The Role of Labor Productivity in Reducing Carbon Emission Utilizing the Method of Moments Quantile Regression: Evidence from Top 40 Emitter Countries

Mohamed Khaled Al-Jafari¹ & Hatem Hatef Abdulkadhim Altaee²

¹ Professor of Finance, Former Dean of Graduate Studies, and Chair of Accounting & Finance, Brownsville, Texas, USA

² Professor of Economics, College of Administration and Financial Sciences. Cihan University, Sulaimani, Sulaymaniyah–Kurdistan Region, Iraq

Correspondence: Mohamed Khaled Al-Jafari, Professor of Finance, Former Dean of Graduate Studies, and Chair of Accounting & Finance. Brownsville, Texas 78526, USA. Tel: 1-956-408-5658.

| Received: January 1, 2023 | Accepted: January 30, 2023 | Online Published: February 2, 2023 |
|---------------------------|---------------------------------------|------------------------------------|
| doi:10.5539/ijef.v15n3p1 | URL: https://doi.org/10.5539/ijef.v15 | 5n3p1 |

Abstract

Global warming has become one of the most serious world-challenging issues nowadays, and much effort is being done to combat its consequences. Therefore, studying the trade-off between carbon emissions and economic activity remains an attractive subject for researchers. In this study, the environmental Kuznets curve (EKC) hypothesis is adopted to verify the trade-off between carbon dioxide emissions per capita and labor productivity in the top 40 emitter countries. Accordingly, a panel data from the top 40 emitter countries is employed from 1992 to 2018, and the novel method of moments quantile regression (MMQREG) is used to analyze the nexus among the variables. In addition, four robustness tests were used to validate the initial results. The findings reveal evidence for the N-shape EKC in the top 40 emitter countries. This indicates that economic growth initially will improve environmental quality up to a certain labor productivity level. However, after reaching a certain turning point, per capita CO_2 emission began to fall with rising labor productivity up to the second tipping point, and then, a subsequent phase of deterioration. Heterogeneous characteristics are, however, detected over the N-shape EKC. Like the conclusion reached from the MMQREG, the pooled ordinary least squares (POLS), the fixed-effects (FE), the random-effects (RE), and the fully modified ordinary least squares (FMOLS) all confirmed the existence of the N-shape hypothesis.

Keywords: carbon emission, labor productivity, Environmental Kuznets Curve, panel models, method of moments quantile regression

JEL Classification: F43, Q43, Q53, Q56.

1. Introduction

Since the early years of the 1980s, the world has realized the environmental risks surrounding it due to its excessive consumption of fossil fuels, which coincided with the industrial revolution and increased with the rise of global production activities. Environmental challenges can be classified as a global problem focused on global warming (ozone depletion), a global threat that needs a collective effort to minimize its effects. The second challenge is a local challenge related to environmental pollution, which is supposed to be faced locally and is, therefore, an internal problem.

According to the Intergovernmental Panel on Climate Change (IPCC), the rise in the temperature of the climate system has become unequivocal, and as a result, the world has witnessed since the 1950s, many changes, and phenomena that humanity has not experienced throughout history.

In the September 2019 IPCC report, "The Ocean and Cryosphere in a Changing Climate", the Intergovernmental Panel on Climate Change discussed the impacts of climate change on coastal, oceanic, polar, and mountain ecosystems, as well as the impacts on human communities that depend on these ecosystems (IPCC, 2019).

On the other hand, the international effort towards the inter-linkage between environment protection and economic development officially began in 1983 when the Secretary-General of the United Nations asked the

Norwegian Prime Minister Gro Harlem Brundtland to initiate and lead the World Commission on Environment and Development (WCED). As a result of the Commission's efforts, the report titled "Our Common Future" was established. The recommendations of that report spurred the Rio Summit or the Earth Summit, which was first coined by the United Nations in Rio de Janeiro, Brazil from June 3-14, 1992, and addressed issues related to the environment and sustainable development.

In 2015, the United Nations set the 17 sustainable development goals as a global call to end poverty, reduce inequality, and promote economic growth through strategies that bolster health, and education systems - all while addressing climate change and working to preserve our ecosystem.

Quite a few countries, regardless of their level of development, have begun to develop and implement national plans to address climate change and its harmful effects on countries as well as on the lives of individuals. Some of which have integrated the issue of addressing these damages into their development plans by increasing the ability of countries to finance and develop sustainability.

Therefore, this study's contribution to the literature can be viewed by investigating the tradeoff between labor productivity, as a proxy variable for economic activity, and CO_2 emissions in the top 40 emitter countries (Appendix I). In addition, the study utilized the novel method of moments quantile regression, with N-shape EKC for its investigation.

Accordingly, this paper is structured as follows: Section 2 presents a summary of the previous studies while data description, econometric models, and methodology are detailed in Section 3. The empirical findings and discussion are addressed in Section 4. Finally, the concluding remarks and recommendations are summarized in Section 5.

2. Literature Review

There are no shortages in the literature that studied and investigated the causes that led to the deterioration of environmental quality. Most previous studies have used economic and non-economic variables, in addition to different econometric methodologies to investigate factors that have an impact on the quality of the environment.

Starting with the most recent studies, Chen et al. (2022) investigated if labor productivity can reduce CO_2 emission. They utilized several models to include the pooled OLS, the fixed effect, and the random effect on 36 OECD countries and China. The findings support the N-Shape EKC hypothesis suggesting that carbon emission increases with labor productivity at an early stage, but after reaching a certain level, it starts to decline with the increase in labor productivity.

On the other hand, Tu et al. (2022) studied the effect of GDP, fossil fuel consumption, renewable energy electricity output, and energy efficiency on related CO_2 emissions. They utilized the method of moments quantile regression and the Granger causality test on 12 Regional Comprehensive Economic Partnership (RCEP) economies. The results show a positive and significant association between economic growth, energy consumption, and energy-related emissions, suggesting degradation of the environmental quality. In contrast, the renewable electricity output and energy efficiency exhibited a negative and significant association with CO_2 emissions indicating amelioration in the environmental quality.

Additionally, Ali et al. (2022) explored the impact of green energy, urban population, economic policy uncertainty, and per capita GDP on carbon dioxide emissions in BRICS countries. They utilized the cross-sectional autoregressive distributed lag technique to measure the short- and long-run effects of the previous variables on the environmental quality. The study concluded that economic growth and urbanization increased the emission of CO_2 . Contrary to green energy, which reduces carbon emission and decreases environmental deterioration.

Furthermore, Zou et al. (2022) studied the effect of the natural resource rent (NRR), financial development, and technological innovation on the ecological condition. They used annual data from 1991 to 2018 and employed the second-generation panel unit root, cointegration, and augmented mean group estimators on 90 Belt and Road Initiative (BRI) economies. The results showed a significant and negative effect of NRR on the quality of the environment. In contrast, technological innovation found to improve the ecological quality. The financial development variable provided mixed results. It improved the quality of the environment in the middle-income BRI economies and reduced it in high-and low-income BRI economies. The study encouraged policymakers to support green foreign investment and move into renewable energy sources.

Similarly, Huang et al. (2022) tested the effect of foreign direct investment (FDI) inflows on carbon emissions and utilized economic development and regulatory quality as moderators. They employed a panel data from 1996 to 2018 for the G20 economies and used the feasible generalized least squares method. The findings show a

positive association between FDI inflows and carbon emissions. However, this relationship was less severing in countries that have higher levels of economic development and regulatory quality. The study concluded that encouraging FDI inflows, supporting economic development, and improving regulatory quality will reduce CO_2 emissions and improve environmental quality. Also, Li et al. (2021) studied the linkage between economic growth, energy consumption, and carbon emissions in G20 countries from 1992 to 2014. The results suggested that economic growth and energy consumption enhanced carbon emissions, reducing ecological quality. Moreover, when the control variables of urbanization and foreign direct investments were used, the emissions of CO_2 were even increased in the G20 countries.

In the same way, Akadiri and Adebayo (2022) tested the asymmetric impact of financial globalization on CO_2 emissions in India from 1970 to 2008 utilizing the nonlinear autoregressive distributed lag technique. The results support the argument that economic and financial growth, in addition to non-renewable energy usage promotes carbon emissions and thus negatively affects the quality of the environment. In contrast, renewable energy found to reduce CO_2 emissions and improve the quality of the environment. Similar results were obtained by Hu et al., (2021) who tested the influence of energy resources on economic growth in India utilizing time series data from 1990 to 2018. The empirical results revealed that energy use and technology development promote economic growth and enhance carbon emissions. At the same time, renewable energy found to reduce CO_2 and improve the environmental quality.

Further, Nathaniel et al. (2021) studied the effect of economic growth on carbon emissions in some selected African countries from 1990 to 2014 utilizing static and dynamic models. The findings indicate that energy consumption is positively associated with economic growth supporting the argument that growth in Africa is an energy dependent. In contrast to some studies, no significant associations were found between economic growth and carbon emissions.

Likewise, Zhang (2021) examined the validity of the EKC hypothesis on carbon emissions in China. The study used the ARDL model and bounds test, in addition to the quantile regression method. The empirical findings reveal an N-shape relationship between carbon emissions and economic growth as measured by the GDP per capita. In addition, the study found a positive influence of energy consumption on carbon emissions leading to degradation of the quality of the environment. On the other hand, a negative impact was found between urbanization and carbon emissions suggesting an improvement indent the quality of the environment.

In addition, Zakari et al. (2021) evaluated the impact of energy utilization on environmental quality in 22 OECD countries between 1985 and 2017. The results revealed that in the long run, energy consumption and economic policy uncertainties have a negative effect on environmental quality. On the other hand, renewable energy found to have a positive effect and enhance the quality of the environment. Similar results were also obtained for the short run, where energy consumption and economic growth were found to have a negative impact on environmental quality.

From another perspective, Matsumoto et al. (2021) investigated the effect of climate change on labor productivity changes and ultimately economic growth as measured by the GDP. They employed two models: the computable general equilibrium model (CGE) and the earth system model of intermediate complexity (EMIC) on 129 regions and 57 sectors of the Global Trade Analysis Project (GTAP) database. The findings suggested that a continuous climate change reduced labor productivity in most regions and ultimately decreased global economic growth. Consequently, leading to lower emissions and concentration of CO_2 and improvement of environmental sustainability.

On the other hand, Mahapatra and Irfan (2021) conducted a comparative study on the effect of energy efficiency on CO_2 emissions. The study sample covered 28 developed countries and 34 developing countries from 1990 to 2017 and utilized a nonlinear panel autoregressive distributed lag model. The results indicated that a long-run improvement in energy efficiency reduces carbon emissions and promotes environmental quality. Similarly, Razzaq et al. (2021) used quarterly data from the US spanning from 1990 to 2017 and employed the bootstrapping ARDL modeling to investigate the cointegration among solid waste recycling, economic growth, carbon emissions, and energy efficiency. The study found that solid waste recycling promotes economic growth and reduces CO_2 emissions. The study also found that an increase in energy efficiency enhances economic growth and alleviates CO_2 emissions reflecting positively on the quality of the environment.

Another study by Akadiri et al. (2020) examined the effect of energy consumption, globalization, and economic growth on CO_2 emissions in Turkey from 1970 to 2014 utilizing the ARDL bounds testing technique and the Toda-Yamamoto Granger causality testing approach. The study revealed no significant effect of globalization on CO_2 emissions in Turkey. On the other hand, economic growth and electricity consumption enhanced carbon

emissions negatively affecting the quality of the environment. Similar results were obtained by Schröder and Storm (2020). They tested the effect of economic growth on CO_2 emissions in 58 countries of OECD from 2007 to 2015. The results of the fixed effect regression support the argument that economic growth significantly affected and enhanced emissions of CO_2 . In addition, the study in contrast to Chen et al. (2022) found no link or support for the EKC hypothesis.

Finally, Saidi and Omari (2020) examined the effectiveness of utilizing renewable energy on economic growth and CO_2 emissions. The study used a sample from 1990 to 2014 from 15 major renewable energy-consuming countries and employed the fully modified ordinary least squares technique and the Vector error correction model. The findings reveal that an increase in the utilization of renewable energy will enhance economic growth, reduce carbon emissions, and improve the quality of the environment.

In summary, most previous studies support the findings that an increase in energy consumption promotes economic growth at the expense of environmental quality. Alternatively, renewable energy consumption is found to be another way for enhancing economic growth without degradation of the ecological quality.

3. Data and Methodology

3.1 Research Strategy

To assess the possible existence of the N-shape EKC for the 40 highest carbon dioxide emitter countries, several estimation techniques were used, taking into consideration the possibility of some issues we might encounter such as the nonnormality, cross-sectional dependency, and the non-stationarity of the variables in our panel.

Figure 1 exhibits the econometric mechanisms through which the effects of labor productivity on CO_2 emissions are going to be tested.



Figure 1. Econometric mechanisms

Source: Own research.

3.2 Data

The dataset used in this study is a panel of (N = 40) for the period 1992 to 2018 (T = 27). Series on per capita CO_2 emissions, measured in millions of metric tons are extracted from Energy Information Administration (EIA), (Available: https://www.eia.go), while series on labor productivity are defined as gross domestic product (GDP) divided by employment. GDP is extracted from the World Bank, World Development Indicators, https://databank.worldbank.org.

3.3 The Econometric Models

Following the works of Chen et al. (2022), we use labor productivity as a proxy of economic activity instead of the widely used per capita GDP. The widely used indicate i.e. per capita CO_2 emissions is utilized as an environmental indicator. The validity of using labor productivity as an indicator for economic development comes from the fact that productivity growth is the key driver of sustainable income growth and poverty reduction (Dieppe, 2021). Productivity is the single most important contributor to living standards in the long run. The justification for adopting carbon dioxide to represent the environment is that it accounts for 76% of all greenhouse gas emissions according to the United States Environmental Protection Agency (EPA) (US-EPA, 2022).

The EKC model for this study with the incorporation of labor productivity is expressed in Equation 1:

LnCO2PC = f(LnPROD)

(1)

To confirm the rationality of the EKC hypothesis in Equation (1), we introduced the square of labor productivity into Equation (2) to count for a U or inverted U shape of EKC. Hence, LnPRODSQ is included as an explanatory variable to mitigate the environmental problems (Qamruzzaman, 2021; Andriamahery & Qamruzzaman, 2022). The cubic term of labor productivity (LnPRODQU) is added to allow two turning points. Hence, to capture both N and the converted N shape of EKC specification or to the possibility of environmental quality and economic growth in the long-term (Shafik & Bandyopadhyay, 1992; Grossman & Krueger, 1995; Torras & Boyce, 1998, among others). The base nonlinear EKC, namely the cubic form, specification of Equation 1, is as follows:

$$LnCO2PC_{it} = \alpha_{it} + \beta_1 LnPROD_{it} + \beta_2 LnPRODSQ_{it} + \beta_3 LnPRODQU_{it} + \varepsilon_{it}$$
(2)

The coefficient α_{it} refers to the intercept, β_i refers to the coefficients in the regression model. The term Ln stands for natural logarithm and ε_{it} is the error term and is assumed to be independent and normally distributed.

Bearing in mind the number of countries included in this research and the results of the normality tests, it is necessary to employ a heterogeneous panel model. By doing so, one can handle the problems created by the violation of the normality assumption and the presence of outlier's problems in the ordinary least squares (OLS) and related alternative methods (Zhu et al., 2018), the novel method of moments quantile regression as introduced by Koenker and Bassett (1978) will be used to examine the influence of labor productivity on the CO_2 across different classes of quantile. In this study, we tested the relation in equation (2) at the 5th, 25th, 50th, 75th and 95th, quantiles as below:

$$Q_{0.05}(LnCO2PC_{it}) = \alpha_{0.05} + \beta_{0.05,1}LnPROD_{it}) + \beta_{0.05,2}(LnPRODSQ_{it}) + \beta_{0.05,3}(LnPRODQU_{it}) + \varepsilon_{0.05,it}$$
(3)

$$Q_{0.25}(LnCO2PC_{it}) = \alpha_{0.25} + \beta_{0.25,1}LnPROD_{it}) + \beta_{0.25,2}(LnPRODSQ_{it}) + \beta_{0.25,3}(LnPRODQU_{it}) + \varepsilon_{0.25,it}$$
(4)

$$Q_{0.50}(LnCO2PC_{it}) = \alpha_{0.50} + \beta_{0.50,1}LnPROD_{it}) + \beta_{0.50,2}(LnPRODSQ_{it}) + \beta_{0.50,3}(LnPRODQU_{it}) + \varepsilon_{050,it}$$
(5)

$$Q_{0.75}(LnCO2PC_{it}) = \alpha_{0.75} + \beta_{0.75,1}LnPROD_{it}) + \beta_{0.75,2}(LnPRODSQ_{it}) + \beta_{0.75,3}(LnPRODQU_{it}) + \varepsilon_{0.75,it}$$
(6)

$$Q_{0.95}(LnCO2PC_{it}) = \alpha_{0.95} + \beta_{0.95,1}LnPROD_{it}) + \beta_{0.95,2}(LnPRODSQ_{it}) + \beta_{0.95,3}(LnPRODQU_{it}) + \varepsilon_{0.95,it}$$
(7)

We have used the new estimation method of moments (MMQREG) proposed by Machado and Santos Silva (2019). The polynomial specification of the EKC hypothesis can be resulted in several forms of the relationship between environmental quality and economic activity. Table 1 shows the different types of association of the EKC hypothesis. On the other hand, the quantile regression model considers the different effects of the trade-off between labor productivity and CO_2 emissions without controlling for heterogeneity, while the classical panel data regression model only controls heterogeneity with a conditional mean. If the independent variable's effect on carbon emissions per capita varies significantly among quantiles, the results of the panel quantile regression should be more robust to other models' results.

| Type of association | β_1 value | β_2 value | β_3 value |
|--|-----------------|-----------------|-----------------|
| N-Shape (cubic polynomial) LnPROD-LnCO2PC relationship | Positive | Negative | Positive |
| Inverted N-shape LnPROD-LnCO2PC relationship | Negative | Positive | Negative |
| Flat pattern or no LnPROD-LnCO2PC relationship | Zero | Zero | Zero |
| Inverted U-shaped LnPROD-LnCO2PC relationship | Positive | Negative | Zero |
| U-shaped LnPROD-LnCO2PC relationship | Negative | Positive | Zero |
| Monotonic increasing LnPROD-LnCO2PC relationship | Positive | Zero | Zero |
| Monotonic decreasing LnPROD-LnCO2PC relationship | Negative | Zero | Zero |

Table 1. Different types of EKC hypothesis

4. The Empirical Findings and Analysis

Our sample consists of the top 40 carbon dioxide emitter countries between 1992 and 2018. The final sample has 1,080 country-year observations.

4.1 The Results of Normality Tests

According to Baissa and Rainey (2020), the violation of the normal assumption would yield no robust OLS. Therefore, before implementing the econometric model estimations, two normality tests were performed on all

variables. The two normality tests used are the Shapiro-Wilk (Royston, 1995), and the Shapiro-Francia W' test (Shapiro & Francia, 1972).

All test results reported in Table 2 have a p-value smaller than 0.01, which suggests that all tested variables are significantly non-normally distributed. Accordingly, the classical ordinary least squares method will give biased and non-robust results. Fortunately, the quantile regression proves to be capable of handling such a problem.

| Variable | Oha | Shapiro-Francia W' test | | Shapiro-Wilk W test | | |
|----------|-------|-------------------------|-------|---------------------|-------|--|
| | Obs. | Statistic | Sig. | Statistic | Sig. | |
| LnCO2PC | 1,080 | 7.343*** | 0.000 | 7.805*** | 0.000 | |
| LnPROD | 1,080 | 8.439*** | 0.000 | 9.005*** | 0.000 | |
| LnPRODSQ | 1,080 | 8.306*** | 0.000 | 8.868*** | 0.000 | |
| LnPRODQU | 1,080 | 8.384*** | 0.000 | 8.951*** | 0.000 | |

Table 2. The results of normality tests

Note. *** significant at 1% sig. level.

4.2 Descriptive Statistics

Table 3 summarizes the basic features of the panel used in this study. The results show that the carbon dioxide (LnCO2PC) is negatively skewed and has heavy tails. The probability values of the Jarque–Bera statistics suggest the rejection of the null hypothesis. Therefore, all variables of the model are not normally distributed.

| Variable Statistics | LnCO2PC | LnPROD | LnPRODSQ | LnPRODQU |
|---------------------|---------|--------|----------|----------|
| Mean | 1.513 | 9.921 | 99.754 | 1015.333 |
| Maximum | 3.768 | 11.685 | 136.536 | 1595.403 |
| Minimum | -1.883 | 7.119 | 50.681 | 360.802 |
| Std. Dev. | 1.024 | 1.150 | 22.364 | 330.305 |
| Skewness | -0.650 | -0.368 | -0.202 | -0.054 |
| Kurtosis | 3.137 | 2.097 | 1.901 | 1.778 |
| Jarque-Bera | 76.925 | 60.999 | 61.671 | 67.738 |
| Probability | 0.000 | 0.000 | 0.000 | 0.000 |
| Observations | 1080 | 1080 | 1080 | 1080 |

Table 3. Summary statistics of the dependent and independent variables

4.3 The Homogeneity Tests Results

In this subsection, we intend to test slope homogeneity. In this regard two tests will be employed, Pesaran and Yamagata (2008), and Blomquist and Westerlund (2013). The latter test allows for heteroskedastic and serially correlated errors (Bersvendsen & Ditzen, 2021).

| Table 4. | The | findings | of the | slope | homog | eneity | tests |
|----------|-----|----------|--------|-------|-------|--------|-------|
| | | | | | | | |

| | Pesaran and Yar | magata | Blomquist and W | esterlund |
|----------------------|--------------------|-----------------------------------|-----------------|-----------|
| | Δ statistic | Δ <i>statistic</i> p-value | | p-value |
| Â | 39.173*** | 0.000 | 17.207*** | 0.000 |
| $\hat{\Delta}_{adj}$ | 43.396*** | 0.000 | 19.062*** | 0.000 |

Note. **** significant at 1% sig. level.

The empirical results, shown in Table 4, suggest that the null hypothesis of slope homogeneity rejected the $\hat{\Delta}$ and $\hat{\Delta}_{adi}$ statistics, suggesting the existence of slope heterogeneity. As such, the estimation technique used should consider this matter.

4.4 The Findings of Cross-Sectional Dependence Tests

After realizing normality distribution tests, it is necessary to identify the presence of cross-sectional dependence (CSD).

| Variable | Breusch-Pagan LM | Pesaran scaled LM | Bias-corr. scaled LM | Pesaran CD |
|----------|---------------------|----------------------|----------------------|---------------------|
| LnCO2PC | 9353.95*** (0.0000) | 217.080*** (0.0000) | 216.310*** (0.0000) | 10.101 *** (0.0000) |
| LnPROD | 13802.2*** (0.0000) | 329.702 *** (0.0000) | 328.933 *** (0.0000) | 99.154*** (0.0000) |
| *** | | | | |

Table 5. Results of dependency tests

Note. **** significant at 1% sig. level.

Table 5 displays the tests results of Breusch and Pagan (1980), Pesaran (2004) scaled LM, Baltagi et al. (2012) bias-corrected scaled LM, and Pesaran (2015) cross-sectional dependence test statistics. The results from the various tests indicated that the null hypothesis of cross-sectional independence is rejected at a significant level of 1 percent. This indicates that labor productivity shares a common impact on CO_2 emission in the top 40 carbon emitters countries.

4.5 The Results of the Unit Root Tests

Having accomplished the cross-section dependence tests, it is necessary to verify the order of the variables in the panel. However, the first-generation unit root tests could not be robust in the presence of CSD. Accordingly, unit root tests that control for the CSD are known as second-generation tests were employed. The results of both constant, and constant and trend conditions are presented in Table 6. The coefficient of LnCO2PC and LnPROD is significant at 1% at both intercept and intercept and trend at the first difference, meaning that they are integrated in an order of one.

Table 6. The results of the second-generation panel unit root tests

| X7 · 11 | | CIPS | | | | CADF | | | |
|----------|------------------------|--------|-----------|-----------|------------------|--------|-----------|-----------|--|
| variable | Level First difference | | Level | | First difference | | | | |
| | constant | trend | constant | trend | constant | trend | constant | trend | |
| LnCO2PC | -2.004 | -2.196 | -4.625*** | -4.766*** | -0.961 | 1.67 | -9.318*** | -6.501*** | |
| LnPROD | -2.295 | -2.362 | -3.409*** | -3.585*** | -4.901*** | -1.222 | -5.702*** | -2.821*** | |
| | | | | | | | | | |

Note. *** significant at 1% sig. level.

4.6 Cointegration Tests Result

Based on what has been done so far, the next step is to investigate if any long-run relationship is present among the variables. Therefore, the study uses three cointegration tests, namely: Westerlund (2005), Pedroni (1999), and Kao (1999) cointegration tests as reported in Tables 7, 8, and 9. Results suggest that there are a cointegration relationship between variables at least at the 5% significant level.

Table 7. Westerlund test results

| Test | Statistic | p-value |
|----------------|-----------|---------|
| Variance ratio | 1.7283** | 0.0420 |

Note. ** denote the rejection of no cointegration at the 5% sig. level.

Table 8. Pedroni cointegration tests results

| Test | Statistic | p-value |
|--------------------------|------------|---------|
| Modified Phillips-Perron | 2.3241** | 0.0101 |
| Phillips-Perron | -5.0049*** | 0.0000 |
| Augmented Dickey-Fuller | -4.5689*** | 0.0000 |

Note. ** and *** denote the rejection of no cointegration at the 5% and 1% sig. level respectively.

Table 9. Kao cointegration tests results

| Test | Statistic | p-value |
|-----------------------------------|-----------|---------|
| Modified Dickey-Fuller | 2.1659** | 0.0152 |
| Augmented Dickey-Fuller | 2.1548** | 0.0156 |
| Unadjusted modified Dickey-Fuller | 1.6999** | 0.0446 |

Note. ** denote the rejection of no cointegration at the 5% sig. level.

4.7 The Results of MMQREG, POLS, FE, RE, and FMOLS Tests

In this section, firstly, we provide the results of the method of moments quantile regression. As stated earlier, this technique was considered appropriate for the analysis of the used panel. In the step following, we compare the results of the selected models for checking the robustness of our initial results. The robustness test models include the panel least quarters, individual fixed effect model, random effect model, and the fully modified ordinary least squares model.

| Variable | Location | Scale | 0.05 | 0.25 | 0.50 | 0.75 | 0.95 |
|-----------|-----------|----------------|--------------|--------|---------------|----------------|------------|
| LnPROD | 16.443*** | 17.535*** | -11.087** | 1.2580 | 11.227*** | 29.203**** | 59.908*** |
| LnPRODSQ | -1.568*** | -1.850** | 1.336*** | 0.0334 | -1.017^{**} | -2.913*** | -6.152*** |
| LnPRODQU | 0.0515*** | 0.0640^{***} | -0.0490**** | -0.004 | 0.0324^{*} | 0.0981^{***} | 0.210**** |
| Constant | -57.53*** | -53.998*** | 27.247^{*} | -10.77 | -41.47*** | -96.826*** | -191.40*** |
| EKC shape | Ν | Ν | N Converted | NO | Ν | Ν | Ν |

Table 10. The results of the method of moments quantile regression

Note. ** and *** denote significant at the 5% and 1% sig. level respectively.

The estimated results obtained from MMQREG are presented in Table 10 and a visual representation of the results compared to OLS is depicted in Figure 2.



Figure 2. Plot of estimated coefficients from OLS regression and MMQREG

Source: Own Research.

The figure above illustrates the heterogeneous trade-off of the labor productivity along with the entire conditional CO_2 distribution. The horizontal lines between the doted two lines are the OLS estimates and are constants as expected, while the confidence intervals are the areas bordered by the two dashed lines. Whereas the effects and corresponding confide intervals obtained by quantile regression are denoted by a red line and shaded area in each graph.

The top right-hand plot displays that the coefficient of LnPROD is positive and increasing over the entire range. Similarly, the coefficient of LnPRODQU is lower in its magnitude than the OLS estimate, for quantiles lower than the 60th quantile, and is higher than the OLS coefficient around upper quantiles. The square term of productivity, LnPRODSQ term shows a different picture. It has a negative slope indicating the N shape of the trade-off between CO_2 and productivity. Moreover, all coefficients are outside the confidence intervals of the OLS estimates, and hence, are significantly different from the OLS coefficients.

The estimated results obtained from MMQREG countries are provided in Table 10. We find N- Shape EKC for labor productivity from the 50th up to the 95th quantiles. No significant trade-off between environmental quality has been outlined at the 25th quantile. Hence, heterogeneous characteristics are detected over the N-shaped EKC in the lowest quantile, our result shows an inverted N-shaped EKC. This indicates that economic activity, proxied by labor productivity, initially will increase CO_2 emissions up to a certain threshold, where the relationship instead will be positive then it converted to be negative again, which we found it difficult to explain.

One additional point that deserved to be mentioned is the significant localization and scale results that validate the use of the MMQREG approach. The N-shape gives rise to the possibility of environmental degradation returns at very high levels of economic growth.

On the other hand, Table 11 reports the estimated results of the diagnostics tests i.e., POLS, FE, RE, and FMOLS models and shows a trade-off between labor productivity and CO_2 emission, with a very strong and significant relationship.

| | POLS | Fixed effect | Random effect | FMOLS |
|-----------|---------|--------------|---------------|--------|
| LnLPROD | 16.444 | 13.122 | 13.066 | 17.068 |
| LnLPRODSQ | -1.568 | -1.179 | -1.177 | -1.622 |
| LnLPRODQU | 0.052 | 0.036 | 0.036 | 0.052 |
| Constant | -57.534 | -47.369 | -47.147 | |
| sigma_u | | 0.687 | 0.629 | |
| sigma_e | | 0.146 | 0.146 | |
| Rho | | 0.957 | 0.949 | |
| R-Sq | 0.616 | | | 0.98 |

Table 11. The results of the POLS, FE, RE, and FMOLS models

Digging deeper into the results of the four diagnoses models, the N-shape relationship between environmental burden and economic growth is confirmed. Another notable point in our finding is that the sign, magnitude, and significance of all parameters are similar. Moreover, the results of the conditional mean models coincide with those of the method of moment quantile regression for the 50th quantile and up to the 95th quantile.

5. Conclusion and Recommendations

This study aims to inspect the trade-off between economic activity proxied by labor productivity, on the quality of the environment for the 40 top CO_2 emitter countries. The study uses a panel data ranging from 1992 to 2018. The main technique used for the analysis is the novel method of moments quantile regression. In addition, four robustness tests were used to validate the initial results.

The most crystal fact in the obtained results is the heterogeneous effects of labor productivity on the quality of the environment. The results show no significant impact of labor productivity on the environmental quality in the 25th quantile and found inverted N shape relationships in the quantiles below.

The estimated coefficients associated with the quadratic term have negative coefficients, statistically significant, and increase in the 50th, 75th, and 95th quantiles. This indicates that economic growth proxied by labor productivity, initially will improve environmental quality up to a certain threshold. The relationship will be positive, and then it converts to be negative again, which we found difficult to explain. The N-shape gives rise to the possibility of environmental degradation returns at very high levels of economic growth. Based on the research findings, future carbon emission reduction must be the imperative goal for present and future environmental preservation.

References

- Akadiri, S., Alola, A., Olasehinde-Williams, G., & Etokakpan, M. U. (2020). The role of electricity consumption, globalization and economic growth in carbon dioxide emissions and its implications for environmental sustainability targets. *Sci Total Environ.* 708, 134653. https://doi.org/10.1016/j.scitotenv.2019.134653.
- Akadiri, S. S., & Adebayo, T. S. (2022). Asymmetric nexus among financial globalization, non-renewable energy, renewable energy use, economic carbon emissions: Impact on environmental sustainability targets in India. *Environmental Science and Pollution Research*, 29(11), 16311-16323. https://doi.org/10.1007/s11356-021-16849-0
- Ali, S., Jiang, J., Ahmad, M., Usman, O., & Ahmed, Z. (2022). A path towards carbon mitigation amidst economic policy uncertainty in BRICS: An advanced panel analysis. *Environmental Science and Pollution Research*, 29(41), 62579-62591. https://doi.org/10.1007/s11356-022-20004-8.
- Andriamahery, A., & Qamruzzaman, M. (2022). A symmetry and asymmetry investigation of the nexus between environmental sustainability, renewable energy, energy innovation, and trade: Evidence from environmental Kuznets curve hypothesis in selected MENA countries. *Front. Energy Res.*, 9, 778202. https://doi.org/10.3389/fenrg.2021.778202

- Baissa, D. K., & Rainey, C. (2020). When BLUE is not best: non-normal errors and the linear model. *Political Science Research and Methods*, 8(1), 136-148. https://doi.org/10.1017/psrm.2018.34
- Baltagi, B. H., Feng, Q., & Kao, C. (2012). A Lagrange multiplier test for cross-sectional dependence in a fixed effects panel data model. *Journal of Econometrics*, 170(1), 164-177. https://doi.org/10.1016/j.jeconom.2012.04.004
- Bersvendsen, T., & Ditzen, J. (2021). Testing for slope homogeneity in Stata. *The Stata Journal*, 21(1), 51-80. https://doi.org/10.1177/1536867X211000004
- Blomquist, J., & Westerlund, J. (2013). Testing slope homogeneity in large panels with serial correlation. *Economics Letters*, 121(3), 374-378. https://doi.org/10.1016/j.econlet.2013.09.012
- Breusch, T., & Pagan, A. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *Review of Economic Studies*, 47(1), 239-253. https://doi.org/10.2307/2297111
- Chen, X., Ma, W., & Valdmanis, V. (2022). Can labor productivity growth reduce carbon emission? Evidence from OECD countries and China. *Management of Environmental Quality*, 33(3), 644-656. https://doi.org/10.1108/MEQ-10-2021-0240
- Dieppe, A., Celik, A. K., & Kindberg-Hanlon, G. (2020). *Global Productivity Trends, in Global Productivity: Trends, Drivers, and Policies*, ed. A. Dieppe. Washington, DC: World Bank.
- Elbatanony, M., Attiaoui, I., Ali, I. M. A., Nasser, N., & Tarchoun, M. (2022). The environmental impact of remittance inflows in developing countries: Evidence from method of moments quantile regression. *Environmental Science and Pollution Research, Forthcoming.* https://doi.org/10.21203/rs.3.rs-186596/v
- Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics*, 110(2), 353-377. https://doi.org/10.2307/2118443
- Hu, K., Raghutla, C., Chittedi, K. R., Zhang, R., & Koondhar, M. A. (2021). The effect of energy resources on economic growth and carbon emissions: A way forward to carbon neutrality in an emerging economy. *Journal of Environmental Management*, 298, 113448. https://doi.org/10.1016/j.jenvman.2021.113448
- 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. *Front. Energy Res.*, 9, 820596. https://doi.org/10.3389/fenrg.2021.820596
- IPCC. (2019). Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC).
- Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. Journal of Econometrics, 90(1), 1-44. https://doi.org/10.1016/S0304-4076(98)00023-2.
- Koenker R., & Bassett, Jr. G. (1978). Regression quantiles. *Econometrica* 46(1), 33-50. https://doi.org/10.2307/1913643.
- Li, K., Hu, E., Xu, C., Musah, M., Kong, Y., Mensah, I. A., Zu, J., Jiang, W., & Su, Y. (2021). Heterogeneous analysis of the Nexus between energy consumption, economic growth, and carbon emissions: Evidence from the group of twenty (G20) countries. *Energy Exploration & Exploitation*, 39(3), 815-837. https://doi.org/10.1177/0144598720980198.
- Machado, J. A. F., & Santos, S. J. M. C. (2019). Quantiles via moments. *Journal of Econometrics*, 213(1), 145-173. https://doi.org/10.1016/j.jeconom.2019.04.009
- Mahapatra, B., & Irfan, M. (2021). Asymmetric impacts of energy efficiency on carbon emissions: A comparative analysis between developed and developing economies. *Energy*, 227, 120485. https://doi.org/10.1016/j.energy.2021.120485
- Matsumoto, K., Tachiiri, K., & Su, X. (2021). Heat stress, labor productivity, and economic impacts: Analysis of climate change impacts using two-way coupled modeling. *Environmental Research Communications*, *3*(12). https://doi.org/10.1088/2515-7620/ac3e14
- Nathaniel,S., Barua, S., Hussain, H., & Adeleye, N. (2021). The determinants and interrelationship of carbon emissions and economic growth in African economies: Fresh insights from static and dynamic models. *Journal of Public Affairs*, 21(1), e2141. https://doi.org/10.1002/pa.2141.
- Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics, 61(S1), 653-670. https://doi.org/10.1111/1468-0084.0610s1653
- Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. Econometric Reviews, 34(6-10),

1089-1117. https://doi.org/10.1080/07474938.2014.956623

- Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. *Cambridge Working Papers in Economics*, 435.
- Pesarana, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, 142(1), 50-93. https://doi.org/10.1016/j.jeconom.2007.05.010
- Qamruzzaman, M. (2021). Nexus between environmental quality, institutional quality, and trade openness through the channel of FDI: An application of common correlated effects estimation (CCEE), NARDL, and asymmetry causality. *Enviro. Sci Pollut Res Int.*, 28(37), 52475-52498. https://doi.org/10.1007/s11356-021-14269-8
- Razzaq, A., Sharif, A., Najmi, A., Tseng, M. L., & Lim, M. K. (2021). Dynamic and causality interrelationships from municipal solid waste recycling to economic growth, carbon emissions and energy efficiency using a novel bootstrapping autoregressive distributed lag. *Resources, Conservation and Recycling*, 166, 105372. https://doi.org/10.1016/j.resconrec.2020.105372
- Royston, P. (1995). Remark as R94: A remark on algorithm as 181: The W-test for normality. *Journal of the Royal Statistical Society*, 44(4), 547-551. https://doi.org/10.2307/2986146
- Saidi, K., & Omri, A. (2020). The impact of renewable energy on carbon emissions and economic growth in 15 major renewable energy-consuming countries. *Environmental Research*, 186, 109567. https://doi.org/10.1016/j.envres.2020.109567
- Schröder, E., & Storm, S. (2020). Economic growth and carbon emissions: The road to "hothouse earth" is paved with good intentions. *International Journal of Political Economy*, 49(2), 153-173. https://doi.org/10.1080/08911916.2020.1778866
- Shafik, N., & Bandyopadhyay, S. (1992). Economic growth and environmental quality: Time series and cross-country evidence. *World Bank Policy Research Working Paper, WBS 904*.
- Shapiro, S. S., & Francia, R. S. (1972). An approximate analysis of variance test for normality. *Journal of the American Statistical Association*, 67(337), 215-216. https://doi.org/10.1080/01621459.1972.10481232
- Torras, M., & Boyce, J. K. (1998). Income, inequality, and pollution: A reassessment of the environmental Kuznets curve. *Ecological Economics*, 25(2), 147-160. https://doi.org/10.1016/S0921-8009(97)00177-8
- Tu, Z., Feng, C., & Zhao, X. (2022). Revisiting energy efficiency and energy related CO₂ emissions: Evidence from RCEP economics. *Economic Research-Ekonomska Istraživanja*, 35(1), 5858-5878. https://doi.org/10.1080/1331677X.2022.2038651
- WCES. (1987). World Commission on Environment and Development, Our common future. Oxford: Oxford University Press.
- Westerlund, J. (2005). New simple tests for panel cointegration. *Econometric Reviews*, 24(3), 297-316. https://doi.org/10.1080/07474930500243019
- Zakari, H., Adedoyin, F. F., & Bekun, F. V. (2021). The effect of energy consumption on the environment in the OECD countries: Economic policy uncertainty perspectives. *Environmental Science and Pollution Research*, 28, 52295-52305. https://doi.org/10.1007/s11356-021-14463-8
- Zhang, J. (2021). Environmental Kuznets curve hypothesis on CO₂ emissions: Evidence for China. *Journal of Risk and Financial Management*, 14(93). https://doi.org/10.3390/jrfm14030093
- Zhu, H., Li, Z., & Guo, P. (2018). The impact of income, economic openness, and interest rates on housing prices in China: Evidence from dynamic panel quantile regression. *Applied Economics*, 50(38), 4086-4098. https://doi.org/10.1080/00036846.2018.1441512
- Zuo, S., Zhu, M., Xu, Z., Ol ah, J., & Lakner, Z. (2022). The dynamic impact of natural resource rents, financial development, and technological innovations on environmental quality: Empirical evidence from BRI economies. *International Journal of Environmental Research and Public Health*, 19(1), 130. https://doi.org/10.3390/ijerph19010130

| No. | Country | No. | Country | No. | Country | No. | Country |
|-----|------------------|-----|-------------|-----|--------------------|-----|----------------|
| 1 | Algeria | 11 | France | 21 | Malaysia | 31 | Singapore |
| 2 | Argentina | 12 | Germany | 22 | Mexico | 32 | South Africa |
| 3 | Austria | 13 | Greece | 23 | Morocco | 33 | Spain |
| 4 | Bangladesh | 14 | Hungary | 24 | Netherlands | 34 | Sweden |
| 5 | Belgium | 15 | India | 25 | Pakistan | 35 | Thailand |
| 6 | Brazil | 16 | Indonesia | 26 | Peru | 36 | Turkey |
| 7 | Chile | 17 | Italy | 27 | Portugal | 37 | Ukraine |
| 8 | China | 18 | Japan | 28 | Romania | 38 | United Kingdom |
| 9 | Colombia | 19 | Kazakhstan | 29 | Russian Federation | 39 | United States |
| 10 | Egypt, Arab Rep. | 20 | Korea, Rep. | 30 | Saudi Arabia | 40 | Vietnam |

Appendix I. List of the 40 highest CO₂ emitters countries

Source: Own Research.

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/4.0/).