 2 and trade globalization—Model 4). Introduction of moderate globalization on natural resources in oil-producing countries offers some interesting findings. First, economic globalization negatively moderates the impact of natural resources on ecological footprint. The parameter estimates of LMod1 follow a decreasing negative trend and are significant across the median and above-average (0.60–0.90) ecological footprints of oil-producing countries. This implies that economic globalization improves environmental quality; however, the impact of natural resources is larger in Model 2 clearly suggesting that this impact is stronger when economic globalization is intensified. In addition, the findings of Model 4 concur with the findings of Model 2 suggesting that the parameter estimates of LMod2 follow an increasing negative trend implicating trade globalization in reducing environmental degradation of oil producers. The negative coefficient of globalization and its interaction term with natural resources outline that globalization effectively improves environmental quality. To be more specific, more globalized countries have experienced significant improvements in environmental quality. The positive coefficients of population, affluence, technology, and natural resources and the negative coefficient of globalization and its interaction term with natural resources verify that globalization seems the main source of environmental sustainability. Accordingly, we could argue that globalization is not complementary to natural resources in increasing ecological footprint and does not provoke a positive contribution to environmental degradation. This finding supports [10,65] who disclosed that globalization makes a positive contribution to environmental quality.

Finally, we evaluate the causal relationship between the inspected variables. Considering the presence of cross-sectional dependence and slope heterogeneity, this study employs the Dumitrescu and Hurlin (DH) panel causality test proposed by Dumitrescu and Hurlin [61]. The findings related to causal examinations are reported in Table 7.

The results presented in Table 7 suggest there is a unidirectional causal relationship from affluence and natural resources to ecological footprint but not the other way round. However, bidirectional causality relation was revealed between population, energy consumption, globalization, and ecological footprint. This implies that any innovations in population, affluence, technology, natural resources, and innovation have implications for ecological footprint. Moreover, any innovation in ecological footprint has implications for population, technology, and globalization.

**Table 7.** The DH Granger causality evidence.

| Null Hypothesis | Zbar-Stat | Prob. |
|---|---|---|
| LNHDI→LNFPEC | 2.688 [a] | 0.007 |
| LNFPEC→LNHDI | 1.319 | 0.187 |
| LNPRLF→LNFPEC | 2.678 [a] | 0.007 |
| LNFPEC→LNPRLF | 3.996 [a] | 0.000 |
| LNEIND→LNFPEC | 1.660 [c] | 0.097 |
| LNFPEC→LNEIND | 1.910 [c] | 0.056 |
| LNNR→LNFPEC | 2.119 [b] | 0.034 |
| LNFPEC→LNNR | 1.484 | 0.138 |
| LNEGL→LNFPEC | 4.486 [a] | 0.000 |
| LNFPEC→LNEGL | 2.013 [b] | 0.044 |
| LNTGL→LNFPEC | 2.046 [b] | 0.041 |
| LNFPEC→LNTGL | 2.942 [a] | 0.003 |

Note: [a] ($p < 0.01$), [b] ($p < 0.05$), [c] ($p < 0.10$).

## 5. Conclusions and Policy Implications

The current study collected balanced panel data for nine oil-producing countries from 1999 to 2018 to explore whether or not variables such as natural resources, globalization, and economic growth affect environmental sustainability by adopting the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT). With the abundance of natural resources in oil-exporting countries, these countries have witnessed substantial economic growth, which, as a result, might have a negative impact on the environment. This study strongly concludes in its findings that economic development, energy consumption, population, and natural resources contribute to increased environmental degradation for all investigated nine oil-producing counties. In the vein of these findings, globalization seems to be the main source of environmental sustainability in the sample of nine oil-producing countries. While regarding the indirect impacts of globalization, expanded interaction, and integration among oil-producing countries help to inhibit ecological footprint, natural resources complicate the design of a sustainable future by promoting environmental degradation. Furthermore, the empirical outcomes of the current study demonstrate that a hike in economic activities in oil-producing countries creates strong environmental pressure, and the implication of this can be found in the explosion of industrialization leading to more human-caused emissions causing environmental degradation. Herein, these countries are advised to push for alternatives for natural resources by implementing strategies to focus on renewable energy resources to prevent environmental degradation. Our findings urge governments to consider redistributing residential areas and lessen densely populated cities and encourage people to reside in the outskirts of bigger cities. This also opens new venues for innovation for urban planners and immigration lawmakers. Moreover, technology, captured by energy consumption in industry, is positively associated with ecological footprint. Thus, more strict policies should be made to maintain green and renewable energy consumption to carry out technology-related activities. Furthermore, outcomes discovered for natural resource abundance are positive and statistically significant regarding economic growth, which should raise awareness regarding environmental policies to maintain healthy water, soil, and diverse habitats in the nine oil-producing countries. The study also concludes that economic globalization alleviates ecological footprint in the oil-producing countries. Therefore, policymakers should align their strategic plans with global objectives of the well-developed countries. Moreover, governments should raise awareness among people regarding the negative effects of natural resources and economic growth on the environment. In addition, decision makers should focus on educating people on the benefits of globalization and provide opportunities for the appropriate training to adopt habits and gain skills useful for the environment. Governments are highly encouraged to devise policies for entrepreneurs, new businesses, and startups to lessen pollution and ultimately preserve the environment. In addition, innovators and new business owners and entrepreneurs should implement environment friendly technologies. Decision makers in the government should promote green business in their mission to preserve the environment while attracting investments. Due to data constraints, this study is restricted to the nine oil-producing countries. This obstacle could be overcome by including importing countries that might describe various impacts relevant to natural resources and economic growth on the environment. This study is further constrained by not investigating the short-run impacts. Although the panel quantile regression has many advantages, there are still some drawbacks. Inference on the parameters can get complicated because it predicts the impacts of heterogenous quartiles and does not provide mean estimates. In addition, it produces the results that are long-run in nature. Herein, it is advised that future studies consider identifying the relationship among variables of interest in the short run.

**Author Contributions:** Conceptualization, E.S.; methodology, E.S.; software, E.S.; validation, E.S.; formal analysis, E.S.; investigation, E.S.; resources, S.D, M.A., F.A.S.; data curation, E.S.; writing—original draft preparation, E.S., S.D., F.A.S., M.A.; writ-ing—review and editing, S.D., F.A.S., M.A.; visualization, E.S.; supervision, S.D., E.S.; project administration, E.S., S.D.; funding acquisition, S.D., M.A. All authors have read and agreed to the published version of the manuscript.

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## Appendix A

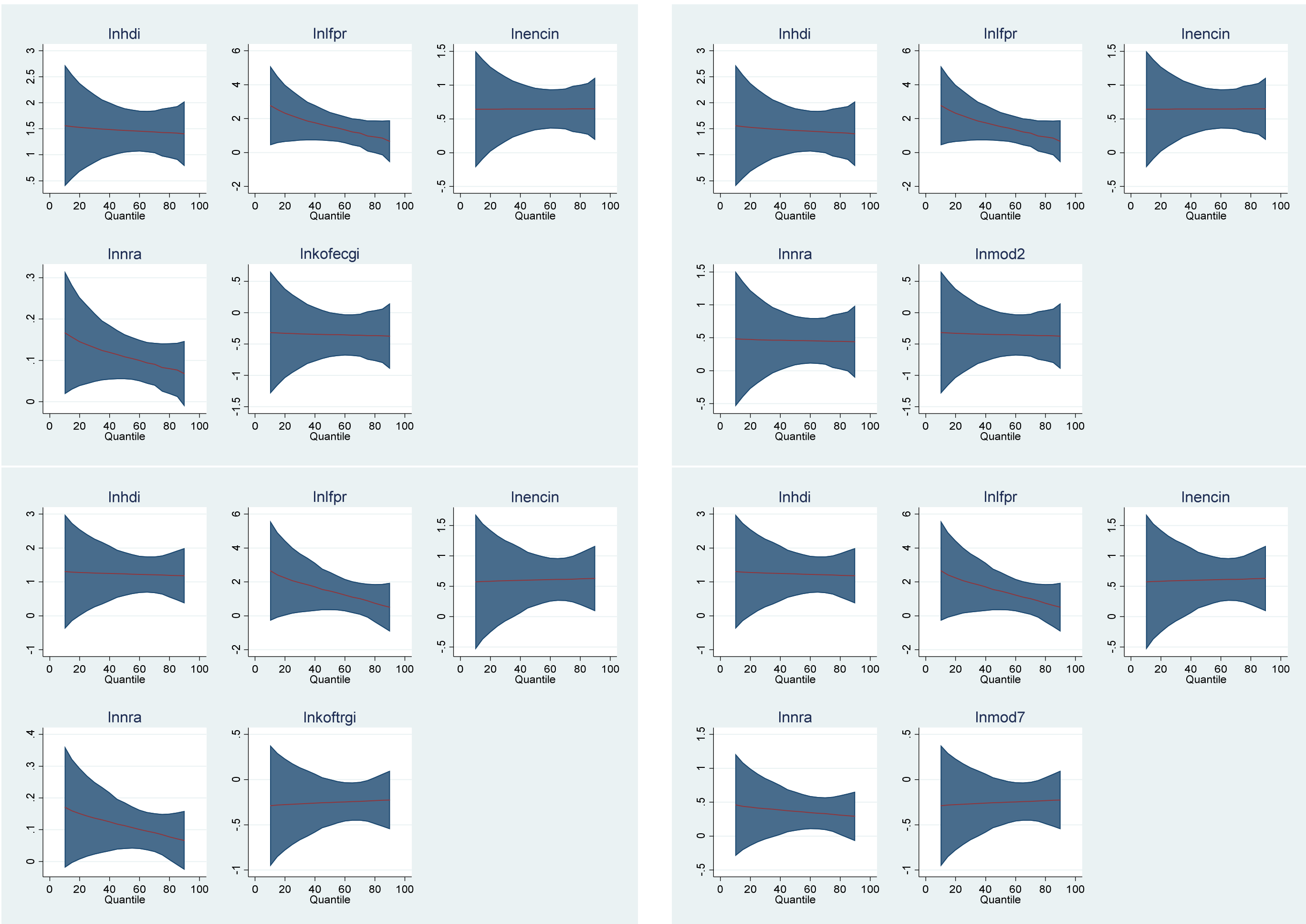


**Figure A1.** Plotting coefficients of quantile regression. Note: lnhdi = LHDI, lnlfpr = LPRFL, lnencoin = LEIND, lnnra = LNR, lnkofecgi = LEGL, lnkoftrgi = LTGL, lnmod2 = LMod1, lnmod7 = LMod2.

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