The Effect of Export Quality, Energy Efficiency, and Economic Complexity on CO_2 Emissions in the Emerging Economies: A Two-step DEA Model and Panel Quantile Regression

Fariba Osmani[1], Zahra Shirzour Aliabadi[2], Emad Kazemzadeh[3], Mohammad Taher Ahmadi Shadmehri[3]*

1,3 Department of Economics, Faculty of Economics and Administrative Sciences, Ferdowsi University of Mashhad, Mashhad, Iran
2 Assistant Professor, Department of Management, Faculty of Literature and Humanities, University of Birjand, Birjand, Iran
2* Associate Professor, Department of Economics, Faculty of Economics and Administrative Sciences, Ferdowsi University of Mashhad, Mashhad, Iran

Journal of Advanced Environmental Research and Technology

Vol. 1, No.4
page 1-21 ,fall 2023
***
Received 05 augest 2023
Accepted 21 augest 2023

Abstract

Today, carbon dioxide emission is one of the concerns of all countries in the world, so in this paper, we examine the effect of export quality, energy efficiency, and economic complexity on CO_2 emissions per capita from 1990 to 2014 in emerging economies. For this purpose, first, energy efficiency is calculated using mathematical programming methods (DEA). Then, the effect of export quality, energy efficiency, and economic complexity on per capita carbon dioxide emissions in the panel of emerging economies is investigated using panel quantile regression. The analysis of energy efficiency reveals a steady improvement in the average efficiency of the countries studied from 1990 to 2014. Among these nations, China recorded the lowest efficiency score. Additionally, the results from the quantile regression suggest that export quality and per capita fossil fuel consumption significantly contribute to increases in CO_2 emissions per capita across all levels of the data distribution. The results also show that the coefficient increases by moving in the level of quantiles, so that the highest effect coefficient of export quality on carbon dioxide emission is related to the quantile 90th and about .874. Energy efficiency has a negative and significant effect in all quantiles except the 90th, and the highest coefficient of influence (0.133) is related to quantile 10th. The increase in economic complexity increases the CO_2 emissions in all quantiles except the 10th, and the highest coefficient (about 0.487) is related to the quantile 90th. The trade openness index has a negative and statistically significant effect on CO_2 emissions per capita. Urbanization has different effects on carbon dioxide emissions in different quantiles. The empirical implications of this study help to guide the sustainable development policies of emerging economies.

key words

CO_2 emissions

Economic complexity

Energy efficiency

Export quality

Mathematical programming methods

Panel quantile regression

*To whom correspondence should be addressed:
emad.kazemzadeh67@um.ac.ir

[DOI: 10.22034/JAERT.1.4.1]

1. Introduction

In recent years, with rapid economic growth, carbon dioxide emissions have increased significantly. One of the significant consequences of carbon emissions is global warming and climate change, which poses many environmental problems to communities. Therefore, most countries are looking for ways to reduce CO_2 emissions as a major environmental goal [1, 2]. Since this is a global issue, countries and international organizations have sought solutions to the problem of global warming. For this purpose, some countries hold conferences and agreements, including the protocols of the 2015 Paris Climate Change Conference, to address global warming. At the conference, it was decided that global economies would share their assessments and strategies to reduce CO_2 emissions at regular intervals [3].

Recently, the study in this field has been considered by many researchers and economists. Many researchers have studied the effect of economic growth on the environment in the context of the Kuznets curve in different countries [4, 5, 6, 7, 8]. Kuznets hypothesis argues that countries in the early stages of economic growth do not pay much attention to the environment, but as income and welfare levels increase, governments are turning to advanced technologies that reduce environmental damage [9].

Some studies have also focused on economic growth, energy consumption, and environmental degradation [10, 11, 12, 13]. Economic growth and energy consumption have a significant impact on CO_2 emissions, but these variables alone cannot explain the changes in CO_2 emissions [14]. Therefore, in addition to economic growth and energy consumption, some studies examined the effect of other variables such as financial development, trade openness, urbanization, etc. on environmental degradation [2, 15, 16, 17, 18, 19, 20, 21, 22, 23]. However, few studies have investigated new indicators such as economic complexity index, export quality, and export diversity [5, 19, 24, 25].

Emerging economies seek to increase their share of international trade to achieve high economic growth so that the average share of international trade in GDP during the period under review for 16 emerging economies is about 70% [26]. The expansion of trade leads to rapid economic growth but also increases energy consumption. Increasing energy consumption due to expanding trade increases greenhouse gas emissions [21, 24]. Therefore, the development of trade regardless of technology, production process, and quality of export products causes more damage to the environment [20, 27]. The quality of exports is related to certain characteristics of countries (such as the level of production productivity, resources, and R & D activities) and indicates an increase in the added value of export products [24, 28]. Many studies have examined the effect of trade openness on environmental [24, 29]. However, studies on the impact of export quality on quality of environment were limitedly reviewed, and of course, the existing studies did not reach a single conclusion on the impact of export quality on the environment. Some studies argue that increasing the quality of a country's exports increases its competitive advantage in international trade and thus increases its wealth and income. Increasing demand for goods in a rich society leads to more energy consumption and it increases environmental degradation [2, 24, 30]. On the other hand, increasing the quality of export products is accompanied by improving production technologies, which leads to a reduction in CO_2 emissions [19, 25, 31]. Therefore, examining how the quality of exports affects CO_2 emissions provides policymakers with important policy implications for sustainable development.

To achieve a high level of export quality, countries must produce different types of products with higher knowledge and more advanced technology. Diverse and high-quality products require a complex economic structure. The Economic Complexity Index measures the ability of countries to produce complex goods that require higher knowledge and better technologies. Therefore, the production of complex products, requiring high innovation and knowledge, can help improve the environment with high efficiency of production resources (such as energy) [30, 32, 33]. In addition, emerging economies in the middle stages of economic growth have moved towards producing goods with higher knowledge, so that most of the countries studied in this article rank high in the index of economic complexity. On the other hand, countries with higher ECI have competitive advantages over countries with lower ECI. So more complex economies are more inclined to trade and, with the income from trade, they have the financial resources to create green technologies and carry out innovative environmentally friendly activities that can reduce environmental degradation [33, 34]. Therefore, examining the effect of ECI and export quality on environmental sustainability in

[DOI: 10.22034/JAERT.1.4.1]

emerging economies can provide many policy implications. Complex structures that use green technologies in the production of goods with the help of extensive knowledge increase energy efficiency and have a great positive impact on environmental performance by making optimal use of resources and energy. Regarding the fact that there are no single accepted standard criteria for energy efficiency, the DEA approach provides an opportunity for a more comprehensive analysis of energy inefficiency that is important to policymakers [35]. In this study, energy efficiency is calculated by the DEA method for emerging economies. In addition, evaluating the energy efficiency of a region gives planners a direction in implementing environmental protection policies. Therefore, by evaluating energy efficiency, in addition to orienting regional policies and ranking countries in terms of energy efficiency, the effect of energy efficiency on CO_2 emissions can also be analyzed.

Samples from the study countries were selected from 16 MSCI Emerging Markets. This classification was selected based on financial market criteria including access, liquidity size, and market size, which indicates the similarity of the structure of the countries studied [36, 37]. In addition, previous studies have not analyzed the effects of export quality, energy efficiency, and economic complexity on per capita CO_2 emissions in emerging economies, and it is important to study effective policies to reduce environmental degradation.

As mentioned above, environmental researchers did not focus on studies with new indicators such as ECI, export quality, and energy efficiency. Therefore, the purpose of this article is to contribute the literature related to these topics. This study enriches the literature in several points. First, in this study, energy efficiency is calculated using the DEA model, and in the next step, the effect of export quality, energy efficiency, and economic complexity on CO_2 emissions per capita in the panel of emerging economies is investigated using quantile regression. On the other hand, this study helps policymakers to guide development policies by classifying emerging economies into 6 groups based on characteristics related to per capita CO_2 emissions. Second, choosing to calculate energy efficiency with mathematical programming models gives us more interesting community results. Third, to our knowledge, no studies have yet examined the impact of export quality, energy efficiency, and economic complexity on CO_2 per capita in the emerging economies. On the other hand, it is predicted that the economic complexity and quality of exports will increase in most emerging economies, and a better understanding of how these variables affect CO_2 emissions per capita is essential. Therefore, in this research, we answer the following questions:

1. Are emerging economies efficient in energy consumption?
2. What is the energy efficiency score of each country compared to other countries in the group?
3. Does increasing energy efficiency in the studied countries reduce CO_2 emissions?
4. Does increasing the complexity of the economic structure in emerging economies help improve the environment and reduce carbon emissions?
5. Can increasing the export quality of emerging economies lead to an improvement in the environment?

To answer these questions, the main purpose of this article is to study the effect of export quality, energy efficiency, and economic complexity on per capita CO_2 emissions. Experimental models are analyzed using the DEA model and quantile regression. The empirical findings of this study not only contribute to the development of the existing literature but can also have significant implications for emerging economies' policies with complex and diversified export products to reduce carbon dioxide emissions and can contribute to the development of new policies to use clean energy, to increase energy efficiency, and to help sustainable development. The rest of the paper is organized as follows. The 2nd section presents the literature review. The 3rd section describes the data and models. The 4th section provides the empirical results and discussion. The 5th section discusses conclusions and policy implications.

2. Literature review

This section examines previous studies related to the variables of export quality, energy efficiency, and economic complexity on environmental performance.

2.1. The relationship between export quality and CO_2 emissions

Studies show that in addition to the volume of exports, the quality of export goods is of importance [34]. Moreover, improving the quality of export products leads to faster economic growth. The

[DOI: 10.22034/JAERT.1.4.1]

nature of exports in emerging countries is related to structural change [38]. In this regard, economic growth causes a change in the economic structure of a country, including the creation of new sectors and opportunities, allocation of resources to efficient manufacturing enterprises, higher knowledge and more advanced technologies, and increasing the quality of exports. The Export Quality Index was presented by [39], which increases the value added of export goods.

The relationship between international trade and CO_2 emissions has been well studied [19, 22]. But the quality of exports has not yet been considered widely enough. This study is also an attempt to fill the gap identified in the literature on export quality. Studies on the effect of export quality on CO_2 emissions and the environment have also yielded different results. Some studies have found a positive relationship between export quality and CO_2 emissions. [24] analyzed the effect of export product quality on per capita CO_2 in 82 developing countries during the period of 1970 to 2014 using a fixed-effects model. The control variables used in their study included per capita income, per capita energy consumption, natural resource rent, and trade openness. They found that increasing the quality of exports increased environmental degradation and CO_2 emissions. [2] examined the impact of export quality, urbanization, trade openness, economic growth, and energy consumption on CO_2 per capita in 63 developing and developed countries during the period of 1971-2014 using the quantum panel model. Their results showed that increasing the quality of exports causes environmental degradation. [30] examined the dynamic correlation between per capita income, renewable and non-renewable resources, urbanization, export quality, and CO_2 emissions with the DOLS and FMOLS approach in the top ten renewable energy countries and 10 countries with the highest ECI rankings. They found that renewable energy, urbanization, per capita income, and export quality increase CO_2 emissions in the long run. Some studies also showed that increasing the quality of exports reduces environmental degradation. [24] analyzed the effect of export quality on CO_2 emissions in China during the period of 2010-2017. They showed that the quality of exports helps to protect the environment. [31] examined the effect of export quality on environmental degradation in the selected South Asian countries during the period of 1972-2014 with the FMOLS approach and found that improving export quality would reduce CO_2 emissions.

2.2. The relationship between energy efficiency and CO_2 emissions

Today, the expansion of economic activities causes a greater need for energy consumption, which increases energy consumption and reduces energy efficiency, and this leads to a worsening of the environmental situation [40]. Therefore, the calculation of energy efficiency has recently been considered by many researchers. Many studies use different types of DEA models to evaluate energy efficiency [35, 41]. Energy efficiency is an important indicator of restructuring policy to achieve the goals of sustainable development [5]. Improving energy efficiency, as reported by the IEA, provides the most cost-effective opportunities to control energy demand and reduce CO_2 emissions [42]. Therefore, evaluating energy efficiency helps policymakers in line with environmental improvement policies.

[43] calculated energy efficiency in OECD countries using the DEA approach. Some researchers have also studied the effect of energy intensity on the environment. Some studies have analyzed the effect of energy efficiency on environmental degradation [44, 45]. [45] examined the relationship between economic development, corruption, energy efficiency, and ecological footprint in Brazil, Russia, India, China, South Africa (BRICS), and other 11 countries from 1995 to 2014 with two approaches DEA and GMM. They found that increasing energy efficiency improves the environment. [46] studied the effect of improving energy efficiency on CO_2 emissions in 30 OECD countries and found that improving energy efficiency has the greatest contribution to reducing CO_2 emissions. In this study, energy efficiency is also calculated with the DEA model. Assessing the energy efficiency of a particular region can determine the direction for regional development policies [35]. Therefore, in this study, the energy efficiency of emerging economies is calculated in order to make policy proposals related to these countries.

2.3. The relationship between economic complexity and CO_2 emissions

A complex structure means a production structure that produces a variety of high-tech products through a wide range of highly knowledgeable individuals [47]. Countries with a lower complexity index produce fewer products. Producing fewer products reduces energy demand [48, 49]. On the other hand, a country with a high complexity index

[DOI: 10.22034/JAERT.1.4.1]

indicates a high level of knowledge with advanced technologies that can reduce environmental degradation due to the availability of financial resources for research and development activities, investment in clean technologies, and development of alternative energy sources (e.g.: renewable, core) [34, 50].

Despite the importance of the relationship between the complexity of the economy and the environment, this issue has received very little attention so far [2, 19]. Previous studies on the economic complexity of environmental quality have not reached a single conclusion. Some researchers have concluded that there is a positive relationship between economic complexity and CO_2 emissions. [51] analyzed the effect of ECI on the ecological footprint under the Kuznets hypothesis in China during the period of 1965-2016 using the ARDL approach and the time-varying causality test. Their results showed that increasing ECI increases the ecological footprint in the short and long term. [52] examining the effect of ECI on the ecological footprint in 25 countries with data during the period of 1970-2016, they found that increasing ECI improves the state of the environment. On the other hand, some studies have found a negative relationship between economic complexity and environmental degradation. [19] analyzed the relationship between ECI and CO_2 emissions in France during the period of 1964-2014 using the DOLS method and found that increasing ECI improves the environment. [33] examined the impact of ECI on environmental performance in 88 developing and developed countries were examined using the ARDL model. Their results showed that increasing ECI helps to improve environmental performance. [53] also examined the effect of ECI, globalization, renewable, and non-renewable energy consumption on the Kuznets environmental curve for the United States during the period of 1980-2017 in 2020 and found that the EKC hypothesis is valid for the United State and increasing the ECI reduces CO_2 emissions. [32] also examined the effect of economic complexity, economic development, renewable energy consumption, and population on CO_2 emissions in 28 OECD countries from 1990 to 2014 and found that increasing ECI reduces CO_2 emissions. Since economic complexity plays an important role in CO_2 emissions, investigating the relationship between ECI and environmental degradation can provide manufacturing and industrial policies for emerging economies to accelerate economic growth while protecting the environment.

As can be seen, the results of different studies are different. This can be due to the choice of different environmental indicators, the choice of country (which country or group of countries and the conditions of their development), the study period, and also econometric methods. Therefore, according to the above overview of the literature, it is clear that existing empirical studies on export quality, energy efficiency (energy intensity), and economic complexity have not reached a single conclusion. On the other hand, due to the few studies on export quality, energy efficiency, and economic complexity, the recent study updates the previous literature and offers new insights into the importance of export quality, energy efficiency, and economic complexity (ECI) on the environment. In addition, the present study is different from previous studies using the quantum econometric method that has been analyzed in different quantiles. The main purpose of this paper is to provide innovative evidence and findings to achieve energy efficiency goals and improve the environment of emerging economies by studying the role of export quality, energy efficiency, and economic complexity.

This study contributes to the literature in several ways. First, analysis based on a sample of emerging economies can provide specific development policies for emerging economies. Secondly, in this study, energy efficiency was first calculated by the DEA method and the studied countries were ranked in terms of energy efficiency, then the effect of energy efficiency, export quality, and economic complexity on per capita CO_2 emissions was analyzed by quantitative regression. By classifying the countries into 6 groups based on the CO_2 variable, the results for each classification were tabulated separately. Finally, to our knowledge, this is the first research that, unlike previous studies, examines the effects of export quality, energy efficiency, and economic complexity on per capita CO_2 emissions in emerging economies. In the next section, we will present the data and methods used for the experimental studies.

3. Data and Methods

This section is divided into two parts. The first section describes the data and variables. The second section presents the models used in this study.

3.1. Data

The dataset includes data for 16 emerging economies (including Brazil, Chile, China, Colombia, Egypt, Hungary, India, Indonesia, Korea (South),

[DOI: 10.22034/JAERT.1.4.1]

Malaysia, Mexico, Morocco, Philippines, South Africa, Thailand, and Turkey) during 1990-2014. 16 countries were selected from the MSCI Emerging Markets Classification. MSCI classifies countries based on financial market metrics.

From 20 indicators for measuring the level of environmental degradation, the CO_2 index is superior to the other indicators [4]. Therefore, in this study, CO_2 per capita is considered as a proxy for environmental degradation. In addition, the CO_2 per capita variable provides better measurements and more realistic results than total CO_2 [24].

In the experimental study, all variables are considered logarithmically. Since some data were available until 2014, the study period of 1990 to 2014 is intended for analysis. The frequency of data is annual. Variables are presented in Table 1.

Table 1 Define variables and their sources.

Abbreviation	Variables	Sources
CO_2	CO_2 emission per capita (kg)	WBD (2021)
EQ	Export quality index	IMF (2021)
EF	Energy Efficiency	Calculated by the method DEA
ECI	Economic Complexity Index	Observatory of Economic Complexity (OEC) (2021)
TO	Trade openness = (Import+Export)/GDP	WBD (2021)
URB	Urban population = % of total population	WBD (2021)
FOSSIL	Consumption of fossil fuels per capita (e.g., oil, gas, and coal) kg of oil equivalent	British Petroleum (BP) (2021)
L	Labor force total	WBD (2021)
K	Total capital stock (constant 2010 US$)	WBD (2021)
E	Energy consumption total(kg)	WBD (2021)
Y	GDP (constant 2010 US$)	WBD (2021)

This table was created by the authors.

Descriptive statistics of the variables are presented in Table 2. Mean CO_2 is 3548.041, mean ECI is 3.23039, and mean EQ is 0.872225. Min efficiency is 0.124 and max is 1.

3.2. Method approach

Two different methods are applied in this research; the data envelopment analysis (DEA) and the panel quantile regression model. The methods are explained in the following subsections.

3.2.1. Data Envelopment Analysis (DEA)

DEA is a parametric linear programming method used to evaluate the performance of decision units [54]. DEA efficiency score indicates the ability to obtain the maximum output of given inputs, which is calculated by its relative distance from the production boundary by the mathematical programming method. This approach is based on input and output [41]. DEA is more objective and, therefore, used by many researchers in various fields [41, 55].

Energy efficiency is calculated by solving the following linear programming problem:

Min θ

s.t:

$$\sum_{j=1}^{n} \lambda_j L_j \leq L_i$$
$$\sum_{j=1}^{n} \lambda_j K_j \leq K_i$$
$$\sum_{j=1}^{n} \lambda_j E_j \leq \theta E_i$$
$$\sum_{j=1}^{n} \lambda_j Y_j \geq Y_i$$

$$\lambda_{(j\geq 0)} \qquad j=1, 2, \ldots, n \qquad (1)$$

In this study, three inputs of capital (K), labor (L), and energy consumption are considered (E) to produce the desired output (GDP, denoted by Y) according to previous studies [56] and based on

[DOI: 10.22034/JAERT.1.4.1]

the input CRS model. The decision-making units are 16 emerging economies. Assessing energy efficiency is very essential for environmental improvement policies.

3.2.2. The panel quantile regression

The quantile panel regression was introduced by [57] for variables with asymmetric distributions. Quantile regression is by identifying the distribution pattern of the dependent variable of the model at different levels of the independent variable, which is done by fitting multiple regression patterns on a data set for different quantiles. Each quantile regression defines a unique point in the conditional distribution. This model is suitable for studies with asymmetric distribution, distribution with wide sequences. Quantile regression estimates the pattern parameters by minimizing the sum of the absolute values of the residuals.

$$y_i=x_i\, b_{\theta i}+\mu_{\theta i}\,. \quad 0<\theta<1$$

$$Quant_{i\theta}\,(y_i/x_i)=x_i\,\beta_\theta, \qquad (2)$$

x: the vector of independent variables, y: the vector of the dependent variable, μ: random error, Quant_iθ (y_i/x_i): the θth quantile of the explanatory variable; the βθ estimate shows the quantile regression θth and solves the Eq. 2:

$$min \sum_{yi\geq x_i'\beta} \theta|y_t - x_i'\beta| + \sum_{yi<x_i'\beta} (1-\theta)|y_t - x_i'\beta| \qquad (3)$$

Given that θ takes different values, so different parameters are also estimated, for example θ = 0.5 is the mean regression [58]. According to econometric theories, to eliminate the possibility of heterogeneity of phenomena, it is better to use variables as logarithms in the model. Therefore, our model follows Equation (4), below:

$$LCO_{2it}=La+\beta_1 LEQ_{it}+\beta_2 LEF_{it}+\beta_3 LECI_{it}+\beta_4 LTO_{IT}+\beta_5 LURB_{it}+\beta_6 LFOSSIL_{it}+\delta_{it} \qquad (4)$$

where CO_2 represents CO_2 per capita emissions; EQ is export quality; EF is energy efficiency calculated with the DEA model; ECI denotes economic complexity; TO is trade openness; URB is urban population and FOSSIL is fossil per capita energy consumption (which includes oil, gas, coal) calculated in a kg of oil equivalent.

Table 2 Descriptive statistics of the variables

Variables	Mean	Std. dev	Min	Max	Obs
CO_2	3548.041	2719.554	620.9146	12956.42	400
EQ	0.872225	0.0832474	0.66	1.05	400
EF	0.81229	0.2310129	0.124	1	400
ECI	3.23039	0.551969	2.141288	4.90646	400
TO	67.04386	41.52926	15.16176	220.4068	400
URB	58.75274	17.90882	25.547	87.303	400
FOSSIL	1.22e+09	9.51e+08	1.98e+08	4.81e+09	400
L	9.79e+07	1.91e+08	4011205	7.84e+08	400
K	8.70e+12	4.26e+13	9.40e+09	3.65e+14	400
E	2.13e+12	4.36e+11	7.62e+09	3.04e+12	400
GDP(Y)	6.73e+11	1.03e+12	4.32e+10	8.32e+1216	400

Obs: the number of observations; Std. dev: the Standard Deviation.

Given that in this study panel quantile regression was used to measure CO_2, Equation (5) is changed to the following form:

$$Q_\tau\,(LCO_2)=(La)_\tau+\beta_{1\tau}LEQ_{i\tau}+\beta_{2\tau}\,LEF_{i\tau}+\beta_{3\tau}\,LECI_{i\tau}+\beta_{4\tau}\,LTO_{i\tau}+\beta_5\,LURB_{it}+\beta_{6\tau}\,LFOSSIL_{i\tau}+\delta_{i\tau} \qquad (5)$$

Q_r: The estimation of the quantile regression τth in the CO_2, $(la)_r$: the constant component. The coefficients $\beta_{1\tau},\beta_{2\tau},\beta_{3\tau},\beta_{5\tau},\beta_{6\tau}$: the quantile regression parameters.

4. Empirical results and discussion

This section consists of two parts. In the first part, we calculate energy efficiency using the DEA model. Then we examine the effect of independent

[DOI: 10.22034/JAERT.1.4.1]

variables on the CO_2 using the panel quantile regression model.

4.1. DEA model

In this study, energy efficiency is calculated by Equation (1). The energy efficiency results are shown in Table (3). In addition, the countries studied in this article are ranked based on efficiency scores.

In this study, like most studies [35, 41], to evaluate Energy efficiency, we used DEA models. As shown in Table 3, Brazil, Chile, and Hungary scored an efficiency score, meaning they are more energy-efficient than other countries studied. In addition, the average efficiency score of these countries is 0.799, which indicates that most emerging economies in energy consumption are very close to the optimal stage. As [56] found that China was inefficient in energy consumption, in this study the lowest efficiency score is related to China, significantly different from the efficiency score of other countries, although China was the largest energy consumer since 2010 in the world. This may explain the large difference between China's performance score and the average performance score of other emerging economies under study [41]. Of course, many issues such as unfavorable energy structures, high energy consumption, and technology gaps between the studied countries can account for the difference in efficiency scores of these economies [35]. Achieving optimal energy consumption must, therefore, be a key goal in Chinese policy. China, on the other hand, is the world's largest consumer and consumer of coal. Since coal consumption is one of significant reasons in CO_2 emissions, achieving a higher score on energy efficiency in China, in addition to reducing energy consumption and economic benefits, would help to improve the environment.

After calculating the energy efficiency in this study, panel quantile regression is now used to study the effect of the export quality, energy efficiency, and economic complexity on CO_2 emissions.

4.2. Panel quantile regression results

Before estimating the econometric method, pre-estimation tests should be performed to ensure the reliability of the estimation results. The precondition for the quantile test is the absence of data normality, so first, the data normality test is performed, which is possible in both graphical and numerical. In the next step, other tests such as variance inflation factor (VIF) test, cross-sectional dependence test, unit root test, and finally cointegration test are performed.

4.2.1 Normal distribution test

In some cases, economic phenomena do not follow a normal distribution because they are change-

Table 3 Energy efficiency means and ranks from the DEA model.

Country	DEA(CRS)	Rank
Brazil	1	1
Chile	1	1
China	0.229	14
Colombia	0.957	5
Egypt	0.92	7
Hungry	1	1
India	0.576	12
Indonesia	0.561	13
South Korea	0.991	3
Malaysia	0.746	9
Mexico	0.944	6
Morocco	0.684	10
Philippines	0.816	8
South Africa	0.971	4
Thailand	0.598	11
Turkey	0.995	2
Mean	0.799	-

Authors' calculations

[DOI: 10.22034/JAERT.1.4.1]

able. The quantile panel regression is more powerful than ordinary least squares regression when the data is not normally distributed or the data is out of date. Using the OLS method is inefficient when the data is abnormally distributed. Therefore, before estimating the model, the normality test is performed first. Numerical tests of Skewness and Kurtosis and Shapiro-Wilk and Shapiro-France tests are used to check the normality of the data. Skewness results show that the coefficients are significantly non-zero, which indicates that the data are abnormal. On the other hand, considering that the results of Kurtosis coefficients are significantly different from 3, it confirms the abnormality of the data. Also in Table 4, the probability values of the Shapiro-Wilk and Shapiro-France tests indicate that the null hypothesis (data normality) is rejected.

According to the results in Table (4), the variables do not have a normal distribution, so quantitative panel regression is suitable for estimation.

4.2.2 Multicollinearity tests and Cross-sectional independence test

In this section, after examining the normality of variables, we used the VIF test to check the multilinearity of the variables. VIF test results are less than the normally accepted standard value (10) and the mean VIF is less than the normally accepted standard value (6) (see table 5). In the next step, several tests can be used to check for cross-sectional correlation (LM Brush Pagan; CD Pesaran). In this study, since the number (T> N) means that the number of years (T) is more than countries (N), the lm test was used to examine the cross-sectional dependence of the data.

The results of the Breusch-Pagan LM test of independence are shown in Table 5. According to the above results, the null hypothesis is rejected and this means that the variables are cross-sectionally dependent.

4.2.3. Panel unit root tests

The selection of the appropriate test from among the unit root tests depends on the results of the cross-sectional dependency test of the previous stage. Given that the results of the pagan lm test (see Table (5)) confirm the existence of cross-sectional dependence, we must use the generalized unit cross-sectional root test (CIPS) to check the significance of the variables. In this study, due to cross-sectional correlation, panel unit root test was used. See the results of this test in the table below.

In this study, the CIPS panel unit root test with the trend and without trend was used for variables. As you can see in Table (6), except for the energy efficiency variable which is significant at the level with the trend at the level of 1%, the other variables are not significant at the level. The unit root panel test in the first-order difference indicates that all variables without trend at the level of 1% and except the urbanization variable other variables with trend at the level of 1% are significant. According to the results of the table, since all variables are significant in the first-order difference, the cointegration test can be used to examine the long-run relationship between the CO_2 variable and other variables.

4.2.4. Panel cointegration test

Panel cointegration test is used for long-term relationships between variables [4]. In this study, Pedroni and Kao cointegration tests were used to investigate the existence of a long-term relationship between variables. Null-hypothesis in both tests is the absence of a long-run relationship. The results in Table (7) show that both tests reject the null hypothesis, which indicates a long-term relationship between CO_2 and explanatory variables. Therefore, by confirming the existence of a long-run relationship between variables, we can estimate the models without worrying about the existence of false regressions.

After reviewing the pre-estimation tests, and according to their results, the best regression model was selected. The quantile regression is more robust than OLS regression if the data is not normally distributed. According to the results of the normality test, it was found that all variables had an abnormal distribution, so quantitative regression is suitable for estimation. The next section presents the results of the quantile test.

4.2.5. Quantile panel regression results

Quantile panel regression estimates the effects of independent variables on the dependent variable in different quantiles between 0 and 1.

Similar to most studies, we used quantile values of 10th, 25th, 50th, 75th, and 90th as representative values for experimental analysis [36]. In addition to quantiles regression, OLS regression was used to robustness check results and comparative analysis (See the results of the Fixed Effects panel in Table 8). Different quantiles (10th, 25th, 50th, 75th, and 90th) were used to estimate this research. The results of these estimates are reported in Table

[DOI: 10.22034/JAERT.1.4.1]

Table 4 Normal distribution test results

Variables	Skewness	Kurtosis	Shapiro-Wilk test		Shapiro-Francia test		Obs
			Statistic		Statistic		
CO_2	1.254739	4.036175	0.86135	***	0.86263	***	400
EQ	0.1880609	2.298991	0.98112	***	0.98255	***	400
EF	-1.11362	3.347742	0.91948	***	0.93964	***	400
ECI	0.2741492	2.83816	0.96734	***	0.96856	***	400
TO	1.670142	5.459807	0.81749	***	0.81810	***	400
URB	-0.150751	1.82842	0.95003	***	0.95308	***	400
FOSSIL	1.407392	5.004455	0.85893	***	0.85981	***	400

*** means statistical significance at a 1% level.

8 and Fig 1.

As shown in Table 8, the export quality has a positive and significant effect on CO_2 at all quantiles levels (See Table 8). Some studies support our results [24, 30, 36]. In previous studies, [24] in 82 developing countries and [2] in 63 developing and developed countries found that increasing export quality leads to increased CO_2 emissions, we came to the same conclusion in this study. A similar result was found by [30] studying the effect of export quality on CO_2 emissions in the top 10 renewable energy producing countries and 10 countries with high ECI rankings, and they found that increasing export quality would increase CO_2 emissions in the long run. [36] also found that increasing the quality of exports in emerging economies causes an increase in the ecological footprint and environmental degradation. The positive relationship between export quality and CO_2 emissions in emerging economies can be argued as follows. Since emerging economies are in the middle stage of economic growth and are trying to achieve a high level of economic growth through advantage in the international market, despite the increase in the volume and quantity of their export goods, they do not consider environmental issues. Some studies have shown that higher quality of export goods reduce CO_2 emissions. As improving the quality of exports increases the income of people in society, people's demand for a healthier and cleaner environment in a richer society is intensifying [19, 31].

The results of Table (8) show that the effect of energy efficiency on CO_2 emissions in the 10th, 25th, 50th quantiles is negative and significant. Improving energy efficiency reduces costs in energy consumption, reduces dependence on energy imports, and reduces regional and global environmental damage. In addition, higher efficiency leads to higher value-added economic activities

Table 5 VIF test and Breusch- Pagan (LM test) results

Variables	VIF-test		Breusch- Pagan (LM test)	
	VIF	Mean VIF	t-statistic	Prob.
CO_2	n.a.	2.27	573.027	0.000
EQ	2.30			
EF	2.45			
ECI	2.23			
TO	1.23			
URB	2.53			
FOSSILP	2.85			

n.a. it means not available.

[DOI: 10.22034/JAERT.1.4.1]

Table 6 Panel unit root test (CIPS) results

Variables	CIPS (Zt-bar)		CIPS (Zt-bar)		
	Without trend	With trend	Variables	Without trend	With trend
CO2	-0.738	-0.993	LCO2	-2.906***	-2.536***
EQ	-0.076	-0.016	LEQ	-3.047***	-2.85***
EF	-1.588	-2.633***	LEF	-2.215***	-3.202***
ECI	-1.442	-1.35	LECI	-3.82 ***	-2.81***
TO	-0.774	-0.972	LTO	-3.04***	-2.068***
URB	0.523	1.384	LURB	-3.021***	-1.063
FOSSIL	-1.303	-0.985	LFOSSILP	-4.154***	-3.343***

"L" denotes variables in the natural logarithms; *** denotes statistical significance at 1% and ** denotes statistical significance at 5% level.

Table 7 Kao and Pederoni cointegration test

Kao cointegration test			Pedroni cointegration test		
Estimators	t-Statistic	Prob.	Estimators	t-Statistic	Prob.
Modified Dickey-Fuller t	3.5764	0.0015	Modified Phillips-Perron t	6.1969	0.0000
Dickey-Fuller t	-3.0905	0.0010	Phillips-Perron t	-3.0638	0.0011
Augmented Dickey-Fuller t	-2.9757	0.0176	Augmented Dickey-Fuller t	-1.9205	0.0000
Unadjusted modified Dickey-Fuller t	-16.4892	0.0000			
Unadjusted Dickey-Fuller t	-13.5893	0.0000			

and lower energy consumption [10, 35]. In this study, energy efficiency, like previous studies [35, 43, 56] improves the environment. [36] also found that increasing energy efficiency helps to reduce the ecological footprint in emerging economies. [59] also found that increasing energy efficiency reduces the ecological footprint in the short and long term in 45 exporting countries.

The ECI has a negative and significant effect on CO_2 at 25th, 50th, 75th, and 90th quantiles levels (See Table 8). Complexity arises through the type of goods produced that make up a country's production structure [47]. Countries with higher complexity have better infrastructure that reduces

Table 7 Kao and Pederoni cointegration test

Quantile	Country
The lower 10th quantile group	Philippines, India
The 10the25th quantile group	Morocco, Indonesia
The 25the50th quantile group	Colombia, Brazil, Egypt, Thailand
The 50the75th quantile group	Turkey, Mexico, Chile, China
The 75the90th quantile group	Hungary, Malaysia
The upper 90th quantile group	South Africa, South Korea

According to the level of CO_2, 16 countries into six groups.

[DOI: 10.22034/JAERT.1.4.1]

environmental degradation. Complex economies use advanced energy consumption structures [60] in their economic structure, which increases productivity [24, 60]. In this study, the effect of the economic complexity index on CO_2 emissions is negative, as [2] showed that the economic complexity index in high-income countries controls CO_2 emissions. More sophisticated products can also lead to economic prosperity, but they can also increase or at least maintain the quality of the environment [19, 32, 33, 53]. The results of [59] also support our results. They found that increasing economic complexity reduces ecological footprints in exporting countries. Some studies also consider the index of economic complexity as a threat to the environment [36, 51]. [29] found that economic complexity in the long run increases pollution emissions in 8 Asian economies.

The effect of trade openness on CO_2 has a negative and significant effect on all quantiles. In this study, a negative relationship was found between CO_2 emissions and trade openness. Trade liberalization improves the environment due to the use of advanced technologies and energy efficiency in developed countries and the transfer of technology to other countries [20]. Some studies have also found a positive relationship between trade openness and CO_2 emissions. They argued that as expanding trade leads to economic growth, it causes an increase in environmental degradation as well [21, 22, 24]. Trade openness requires more production, which leads to more energy use [21]. Some studies did not find a significant relationship between trade expansion and CO_2 emissions [61].

The results show that the effect of urbanization on the CO_2, in the 10th and 25th quantiles is positive and significant and in 50th, 75th, and 90th is negative and significant (see Table 8). Today, cities' share of economic growth is increasing [11]. Increasing the share of urbanization in economic growth has led to prosperity and wealth [62]. Growing urbanization will change the pattern of consumption and production and development of urban public infrastructure (including hospitals, public transportation, education, etc.), which can help improve the environment. Theories of ecological renewal and urban environment transfer argue that urbanization can have both positive and negative effects on the environment. [63], as the finding in this study also demonstrated a negative relationship between urbanization and environmental degradation in the 50th, 75th, and 90th quantiles and positive relationship in the 10th and 25th quantiles. Numerous studies have shown that increasing urbanization reduces CO_2 emissions because, as economic activity increases, citizens become wealthier, and in some societies, wealthier citizens are more inclined to use quality products and clean technologies. Urbanization leads to greater use of public infrastructure that is environmentally friendly [2, 61, 63]. Some studies have also concluded that increasing urbanization leads to increased environmental degradation [20]. Therefore, urbanization changes have a significant

Table 9 the panel quantile regression estimation results and panel fixed effects

Variables	Quantiles					OLS
	10th	25th	50th	75th	90th	Fixed Effects
LEQ	0.429	0.774	0.584	0.610	0.874	0.6266
LEF	-0.113	-0.085	-0.043	-0.016	0.034	-0.0425
LECI	0.006	-0.141	-0.174	-0.379	-0.487	-0.2039
LTO	-0.032	-0.029	-0.063	-0.089	-0.137	-0.0895
LURB	0.059	0.083	-0.025	-0.121	-0.155	-0.0429
LFOSSIL	0.949	0.916	0.955	1.014	1.042	0.9855
Constant	-11.87	-11.03	-11.18	-11.61	-11.62	-11.592
Pseudo R2	0.9134	0.9130	0.9137	0.9068	0.9030	0. 9997

"L" denotes variables in natural logarithms; ***, ** denote statistically significant at the 1%, and 5%, levels, respectively.

[DOI: 10.22034/JAERT.1.4.1]

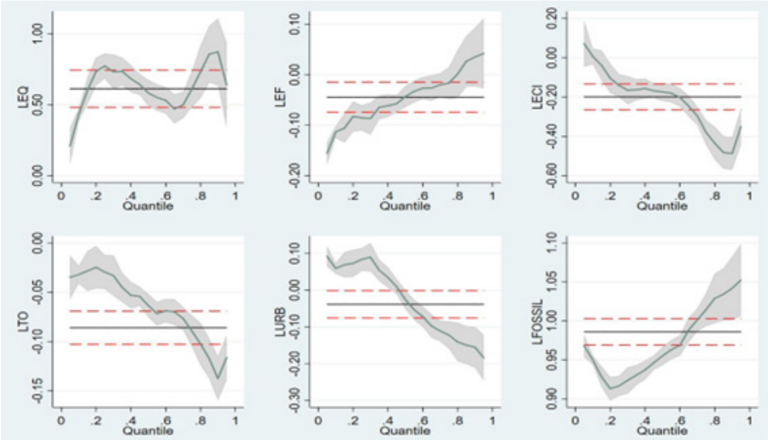

Fig. 1 Quantile estimate: Shaded areas: 95% confidence band for the quantile regression estimates. The vertical axis: shows the elasticities of the explanatory variables. The red horizontal lines: the conventional 95% confidence intervals for the OLS coefficient

impact on energy consumption and CO_2 emissions, which can affect sustainable development policies.

The results of Table (9) show that fossil energy consumption has a positive and significant effect on CO_2 emissions in all quantiles. Every country that seeks sustainable economic growth and development needs energy consumption. Energy is a key factor in production to achieve economic growth, which in turn increases CO_2 emissions (Kraft & Kraft, 1978). In this study, as in previous studies [2, 20, 61], fossil energy consumption causes degradation of the environment.

Fig. 1 Quantile estimate: Shaded areas: 95% confidence band for the quantile regression estimates. The vertical axis: shows the elasticities of the explanatory variables. The red horizontal lines: the conventional 95% confidence intervals for the OLS coefficient

5. Conclusion and policy implications

In this article, energy efficiency for emerging economies with three inputs of labor, capital, and energy consumption, and an optimal output of GDP is first calculated by the DEA method. The results of mathematical models of energy efficiency show that Brazil, Chile, and Hungary are more efficient in using their energy consumption compared to other emerging economies and have obtained an efficiency score of one. China has the lowest efficiency score, given that it has the highest energy consumption in the world. The average efficiency score of these countries is about 0.799, this shows that China is very different from other emerging economies in terms of energy consumption, which can be explained by the fact that one of the most important factors affecting CO_2 emissions is the level of production. Energy demand raises with increasing production and economic activity, and this leads to increased CO_2 emissions. The primary goal of countries like China is to achieve sustainable economic growth to create new job opportunities. Therefore, the effects of incomes and rapid economic growth of countries like China on CO_2 emissions are not negligible.

In the second step, after calculating energy efficiency, the effect of export quality, energy efficiency, and economic complexity on per capita CO_2 emissions in panel 16 of emerging economies during the period of 1990-2014 with quantile panel regression was examined. The results showed that there is a positive relationship between the independent variables of export quality and the amount of non-renewable energy consumption per capita with CO_2 emissions. There is a negative relationship between energy efficiency, economic complexity, and trade openness with CO_2 emissions in emerging economies. Urbanization has a positive relationship with environmental degradation in the 10th and 25th quantiles and a negative relationship with CO_2 emissions in the 50th, 75th, and 90th quantiles.

As economies move from the lower to the higher stages of development, environmental problems increase, because in the middle stages of development, in emerging economies such as China, economic growth is the primary goal and environmental protection is the next step. As communities continue to evolve to higher stages of development, environmental protection becomes more important and communities seek ways to make their environment more sustainable. In addition, these countries consume large amounts of fossil fuels to produce the energy needed to accelerate econom-

[DOI: 10.22034/JAERT.1.4.1]

ic growth, which is a major source of greenhouse gas emissions and environmental damage. China, for example, has a significant impact on global warming and other environmental hazards due to its relatively low energy efficiency due to high energy consumption. Taking the fact into account that fossil fuels are the main source of total energy consumption in emerging economies, to improve energy efficiency and reduce CO_2 emissions, governments must impose strict regulations on fossil fuel products and inefficient low-tech products. Since higher energy efficiency can be achieved through joint efforts at the micro and macro levels, imposing a tax on carbon emission, increasing investment in advanced technologies, financial incentives in research and development activities, as well as eco-friendly technologies can increase energy efficiency. It can also develop countries' ability to upgrade their export portfolio with clean technologies. Governments need to legislate for more renewable energy consumption. Therefore, emerging economies should aim to improve energy efficiency through appropriate policies and investment projects because energy efficiency requires less energy and resources to produce the same amount of products and services, and this increases the quality of the environment. In addition, policymakers should formulate policies related to environmental protection. To this end, encouraging manufacturers to use clean technologies will be very useful because higher quality products will increase the quality of export products, which will help reduce carbon dioxide emissions in emerging countries.

The results of this paper show that the greatest way for the emerging economy to reduce CO_2 emissions is to reduce the consumption of fossil fuels and replace renewable energy and reduce exports of low-tech and low-quality goods. However, emerging economies are on track to increase per capita production and expand trade. On the other hand, as countries increase their incomes as production increases, communities use more advanced and environmentally friendly production techniques that reduce environmental degradation. As a result, reducing CO_2 emissions is possible due to increased energy efficiency and greater efforts to replace fossil fuels with renewable sources. Pricing carbon dioxide emissions or the trade system tax can also help reduce fossil fuel consumption. Emerging economies tend to stabilize export demand and sustainably improve economically in the face of global warming and climate change during the development process.

Acknowledgments

The authors thank Mrs. Bahareh Bazargan for her help.

References

[1] Ahmed K, Shahbaz M, Kyophilavong P (2016) Revisiting the emissions-energy-trade nexus: evidence from the newly industrializing countries. Environmental Science and Pollution Research 23(8): 7676-7691. DOI 7610.1007/s11356-11015-16018-x.

[2] Dogan B, Madaleno M, Tiwari AK, Hammoudeh S (2020). Impacts of export quality on environmental degradation: does income matter? Environmental Science and Pollution Research: 1-38. https://doi.org/10.1007/s11356-11019-07371-11355.

[3] https://unfccc.int/process-and-meetings/the-paris-agreement

[4] Al-Mulali U, Ozturk I (2016) The investigation of environmental Kuznets curve hypothesis in the advanced economies: the role of energy prices. Renewable and Sustainable Energy Reviews 54: 1622-1631. https://doi.org/1610.1016/j.rser.2015.1610.1131.

[5] Apergis N, Aye GC, Barros CP, Gupta R., Wanke P (2015) Energy efficiency of selected OECD countries: a slacks based model with undesirable outputs. Energy Econ 51: 45–53. doi:10.1016/j.eneco.2015.05.022.

[6] Jimenez C, Moncada L, Ochoa-Jiménez DA, Ochoa-Moreno WS (2019) Kuznets Environmental Curve for Ecuador: An Analysis of the Impact of Economic Growth on the Environment. Sustainability 11(21) 5896. https://doi.org/10.3390/su11215896.

[7] Germani AR, Ker AP, Castaldo A (2020) On the existence and shape of an environmental crime Kuznets Curve: A case study of Italian provinces. Ecol. Indic. 108, 105685. DOI: 10.1016/j.ecolind.2019.105685.

[8] Arango-Miranda R, Hausler R, Romero-López R, Glaus M, Pasillas-Díaz JR (2020) Testing the Environmental Kuznets Curve Hypothesis in North America's Free Trade Agreement (NAFTA) Countries. Energies 13(12) 3104. https://doi.org/10.3390/en13123104.

[9] Can M, Gozgor G (2017) The impact of economic complexity on carbon emissions: evidence from France. Environmental Science and Pollution Research 24(19): 16364-16370. https://doi.org/16310.11007/s11356-16017-19219-16367.

[10] Pao HT, Tsai CM (2010) CO2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy 38(12):7850–7860. DOI: 10.1007/s11356-018-3165-x.

[11] Bilgili F, Koçak E, Bulut Ü, Kuloglu A (2017) The impact of urbanization on energy intensity: panel data evidence considering cross-sectional dependence and heterogeneity. Energy 133: 242–256. doi:10.1016/j.energy.2017.05.121.

[12] Liu H, Kim H, Choe J (2018) Export diversification, CO2 emissions and EKC: panel data analysis of 125 countries. Asia-Pac J Reg sci 3:361–393. https://doi.org/10.1007/s41685-018-0099-8.

[13] Acheampong AO (2018) Economic growth, CO2 emissions and energy consumption: what causes what and where? Energy Econ 74:677– 692. https://doi.org/10.1016/j.eneco.2018.07.022.

[14] Chen W, Lei Y (2018) The impacts of renewable energy and technological innovation on environment-energy-growth nexus: new evidence from a panel quantile regression. Renew Energy 123:1–14. https:// doi.org/10.1016/j.renene.2018.02.026.

[15] Jayanthakumaran K, Verma R, Liu Y (2012) CO2 emissions, energy consumption, trade and income: a comparative analysis of China and India. Energy Policy 42: 450-460. https://doi.org/10.1016/j.enpol.2011.12.010.

[16] Ozturk I, Al-Mulali U, Saboori B (2016) Investigating the environmental Kuznets curve hypothesis: The role of tourism and ecological footprint. Environmental Science and Pollution Research 23(2):1916–28. https://doi.org/10.1007/s11356-015-5447-x.

[17] Rafindadi, A. A. (2016). Does the need for economic growth influence energy consumption and CO2 emissions in Nigeria? Evidence fromthe innovation accounting test. Renew Sust Energ Rev 62:1209–1225. https://doi.org/10.1016/j.rser.2016.05.028.

[18] Javid M, Sharif F (2016) Environmental Kuznets Curve and financial development in Pakistan. Renewable and Sustainable Energy Reviews 54: 406–414. https://doi.org/10.1016/j.rser.2015.10.019.

[19] Gozgor G, Can M (2017) Does export product quality matter for CO2 emissions? Evidence from China. Environmental Science and Pollution Research 24(3):2866–2875.doi: https://doi.org/10.1007/s11356-016-8070-6.

[20] Dogan E, Turkekul B (2016) CO2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA. Environ Sci Pollut Res 23: 1203–1213. DOI 10.1007/s11356-015-5323-8.

[21] Raza SA, Shah N (2018) Testing environmental Kuznets curve hypothesis in G7 countries: the role of renewable energy consumption and trade. Environmental Science and Pollution Research 25(27):26965-26977. https://doi.org/26910.21007/s11356-26018-22673-z.

[22] Moghadam HE, Dehbashi V (2018) The impact of financial development and trade on environmental quality in Iran. Emp Econ 54(4):1777–1799. https://doi.org/10.1007/s00181-017-1266-x.

[23] Albulescu C, Tiwari AK, Yoon SM, Kang SH (2019) FDI, income, and environmental pollution in Latin America: Replication and extension using panel quantiles regression analysis. Energy Econ 84: 104504. https://doi.org/10.1016/j.eneco.2019.104504.

[24] Fang J, Gozgor G, Lu Z, Wu W (2019) Effects of the export product quality on carbon dioxide emissions: evidence from developing economies. Environmental Science and Pollution Research 26(12): 12181-12193. https://doi.org/12110.11007/s11356-12019-04513-12187.

[25] Adnan- Bashir M, Sheng B, Dogan B, Sarwar S, Shahzad U (2020) Export product diversification and energy efficiency: Empirical evidence from OECD countries. Structural Change and Economic Dynamics 55: 232–243. https://doi.org/10.1016/j.strueco.2020.09.002.

[26] World Bank Data (WBD) (2024) https://databank.worldbank.org/home.

[27] Zhang S, Liu X, Bae J (2017) Does trade openness affect CO 2 emissions: evidence from ten newly industrialized countries? Environmental Science and Pollution Research 24(21):17616-17625. https://doi.org/17610.11007/s11356-17017-19392-17618.

[28] Shahbaz M, Shafiullah M, Mahalik MK (2019) The dynamics of financial development, globalisation, economic growth, and life expectancy in sub-Saharan Africa. Aust. Econ. Pap 58(4):444–479. https://doi.org/10.1111/1467-8454.12163.

[29] Rafiq, M. A., Rauf, A., Shakir, S., Abbas, A. M. A., Sun, H., & Abid, S. (2023). Exploring the Intertwined Nexus between Globalization, Energy Usage, Economic Complexity, and Environmental Quality in Emerging Asian Economies: A Pathway Towards a Greener Future. Environmental Science and Pollution Research, 30(45), 100431-100449.

[30] Wang Z, Jebli MB, Madaleno M, Doğan B, Shahzad U (2021) Does export product quality and renewable energy induce carbon dioxide emissions: Evidence from leading complex and renewable energy economies. Renewable Energy 171:360-370. https://doi.org/310.1016/j.renene.2021.1002.1066.

[31] Murshed M, Dao NTT (2020) Revisiting the CO 2 emission-induced EKC hypothesis in South Asia: the role of Export Quality Improvement. Geo Journal:1-29. https://doi.org/10.1007/s10708-10020-10270-10709.

[32] Doğan B, Driha OM, Balsalobre- Lorente D, Shahzad U (2021) The mitigating effects of economic complexity and renewable energy on carbon emissions in developed countries. Sustainable Development 29(1): 1-12. DOI: 10.1002/sd.2125.

[33] Lapatinas A, Garas A, Boleti E, Kyriakou A (2019) Economic complexity and environmental performance: Evidence from a world sample. https://mpra.ub.uni-muenchen.de/92833/1/MPRA_paper_92833.pdf.

[34] Hausmann R, Hidalgo CA, Bustos S, Coscia M, Simoes A, Yildirim MA (2014) The Atlas of Economic Complexity: Mapping Paths to Prosperity, MIT Press: Cambridge, MA, USA.

[35] Simeonovski K, Kaftandzieva T, Brock G (2021) Energy Efficiency Management across EU Countries: A DEA Approach. Energies 14(9):2619. https://doi.org/10.3390/en14092619.

[36] Kazemzadeh, E., Fuinhas, J. A., Koengkan, M., Osmani, F., & Silva, N. (2022). Do energy efficiency and export quality affect the ecological footprint in emerging countries? A two-step approach using the SBM–DEA model and panel quantile regression. Environment Systems and Decisions, 42(4), 608-625.

[DOI: 10.22034/JAERT.1.4.1]

[37] https://www.msci.com/our-solutions/indexes/market-classification

[38] Harding T, Javorcik BS (2012) Foreign Direct Investment and Export Upgrading. Review of Economics and Statistics 94 (4): 964–980. http://www.mitpressjournals.org/doi/pdf/10.1162/REST_a_00226.

[39] Henn C, Papageorgiou C, Spatafora N (2014) Export Quality in Developing Countries. IMF Working Paper Series No. WP/13/108. Washington, D.C. International Monetary Fund.

[40] Onafowora OA, Owoye O (2014) Bound testing approach to analysis of the environment Kuznets curve hypothesis. Energy Econ 44:47–62. https://doi.org/10.1016/j.eneco.2014.03.025.

[41] Wang S, Li G, Fang C (2018) Urbanization, economic growth, energy consumption, and CO2 emissions: Empirical evidence from countries with different income levels. Renewable and Sustainable Energy Reviews 81:2144-2159. https://doi.org/2110.1016/j.rser.2017.2106.2025.

[42] Costantini V, Crespi F, Paglialunga E, Sforna G (2019) System transition and structural change processes in the energy efficiency of residential sector: Evidence from EU countries. Struct. Chang. Econ. Dyn. doi:10.1016/j.strueco.2019. 05.001.

[43] Fidanoski F, Simeonovski K, Cvetkoska V (2021) Energy Efficiency in OECD Countries: A DEA Approach. Energies 14(4) . 1185. DOI:10.3390/en14041185.

[44] Ke H, Yang W, Liu X, Fan F (2020) Does Innovation Efficiency Suppress the Ecological Footprint? Empirical Evidence from 280 Chinese Cities. Int. J. Environ. Res Public Health 17(18) 6826. https://doi.org/10.3390/ijerph17186826.

[45] Yao X, Yasmeen R, Hussain J, Shah WUH (2021) The repercussions of financial development and corruption on energy efficiency and ecological footprint: Evidence from BRICS and next 11 countries. Energy 223:120063.https://doi.org/10.1016/j.energy.2021.120063.

[46] Tajudeen IA, Wossink A, Banerjee P (2018) How significant is energy efficiency to mitigate CO 2 emissions? Evidence from OECD countries. Energy Economics 72:200–221. doi: 10.1016/j.eneco.2018.04.010.

[47] Anand S, Sen A (2000) The income component of the human development index. J Hum. Dev. 1: 83–106.https://doi.org/10.1080/14649880050008782.

[48] Ferraz D, Fernando Moralles H, Suárez Campoli J, Cristina Ribeiro de Oliveira F, Aparecida do Nascimento Rebelatto D (2018) Economic Complexity and Human Development: DEA performance measurement in Asia and Latin America. Gest. Prod. São Carlos 25(4): 839-853. https://doi.org/10.1590/0104-530X3925-18.

[49] Le-Caous E, Huarng F (2020) Economic Complexity and the Mediating Effects of Income Inequality: Reaching Sustainable Development in Developing Countries. Sustainability 12(5) 2089. https://doi.org/10.3390/su12052089.

[50] Neagu O (2020) Economic Complexity and Ecological Footprint: Evidence from the Most Complex Economies in the World. Sustainability 12(21):1-18. https://doi.org/10.3390/su12219031.

[51] Yilanci V, Pata UK (2020) Investigating the EKC hypothesis for China: the role of economic complexity on ecological footprint. Environmental Science and Pollution Research:1-12. https://doi.org/10.1007/s11356-11020-09434-11354.

[52] Kazemzadeh, E., Fuinhas, J. A., Salehnia, N., & Osmani, F. (2022). The effect of economic complexity, fertility rate, and information and communication technology on ecological footprint in the emerging economies: a two-step stirpat model and panel quantile regression. Quality & Quantity, 1-27. https://link.springer.com/article/10.1007/s11135-022-01373-1

[53] Pata UK (2020) Renewable and non-renewable energy consumption, economic complexity, CO 2 emissions, and ecological footprint in the USA: testing the EKC hypothesis with a structural break. Environmental Science and Pollution Research:1-16. https://doi.org/10.1007/s11356-11020-10446-11353.

[54] Luo M, Fan H, Liu G (2021) A target-oriented DEA model for regional construction productive efficiency improvement in China. Advanced Engineering Informatics 47:101208. https://doi.org/10.1016/j.aei.2020.101208.

[55] Fathi B, Ashena M, Bahari AR (2021) Energy, environmental, and economic efficiency in fossil fuel exporting countries: A modified data envelopment analysis approach. Sustainable Production and Consumption 26: 588-596.

[DOI: 10.22034/JAERT.1.4.1]

https://doi.org/10.1016/j.spc.2020.12.030.

[56] He P, Sun Y, Shen H, Jian J, Yu Z (2019) Does Environmental Tax Affect Energy Efficiency? An Empirical Study of Energy Efficiency in OECD Countries Based on DEA and Logit Model. Sustainability.11(14): 3792. https://doi.org/10.3390/su11143792.

[57] Koenker R, Bassett Jr G (1978) Regression quantiles. Econometrica: journal of the Econometric Society 33-50. https://doi.org/10.2307/1913643.

[58] Xu B, Lin B (2018) What cause large regional differences in PM2. 5 pollutions in China? Evidence from quantile regression model. Journal of Cleaner Production 174:447-461. https://doi.org/410.1016/j.jclepro.2017.1011.1008.

[59] Numan, U., Ma, B., Aslam, M., Bedru, H. D., Jiang, C., & Sadiq, M. (2023). Role of economic complexity and energy sector in moving towards sustainability in the exporting economies. Energy Strategy Reviews, 45, 101038. https://doi.org/10.1016/j.esr.2022.101038

[60] Hu G, Can M, Paramati, SR, Doğan B, Fang J (2020) The effect of import product diversification on carbon emissions: New evidence for sustainable economic policies. Economic Analysis and Policy 65: 198-210. https://doi.org/110.1016/j.eap.2020.1001.1004.

[61] Sharma SS (2011) Determinants of carbon dioxide emissions: empirical evidence from 69 countries. Applied energy 88(1):376-382. https://doi.org/310.1016/j.apenergy.2010.1007.1022.

[62] Chen Y, Wang Z, Zhong Z (2019) CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renewable Energy 131: 208-216. https://doi.org/210.1016/j.renene.2018.1007.1047.

[63] Sadorsky P, (2014) Do urbanization and industrialization affect energy intensity in developing countries? Energy Econ 37:52–59. doi:10.1016/j.eneco.2013.01.009.

[DOI: 10.22034/JAERT.1.4.1]